christian aid

HEINRICH BÖLL STIFTUNG INDIA

India's Energy Transition
Potential and Prospects

INDIA'S ENERGY TRANSITION
POTENTIAL AND PROSPECTS

About Heinrich Böll Foundation

The Heinrich Böll Stiftung / Foundation (HBF) is the Green Political Foundation, affiliated to the "Greens / Alliance '90" political party represented in Germany's federal parliament.

Headquartered in Berlin and with more than 30 international offices, HBF conducts and supports civic educational activities and projects worldwide.

HBF is as a green think-tank and international policy network, working with governmental and non-governmental actors and focusing on gender equity, sustainable development, and democracy and human rights.

With a presence in New Delhi since 2002, the HBF India office coordinates the interaction with stakeholders and partners in the country. Its programme focus areas include climate and resource policy, socio-economic policy from a gender perspective, the dynamics of democracy, and India's role in the new global order.

About Christian Aid

Christian Aid believes that the world can and must be swiftly changed to one where everyone can live a full life, free from poverty. We work globally for profound change that eradicates the causes of poverty, striving to achieve equality, dignity and freedom for all, regardless of faith or nationality. We are part of a wider movement for social justice. We provide urgent, practical and effective assistance where need is great, tackling the effects of poverty as well as its root causes.

Poverty is an outrage against humanity. It robs people of dignity, freedom and hope, of power over their own lives. Christian Aid has a vision – an end to poverty – and we believe that vision can become a reality.

The Christian Aid name and logo are trademarks of Christian Aid. Christian Aid is a key member of ACT Alliance, a coalition of 100 churches and church-related organisations working together in humanitarian assistance and development.

India's Energy Transition : Potential and Prospects

Author : Chandra Bhushan

Research Support : Sugandh Juneja

Published by: Heinrich Böll Foundation-India & Christian Aid, India, October, 2017

Designed by: Satyam Grafix, New Delhi

CONTENTS

ACRONYMS

ABT	Availability based tariff
ACS	Average cost of supply
AD	Accelerated depreciation
AMI	Advanced Metering Infrastructure
APDP	Accelerated Power Development Programme
APDRP	Accelerated Power Development and Reforms Programme
APPC	Average power purchase price
ARR	Average revenue realised
AT&C	Aggregate technical and commercial
BEE	Bureau of Energy Efficiency
BESS	Battery energy storage system
BIS	Bureau of Indian Standards
CAGR	Cumulative annual growth rate
CECRE	Control Centre of Renewable Energies
CEA	Central Electricity Authority
CERC	Central Electricity Regulatory Commission
CPRI	Central Power Research Institute
DCU	Data Collector Unit
DDUGJY	Deen Dayal Upadhyaya Gram Jyoti Yojana
DELP	Domestic Efficient Lighting Programme
DG	Diesel generating
DISCOM	Distribution company
DNO	Distributor Network Operator
DSM	Deviation settlement mechanism
DT	Distribution transformer
EA	Electricity Act
EV	Electric vehicle
FACTS	Flexible AC Transmission Systems
FOR	Forum of regulators
FRP	Financial Restructuring Plan
GBI	Generation based incentive
GCC	Generation Control Centre
GCF	Green Climate Fund
GCF	Gross Calorific Value
GIS	Gas Insulated Sub-stations
GW	Gigawatt
HVDC	High voltage direct current
IEA	International Energy Agency
IEGC	Indian Electricity Grid Code
InSTS	Intra-state transmission networks system
IPDS	Integrated Power Development Scheme

ISGS	Inter-state generating stations
ISGF	India Smart Grid Forum
ISGTF	India Smart Grid Task Force
ISTS	Inter-state transmission system
INDC	Intentionally National Determined Contribution
LDC	Load dispatch centre
LVRT	Low Voltage Ride Through
MDMS	Meter data management system
MNRE	Ministry of New and Renewable Energy
MoP	Ministry of Power
MSME	Micro, small, medium enterprises
MW	Megawatt
MVA	Mega Volt Amp
NAPCC	National Action Plan on Climate Change
NEP	National Electricity Policy
NISE	National Institute of Solar Energy
NLDC	National Load Dispatch Centre
NSEF	National Solar Energy Federation of India
NSGM	National Smart Grid Mission
NTP	National Tariff Policy
NTPC	National Thermal Power Corporation
NVVN	National Vidyut Vyapar Nigam
OFGEM	Office of Gas and Electricity Markets
PDC	Phasor Data Concentrators
PED	Power Electronic Devices
PGCIL	Power Grid Corporation of India Limited
PIRP	Participating Intermittent Resources Programme
PLF	Plant load factor
PMU	Phasor Measurement Unit
POSOCO	Power System Operation Corporation of India
PPA	Power Purchase Agreement
PPP	Public-private partnership
PSHP	Pumped storage hydro plants
PSU	Public sector undertaking
PV	Photovoltaic
R-APDRP	Restructured Accelerated Power Development and Reforms Programme
RE	Renewable energy
REC	Renewable energy certificate
REMC	Renewable Energy Management Centre
RES	Renewable energy sources
REP	Rural Electricity Policy
RLDC	Regional Load Dispatch Centre
RPO	Renewable purchase obligation
RRF	Renewable Regulatory Fund
SERC	State Electricity Regulatory Commission

SCADA	Supervisory Control and Data Acquisition
SEBI	Securities and Exchanges Board of India
SEM	Special Energy Meter
SLDC	State Load Dispatch Centre
SVC	Static Var Compensators
OMS	Outage Management System
QCA	Qualified coordinating agency
T&D	Transmission and distribution
TWh	Terrawatt hour
UDAY	Ujwal DISCOM Assurance Yojana
UI	Unscheduled interchange
UMSPP	Ultra mega solar power project
UNFCCC	United Nations Framework Convention on Climate Change
URTDSM	Unified Real Time Dynamic State Measurement Project
VGF	Viability gap funding
WAMS	Wide Area Measurement System

List of Figures

List of Tables

List of Boxes

FOREWORD

India has the potential for a large-scale energy transition, i.e. the rapid transition away from fossil fuels and towards renewable energy. The country has set for itself ambitious renewable energy targets, with government policy intending to achieve 175 GW of installed renewable energy capacity by 2022 (it is about 59 GW currently, at the end of first quarter of 2017, according to official figures). Furthermore, India's commitment in the UNFCCC process includes achieving 40 per cent of electrical power from non-fossil sources by 2030. As the current figure stand already at about 31 per cent, this latter target is likely to be superseded, although it needs to be noted that large-scale hydro as well as nuclear power is included here, i.e. energy options not generally compatible with sustainability concerns.

These remarkable targets which have raised high expectations, and wind and more recently especially solar power are currently rapidly expanding in India. But it is not enough to merely look at installed capacity and output in terms of billions of units: In order to achieve broad energy access, massive finance needs to be provided, even if nowadays the old price argument against renewable does not hold any more, because unit prices for new solar installations have begun to undercut those from fossil sources, including coal, even in India. At the same serious problems of the distribution system need to be addressed.

The analysis provided in this book encourages the interested reader to envisage the "brave new world" of an India that is powered by renewable energy, to a large extent. It shows that reaching the current renewable targets is entirely possible, envisaging a coexistence of grid and off-grid solutions. The book provides ideas and recommendations about what is needed to reach this new world, especially when it comes to the mobilization of finance, and with regard to reform the power distribution system and the grid itself, technically as well as in terms of grid governance. Solar rooftop, storage systems and cross-subsidy schemes via the distribution companies, this book shows, will all need to be part of the strategy if India is going to achieve energy access for all within the next 15 years.

India's energy transition is right on its way. I expect this book to be helpful for specialists and non-specialists alike in order to understand its critical dimensions and the requirements needed to realize the path forward.

Dr. Axel Harneit-Sievers, Director
Heinrich Böll Foundation, New Delhi

EXECUTIVE SUMMARY

Over the last decade, electricity capacity and power generation in India have continued to grow at a fast pace. The country's installed electricity capacity increased at a cumulative annual growth rate (CAGR) of 9.3 per cent while generation grew at 6.6 per cent. The renewable energy (RE) sector exhibited even faster growth in the past decade, at a CAGR of 20 per cent.

The government of India has set an ambitious target of installing 175 GW of renewable energy in the country by 2022. India has also committed in its Intentionally National Determined Contribution (INDC) to the UNFCCC to achieve "40 per cent cumulative electric power installed capacity from non-fossil fuel based energy resources by 2030 with the help of transfer of technology and low-cost international finance, including from Green Climate Fund". Given the ambitious renewable energy targets, this report looks at what it will take for India to meet these and at the same time provide electricity access to all.

Energy access

Energy access is India is less and less related to availability of energy. The country is power surplus with over 300 GW installed capacity and peak demand of just 160 GW; yet, over 300 million people do not have access to electricity. Availability of energy is neither an important factor now, nor is it likely to be, to meet the growing energy demand in the country. There is enough capacity in the pipeline (including RE targets) to meet the energy access need of the country for the next two decades.

The problem of energy access is the problem of distribution companies (DISCOMs). DISCOMs have long been insolvent on account of below-cost tariffs for different consumer groups, supply of un-metered, free electricity to agriculture, and high transmission and distribution losses. Even though the Government tried to come to the rescue with a series of reform measures and financial bailouts, the sector remains in dire financial straits, requiring yet another bailout. This time around, a new reform-linked bailout scheme – Ujwal DISCOM Assurance Yojana (UDAY) – has been launched to improve the operational and financial performance of DISCOMs. UDAY seems to be moving in the right direction, but it is clear that it will not meet its targets of reducing Aggregate Technical and Commercial (AT&C) losses to 15% and reducing the gap between Average cost of supply (ACS) and Average revenue realised (ARR) to zero by 2018-19. This means that the country will have to find new ways to resolve the DISCOM issue than just hoping that it will get resolved with financial bailout and procedural tweaking.

Energy access is also linked to affordability. There is concern that increased penetration of renewable energy will drive costs upwards and make electricity unaffordable for the poor. But this is not a serious concern. Renewable energy costs have come down significantly in the last 10 years; solar PV costs have reduced by 20% annually since 2007. Projections on future costs indicate that solar PV will be the cheapest source of electricity in India by 2020 and solar rooftop system with battery back-up will achieve grid-parity by 2025. So, energy access should not be hampered by large penetration of renewable energy.

The next question is can India meet its RE targets?

Meeting RE targets

The policy environment in the country at present is conducive to the renewable energy sector. The RE policy in India revolves around the following:

- A preferential tariff and subsidy programme to promote RE: Tariff is the primary vehicle through which RE has been pushed in India. Wind power emerged in India based primarily on preferential tariff while solar power in India has followed the route of competitive bidding to determine tariff.
- Concessions given by various states like reduced transmission and distribution charges, power banking, etc.
- Competitive bidding in allocation of RE projects and procurement of power

- Fixing a minimum percentage of power to be procured by DISCOMs – Renewable Purchase Obligations (RPOs). By 2019-20, 15 per cent of the electricity purchased by DISCOMs in India should be from RE. If India can achieve its target of 175 GW of RE by 2022, then about 16 per cent of the electricity consumed in the country can be derived from RE by as early as 2019-20. However, compliance with the RPO targets is the big concern in the backdrop of no penalty/disincentive.
- A mechanism to enable and recognise the inter-state RE transactions through Renewable Energy Certificates (REC). However, REC is a short-lived instrument as once the cost of RE reaches grid-parity, RECs will cease to be relevant.

As of December, 2016, the installed capacity of RE in India was 47 GW. This means an additional 128 GW of capacity is required in the next five years. This will require a CAGR of 30 per cent in RE installation for the same period. Given the poor rate of RE installations in 2015-16 (and thus far in 2017), meeting this target will be very difficult. The only factor that could turn the tables is if the favourable policy environment is coupled with significant drop in prices.

Impediments to 175 GW target

Finance: The biggest impediment to large-scale expansion of renewable energy in India is availability of low cost finance. Even though the cost of renewable energy has reduced, the total quantum of finance required to meet 175 GW target is very high. About US$ 200 billion (or US$ 40 billion per year) would be needed to meet the 175 GW target. In the last 10 years, the maximum investment in any one year, in the renewable energy sector, has been about US$ 12.8 billion.

India needs to improve the investment climate to raise low-cost finance from both domestic and foreign sources. Currently, the cost of debt is high due to macro-economic factors (high inflation and high government borrowing) as well as many risks associated with renewable energy projects, including the poor financial health of DISCOMs. The expectation on the rate of return on equity is also high because of the perceived high risk. It is estimated that the high cost of capital increases the cost of renewable energy in India by 24-32% compared to similar projects in developed countries.

The key to raising low-cost finance in India is by reducing risks for large foreign and domestic investors as well as by raising funds from the domestic and foreign retail market. Instruments like payment security mechanism – that ensures the investor will be paid for the amount of energy fed into the grid even if the DISCOM defaults – and a government-sponsored foreign exchange hedging facility to reduce the risk of currency fluctuation, can go a long way in increasing the confidence of investors and thereby reduce the costs of finance. Similarly, raising funds from the market via green bonds, etc., can also become an important source.

DISCOMs: Growth in RE will face its biggest challenge from DISCOMs. In the short term, the cost of RE is likely to remain higher than coal-fired power, the main source of electricity in India. In addition, larger penetration of RE also means lower utilisation of coal based power plants. As part of the tariff mechanism a coal power plant (and other conventional power plants) is paid some percentage of tariff even if it doesn't produce electricity; this implies that a larger penetration of RE also increases the cost of coal. In the short term, therefore, the cost of power is likely to increase which will be resisted by DISCOMs.

DISCOMs are likely to resist decentralised RE even more. Currently in India, it is cheaper for many consumer groups in a number of states to install solar rooftops than to buy power from DISCOMs. This trend is likely to become more prevalent in future. Consumers, who pay higher tariff, are likely to shift to solar rooftop and other decentralised systems to offset a high electricity bill. Larger consumers are also likely to move to open access and reduce their dependence on DISCOMs. This could further worsen the operational and financial health of DISCOMs. Most of the accumulated losses – 90 per cent of the total – are in Rajasthan, Uttar Pradesh, Tamil Nadu, Madhya Pradesh, Haryana, Jammu and Kashmir, Telangana, Maharashtra and Chhattisgarh. These states also account for more than 80 per cent of the renewable energy target of 175 GW.

Major reforms are, therefore, required to ensure that DISCOMs support RE. The key reforms required are as follows:

- Allow competition at the distribution end. The distribution infrastructure can still be owned by the state monopolies (ideally these should also be moved to private operators or to public-private partnerships), but the sale of electricity to consumers must be opened to competition. This would lead to better collection efficiency, lower AT&C losses, lower political interference and improved operational parameters and financial health of the distribution segment. The state can still subsidise the poor by directly transferring the subsidy to consumers or the companies.
- Decentralised renewable energy consumers must pay for using the infrastructure and also to cross-subsidise poor consumers. For instance, for rooftop solar consumers, the following steps are needed to incentivise DISCOMs to encourage solar rooftops:

    a. The option of solar rooftop consumer to move to lower tariff slab should be discouraged. This hurts the DISCOMs not only from the cross-subsidy angle, but also from the reduction in fixed charges that is required to maintain the distribution infrastructure.

    b. Time-of-the-day (TOD) tariff for export and import of power needs to be operationalised. This will incentivise export of power during peak time from rooftops, thereby reducing DISCOMs' burden of buying expensive power from generation utilities. This will also discourage export during off-peak and import during peak time. In addition, rooftop solar consumers should pay for the banking charges.

    c. The government needs to develop an incentive scheme to encourage distribution utilities to accelerate the growth of solar rooftop in the country. The Ministry of New and Renewable Energy (MNRE) can provide incentives to DISCOMs to offset any reduction in profitability due to installation of rooftop systems.

Clearly, without reforms at the distribution end, India cannot hope to become a major user of RE.

Grid infrastructure: One of the prerequisites for achieving the ambitious target is to have a grid which will allow integration of RE. The key parameter for a reliable grid is maintaining a constant frequency. There is apprehension that the mismatch between demand and supply will be difficult to manage due to large penetration of RE given its variable nature. In the last few years, however, the situation improved significantly with the demand-supply deficit going down and new institutional and infrastructural mechanisms being put in place to improve load forecasting. Still, in order for the Indian grid to prepare for large-scale integration of RE, the following interventions are needed:

- **A strong conventional grid:** The most basic requirement is a well-functioning and a stable grid. This means that the grid should be operating at optimal frequency, is able to supply required power to all, has a well performing demand forecasting mechanism, incentivises availability and flexibility and has a large power balancing area.

- **Forecasting and management of solar and wind generation:** Accurate forecasting and day ahead scheduling is crucial for ensuring stability of the grid. This requires large number of monitoring stations, better forecasting methodologies and tools, a tariff mechanism that incentivises better forecasting and equipping regional, state and central level load dispatch centres with institutional arrangements for handling and using this information.

- **Supply balancing:** The variable nature of renewable energy necessitates supply balancing from conventional sources. This demands availability of reserve capacity to meet the net-load as well as increased flexibility of the conventional capacity, reinforcement of ancillary services (reserve capacity to be operationalised in times of shortfall) and power storage infrastructure. Supply balancing also demands a market mechanism for storage as well for incentivising availability and flexibility of conventional capacity.

- **Technological interventions:** Interventions like the augmentation of the transmission corridors from renewable rich states, use of power electronic devices for reactive power control, use of synchrophasor technology to stabilise the voltage of the power being supplied to the grid, technical standards for RE generation incorporating features such as Low Voltage Ride Through (LVRT), High Voltage Ride Through (HVRT), frequency thresholds for disconnection from the grid, active and reactive power regulation by RE generators, etc., are required.

- **Smart Grid:** Demand-side management, demand response and two-way communication between the consumer and supplier are key to large-scale renewable power penetration.

The good thing is that the above interventions will also reduce losses, reduce AT&C losses, increase billing and improve the financial performance of DISCOMs. So, investments in grid is a win-win agenda – it allows better performance of DISCOMs and higher penetration of RE.

Focus on the long term, not the short term

Our analysis is that India will not be able to reach 175 GW RE capacity by 2022; 125 GW plus capacity is certainly possible. Still, India will easily meet its INDC target of '40 per cent cumulative electric power installed capacity from non-fossil fuel based energy resources by 2030'. By 2031-32 close to 60% of the installed capacity of the power sector could be from non-fossil fuels. This is likely because:

- With solar power tariff for larger projects hitting Rs 3.0/kWh, these projects are producing electricity at a tariff lower than a large number of new coal-fired plants. If this trend continues, from 2020 onwards, coal power prices will start chasing the solar power prices, and not the other way round, as is the case today.
- Wind power tariff is also showing a significant downward trend. In the latest auction of 1 GW wind power, the tariff fell to a record low of Rs 3.46/ kWh.
- By 2025, rooftop solar with battery storage is projected to be cheaper than grid power, making off-grid houses possible.
- By 2032, electricity storage technology will advance significantly. The price of large energy storage systems like Compressed Air Energy Storage and smaller energy storage systems like batteries (lithium, sodium or lead) would reduce significantly. Estimates show that the cost of batteries could go down to Rs 3/kWh. At this price, solar rooftop with battery storage would be the cheapest energy source for a large number of consumers (including large commercial and industrial users) and they therefore would potentially move out of the grid or reduce their reliance significantly.
- Cheap electricity storage technology would mean that it would become techno-economically viable to make storage act as both a large base-load plant as well as a peaking plant.
- In 2030, it would be more expensive to set up a new coal power plant compared to a new solar or wind plant coupled with storage.

We estimate that between 2016-17 and 2031-32, for every 1 MW of coal power plant installation, 4.5 MW of solar and wind capacity will be installed. India is, therefore, on a 'virtuous cycle' on renewable energy. Whether it has 125 GW or 175 GW RE capacity by 2022, the fact is that RE is becoming the most important energy sector in the country and will drive the energy industry in the future. India should not be fixated with the 175 GW target. Instead, the country needs to plan for the electricity sector keeping in mind that in the next 10-15 years renewable with storage will be the cheapest source of power in the country.

The new brave world

We are staring at a new brave world of renewable energy. For the first time since the climate change negotiations started in 1992, there is a market shift that has the potential to decarbonise the energy sector. As this report illustrates, it is very much possible that coal consumption in the power sector in India could peak by 2030 and at a much lower level than what has been projected by many studies in the past. In addition, in the 2030s, most of the installed capacity of the power sector will come from non-fossil fuels. What will happen to the grid and DISCOMs in this scenario?

- It is clear that in the next couple of years, solar rooftops with storage and open access consumers will start eating away the market of the existing DISCOMs. Most lucrative consumers will slowly start to move out of DISCOMs as renewable energy with storages becomes cheaper. DISCOMs are likely to resist this shift.
- Once the rich consumers start to move out of DISCOMs, their financial performance is likely to deteriorate. Even with schemes like UDAY, the operational and financial positions of DISCOMs are not likely to improve significantly. Most DISCOMs are and are staying afloat with government support.
- The only way to deal with this, as has been done in many developed countries, is to unbundle the sector. The distribution, operation and supply of electricity must be clearly separated. DISCOMs can be dissolved with all their liabilities taken over by the state and the central governments.
- The job of the Distribution Network Operator (DNO) would be to plan, maintain and operate the network. The electricity supplier will pay DNOs for the use of infrastructure. In this arrangement, consumers will have the choice to buy electricity from whoever they wish.
- Smart grids will become common and the distribution network will become bi-directional with solar rooftops feeding electricity to distribution grids. Virtual power companies would emerge that will collect power from individual rooftops and renewable power plants and sell to other consumers. They will have no asset of their own.
- Energy storage companies would emerge that will install big utility-scale electricity storage devices and provide electricity to the grid for balancing, peaking and even base-load requirement.
- The energy efficiency market will also become big with Energy Efficiency Service Companies selling efficiency products to consumers.
- Time-of-day tariff would become the norm.
- Availability based tariff will become the norm for all generators.
- What will happen to the poor? If the rich move out, who will cross-subsidise the poor? The answer is that the rich will cross-subsidise the operations of the grid and the distribution network. As they will use the infrastructure, they should be charged higher to cross-subsidise the poor. As far as electricity is concerned, the government can provide direct subsidy to the consumers to provide for their basic electricity need.

This is the only way India can decarbonise the electricity sector and provide energy access to all.

Photo: Centre for Science and Environment

CHAPTER 1

STATUS OF ELECTRICITY AND ELECTRICITY ACCESS IN INDIA

Over the past 10 years, electricity generation capacity in India has grown at a cumulative annual growth rate (CAGR) of 9.3 per cent and power generation at CAGR of 6.6 per cent. The per capita electricity consumption in the country is more than 1,000 kWh/year, yet 300 million people don't have access to electricity. Why?

In this chapter we will examine the state of electricity and electricity access in India. Our key enquiry is to understand the reasons for the lack of electricity access to all.

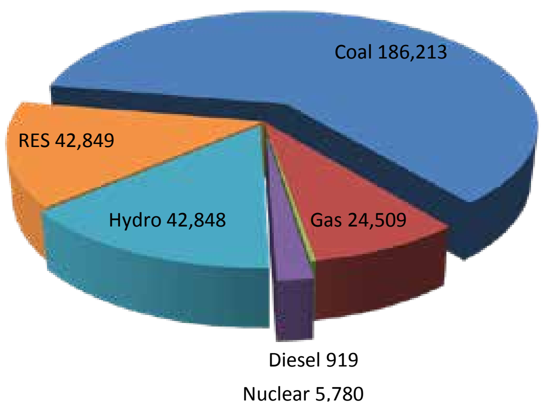
A. Status of Electricity

1. Capacity and Generation

The total installed capacity of electricity in India in November, 2016 was 308,833 megawatt (MW), excluding captive power plants. Over 60 per cent of this power comes from coal, followed by renewable energy sources (RES) and hydropower, at around 14 per cent each (see *Figure 1.1: Installed Power Capacity in India, November, 2016*). RES include small hydro, solar, wind and power from biomass. If we include captive power plants of more than 1 MW capacity, the total installed capacity is close to 370 gigawatt (GW).[1]

Figure 1.1: Installed Power Capacity in India, November, 2016

70% of the installed capacity is based on fossil fuels; 30% on non-fossils



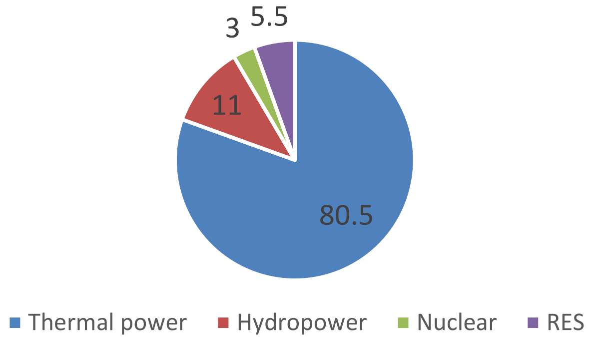
Source: http://www.cea.nic.in/reports/monthly/installedcapacity/2016/installed_capacity-11.pdf

About 80 per cent of the electricity was produced from thermal sources (coal, gas and diesel), 11 per cent from hydropower, 3 per cent from nuclear sources and 5.5 per cent from RES (see *Figure 1.2: Power Generation from Various Sources: 2015-16*). Clearly, India is largely dependent on coal to meet its current electricity requirements.

1 Data on captive power plant capacity is not available for 2016. Captive power plant capacity in 2014-15 was 44,657 MW (Energy Statistics, 2016, Ministry of Statistics and Programme Implementation). These accounted for 14% of the total installed generation capacity in 2014-15. If we extrapolate this number for 2016-17, at least 60,000 MW capacity can be attributed to captive power plants.

Figure 1.2: Power Generation from Various Sources: 2015-16

80% of electricity is produced from fossil fuels; 20% from non-fossils including 5.5% from RES

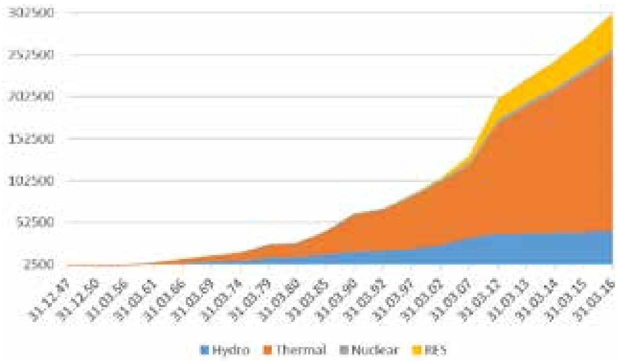


Source: CEA Daily Report on generation, 31 March, 2016 and Prayas renewable energy data portal

India's electricity sector has grown at a rapid pace in the past decade. In the last 10 years (2005-06 to 2015-16), the installed capacity increased from 124 GW to 302 GW at CAGR of 9.3 per cent (see *Figure 1.3: Growth in Installed Capacity*). Generation of electricity has grown from 617 terra-watt hours (TWh) to 1,169 TWh at CAGR of 6.6 per cent (see *Figure 1.4: Growth in Generation*).

Figure 1.3: Growth in Installed Capacity

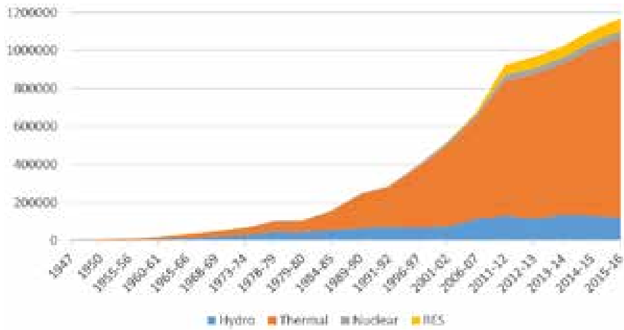
India has installed 178 GW capacity in the last 10 years



Source: Draft National Electricity Plan (Vol-I) Generation, 2016, Central Electricity Authority

Figure 1.4: Growth in Generation

Electricity generation has grown at 6.6% annually in the last 10 years



Source: Draft National Electricity Plan (Vol-I) Generation, 2016, Central Electricity Authority

2. Demand & Deficit

In India, demand and supply of electricity is forecasted one day in advance. This is known as day-ahead scheduling and is used to calculate demand and deficit. Deficit means that distribution companies (DISCOMs) are unable to obtain power from generators when they are willing to purchase and distribute it. Surplus means that generators are ready to supply, but DISCOMs have no demand. DISCOMs forecast demand and generators predict the supply.

At the all-India level, the energy and the peak load deficit have reduced to less than two per cent (see *Table 1.1: Power Situation in India*). But this figure is misleading in all aspects. It reflects neither the actual demand nor the supply. Let us examine.

First, there should not be any deficit in India since the installed capacity is 308 GW and the peak demand is 160 GW. A number of states do report almost no deficit. But there are some that do report deficit. This is because of the lack of grid capacity to transport power to these states. There is deficit because of grid issues and not due to lack of capacity.

Second, there is question mark on how DISCOMs forecast demand. Because of the financial stress, most DISCOMs are not willing to buy power even if there is demand. Certain consumer groups are subsidised, so supplying more electricity to these groups implies more loss for DISCOMs; hence they do not want to supply to them. And because DISCOMs don't want to supply to these consumer groups, the day-ahead schedule does not include this demand. So the projection itself is questionable and underestimated. This is also reflected in the large-scale use of Diesel Generating (DG) sets in almost all sectors.

The demand and deficit figures are misleading and reflect only partially the demand and the capacity of the power sector in India to supply electricity.

Table 1.1: Power Situation in India

Deficit of power has reduced significantly in last decade

Year	Energy			Peak load		
	Demand (MU)	Availability (MU)	Surplus (+)/ Deficit (-) (%)	Demand (MW)	Availability (MW)	Surplus (+)/ Deficit (-) (%)
2009-10	8,30,594	7,46,644	-10.1	1,19,166	1,04,009	-12.7
2010-11	8,61,591	7,88,355	-8.5	1,22,287	1,10,256	-9.8
2011-12	9,37,199	8,57,886	-8.5	1,30,006	1,16,191	-10.6
2012-13	9,95,557	9,08,652	-8.7	1,35,453	1,23,294	-9.0
2013-14	10,02,257	9,59,829	-4.2	1,35,918	1,29,815	-4.5
2014-15	10,68,923	10,30,785	-3.6	1,48,166	1,41,160	-4.7
2015-16	11,14,408	10,90,850	-2.1	1,53,366	1,48,463	-3.2
2016-17*	8,64,691	6,58,648	-0.7	1,59,542	1,56,934	-1.6

Source: http://powermin.nic.in/en/content/power-sector-glance-all-india as viewed on 19 February, 2017
*Till December, 2016

B. Energy Access and Poverty

Energy access and energy poverty are often misunderstood in India. Let us look at these issues one by one.

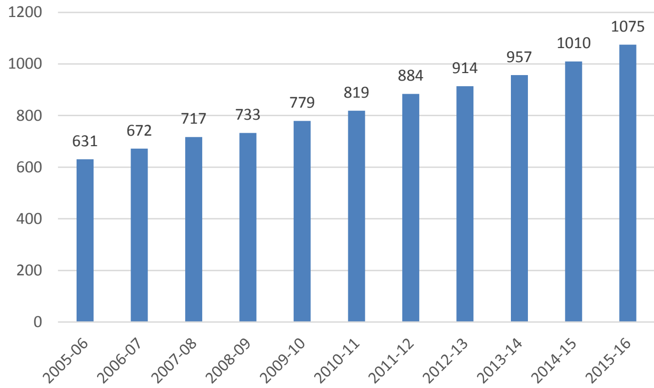
1. Energy poverty

The energy poverty of a country is depicted in terms of its per capita consumption. If we go by the government's data, the per capita consumption of electricity in the country has grown from 631 kWh in 2005-06 to 1,075 kWh in 2015-16 at an annual growth rate of 5.5 per cent (see *Figure 1.5: Per Capita Electricity Consumption*). In the United States, the annual per capita consumption of electricity is 12,954 units and the world average is around 3,064 units[2]. So, India as a whole is relatively energy poor. But this per capita figure is also misleading.

2 UN Data (2012), Electric power consumption (kWh per capita), United Nations, http://data.un.org/Data.aspx?d=WDI&f=Indicator_Code%3AEG.USE.ELEC.KH.PC as accessed on 1 January, 2017

Figure 1.5: Per Capita Electricity Consumption

In 2014-15, the per capita consumption crossed 1,000 KWh



Source: Ministry of Power, http://powermin.nic.in/content/overview as viewed on 17 January, 2017

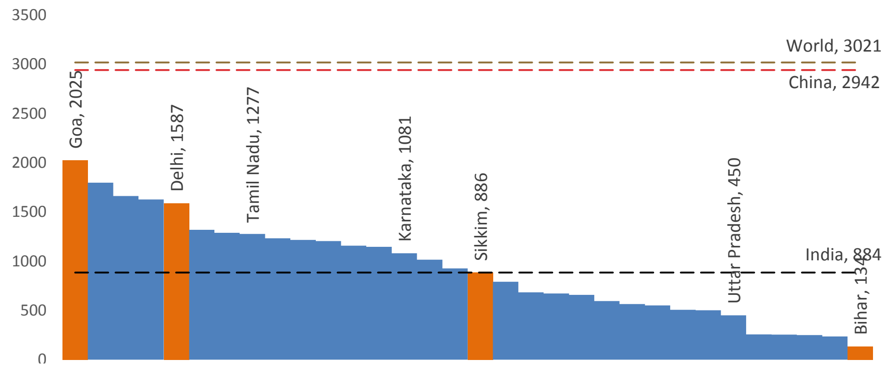
Per capita consumption is calculated as gross generation divided by the total population. It does not consider the fact that a large amount of electricity is consumed by the power plants themselves for auxiliary use (about seven per cent in 2014-15). Then there are high Aggregate Technical and Commercial (AT&C) losses of 22 per cent. Further, the electricity consumption in India is largely in non-domestic sectors – only about 23 per cent of the total electricity is consumed by households. Most of it is consumed in the industrial sector (44.1 per cent), agriculture (17.8 per cent) and in commercial and others sectors (15 per cent).[3]

If we consider all the above losses, the domestic per capita consumption of electricity works out to be only about 175 kWh/year. This means that every person in India consumes less than 0.5 units of electricity every day in households – one of the lowest in the world.[4]

The per capita consumption and electricity access vary widely across states. For instance, Goa's and Delhi's consumption is higher than the average consumption of non-OECD countries. On the other extreme, Bihar's consumption of around 150 kWh per capita per year, with two-thirds of its population lacking access to electricity, is comparable to sub-Saharan Africa (see *Figure 1.6: Per-capita Electricity Consumption of Indian States*).

Figure 1.6: Per-capita electricity consumption of Indian States

There is a wide variation in per capita electricity consumption across states



Source: NITI Aayog annual report on the working of State power utilities and Electricity departments; and India Energy Outlook 2015

3 Consumption of Electricity by Sectors in India in 2014-15, Energy Statistics 2016, Ministry of Statistics and Programme Implementation, GoI

4 http://www.nationmaster.com/country-info/stats/Energy/Electricity/Consumption-by-households-per-capita

2. Energy Access

International Energy Agency (IEA) estimates that 237 million people in India are not connected to the grid.[5] The agency also projects that India will have 147 million people without electricity by 2030. The recent data from the Ministry of Power (MoP) on rural electrification broadly corroborates IEA's figures. According to MoP, about 48 million rural households are not connected to the grid or between 240 and 290 million people do not have access to electricity (see *Table 1.2: State-wise Electrification Status*).[6] If the lack of access in some urban areas is considered too, this figure could go up by another 10-15 million people. Broadly, there could be about 300 million people without access to electricity in the country.

Table 1.2: State-wise Electrification Status

About 237 million people live without electricity in India

	Population without access (million)			Share of population without access		
	Rural	Urban	Total	Rural	Urban	Total
Uttar Pradesh	80	5	85	54%	10%	44%
Bihar	62	2	64	60%	19%	64%
West Bengal	17	2	19	30%	7%	22%
Assam	11	0	12	45%	9%	40%
Rajasthan	10	0	11	22%	2%	17%
Odisha	10	0	11	32%	4%	27%
Jharkhand	8	0	9	35%	4%	27%
Madhya Pradesh	7	1	8	16%	3%	12%
Maharashtra	6	1	6	11%	2%	7%
Gujarat	2	2	3	7%	6%	6%
Chhattisgarh	2	0	3	14%	6%	12%
Karnataka	1	0	1	5%	1%	3%
Other states	3	2	6	2%	2%	2%
Total	221	16	237	26%	4%	19%

Source: National Sample Survey Office (2014); Central Electricity Authority (2014); IEA

But is energy access just about connecting a household to the grid? Or, does it mean supply of adequate power as per demand?

Across the developed world, energy access is defined as the provision of 24x7 electricity as per demand. Let us assess energy access in India based on this definition.

Most Indian cities are subjected to frequent power outages, often during peak hours, which can last as long as 10 hours (see *Figure 1.7: Average hours of power cut per month in selected cities in 2015-*

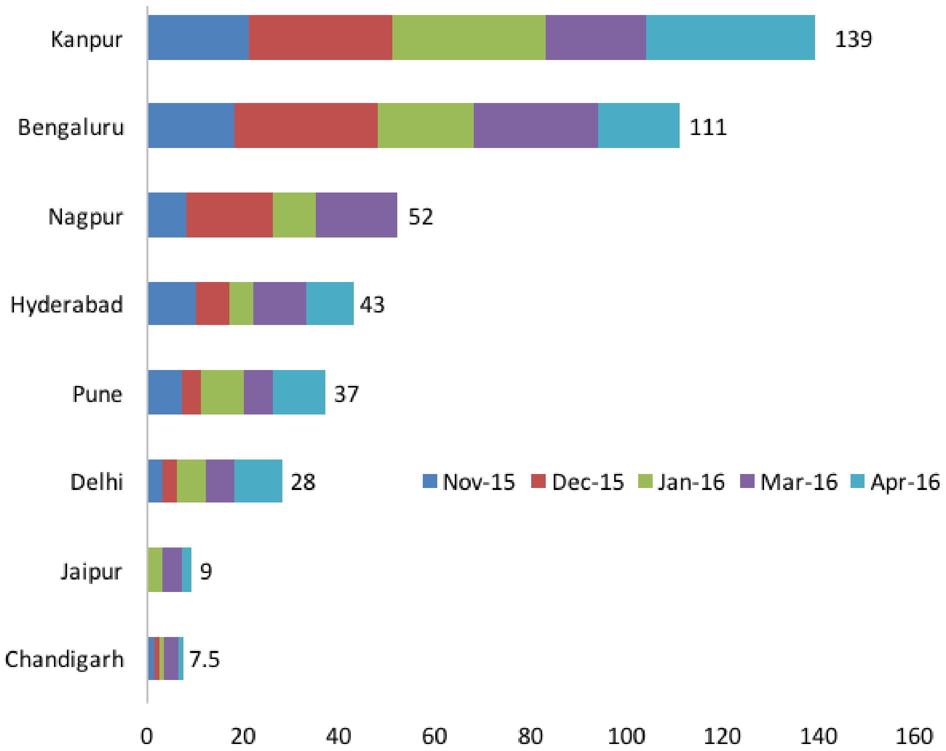
5 International Energy Agency (2015), World Energy Outlook 2015 – Electricity Access Database, International Energy Agency, Paris, France, http://www.worldenergyoutlook.org/media/weowebsite/2015/WEO2015Electricityaccessdatabase.xlsx as accessed on 1 June, 2016.

6 According to the Garv dashboard, the number of rural households yet to be connected to the grid is listed as about 48.1 million. Considering a household comprises 5-6 persons, only 240-290 million people in rural areas are not connected to the grid.

16).[7] A large number of 'electrified villages' do not get even six hours of electricity every day. A study undertaken by the Delhi-based Centre for Science and Environment estimated that close to 600 million people in India do not get even 6 hours of electricity every day and hence can be called energy poor.[8]

Figure 1.7: Average hours of power cut per month in selected cities in 2015-16

Frequent power cut is common in urban India



Source: http://watchyourpower.org/uploaded_reports.php

So, if we define energy access as 24x7 provision of adequate power, more than half a billion people in India can be termed energy poor.

Does India need to have such energy poverty?

India is a power surplus country. The installed capacity is more than 300 GW and the peak demand is just 160 GW – 15 per cent less than the total installed capacity of coal based thermal power plants. Still, close to 48 million households[9] are to get electricity and even the households that have electricity access, don't have it 24x7.

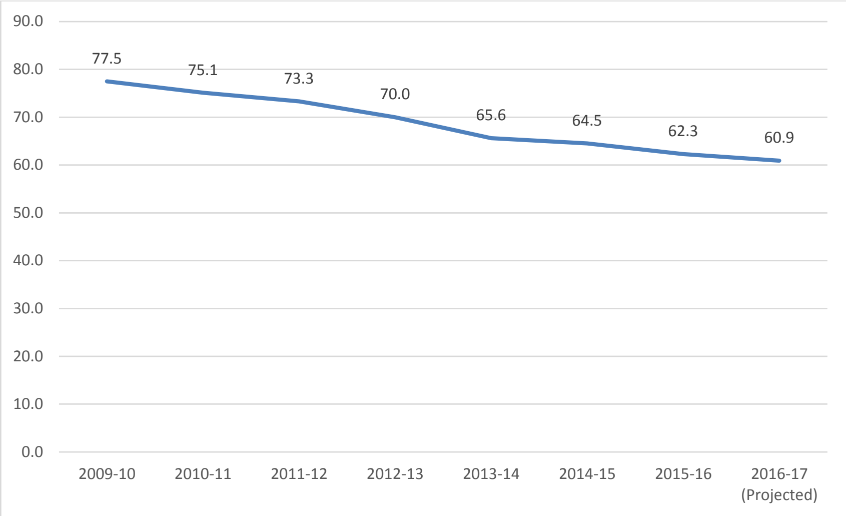
To provide 1,075 kWh/capita electricity (the current average per capita consumption) to the 237 million people who lack access, 250 TWh of electricity is required in addition to what is being supplied currently. The existing coal-based power plants alone can provide this if they improve their performance and increase output as per their installed capacity, that is, increase their plant load factor (PLF).

The coal-based power plants in India currently operate at a plant load factor of 60 per cent, which is likely to go down further (see *Figure 1.8: PLF of Coal and Lignite Power Plants*). If the PLF of these power plants is increased to 80 per cent, they will generate enough power to supply electricity to every citizen of the country.

7 http://watchyourpower.org/uploaded_reports.php
8 Chandra Bhushan and Aruna Kumarakandath 2016, Mini-grids: Electricity for all, Centre for Science and Environment, New Delhi
9 http://garv.gov.in/garv2/dashboard/main, as viewed on 19 February, 2017

Figure 1.8: PLF of Coal and Lignite Power Plants

Coal power plants in India currently operate at just 60% plant load factor



Source: Ministry of Power, http://powermin.nic.in/content/overview as viewed on 17 January, 2016

The Government of India has announced the 'Power for All' initiative, which aims to provide 24-hour uninterrupted power to all households, industries, public utilities, etc., and will be implemented in collaboration with state governments. The minister for power recently announced that electrification of all villages in India will be achieved by the end of 2017 under this initiative.

It is clear therefore that the energy poverty in India is not because of scarcity of power. There is enough capacity to provide uninterrupted power to all. The problem is at the distribution end. Till we fix the structural problems that exist at the distribution level, the government will find it difficult to meet its pledge to provide power to all.

Photo: Centre for Science and Environment

CHAPTER 2

RENEWABLE ENERGY: POTENTIAL AND PERFORMANCE

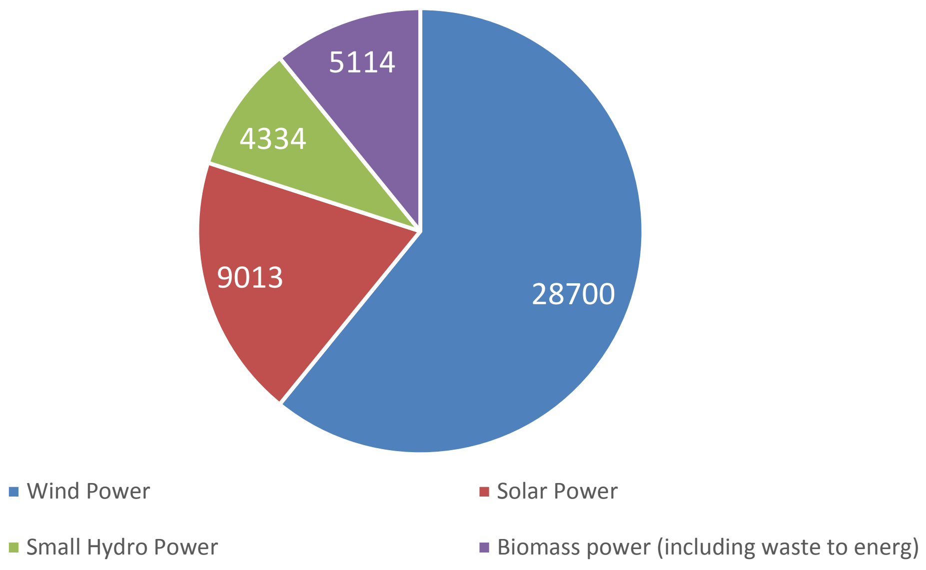
The renewable energy sector (RES) has grown at a rapid pace in the last few years and will continue to grow at even higher pace in the next five years to meet the 175 Giga-Watt (GW) target set by the government. But achieving the target will depend broadly on four factors – enabling policy environment, finance, managing the health of DISCOMs and integrating RE into the grid. Before we examine the policy environment, let us understand how this sector has grown in the past and its potential for the future.

A. RE status

India is a major global player in RES with little over 47 GW installed capacity (as of December, 2016). Renewable energy (RE) sources that dominate the sector in India at present are solar, wind, biomass and small hydropower; large hydropower is excluded from this list. India has the fourth largest installation of grid-connected RE capacity in the world (see *Figure 2.1: Renewable Energy Installed Capacity in India*). At present, about 60 per cent of the RE capacity comes from wind power and 19 per cent from solar power; small hydropower and biomass (biomass gasification and bagasse cogeneration) account for the remaining 20 per cent.

Figure 2.1: Renewable Energy installed capacity in India

Solar and wind account for 80% of the installed capacity



Source: Estimated from MNRE (http://mnre.gov.in/mission-and-vision-2/achievements/, as viewed on 20 February, 2017) and Bloomberg report on Financing India's Clean Energy Transition

Tamil Nadu has the highest installed capacity attributed to RES followed by Maharashtra, Rajasthan and Gujarat. Regionally, the highest installed capacity is located in the western parts of India (see *Table 2.1: State-wise Installed Capacity*).

Table 2.1: State-wise Installed Capacity

Highest installed capacity is in the Western states

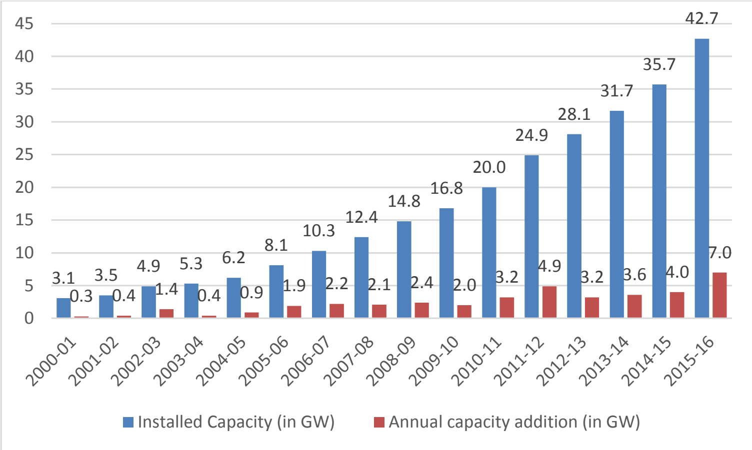
	Thermal (in MW)					Renewables (MW)				
State/Union Territory	**Coal**	**Gas**	**Diesel**	**Sub-total thermal**	**Nuclear (MW)**	**Hydel**	**RES**	**Sub-total renewables**	**Total (MW)**	**%**
Andaman & Nicobar	-	-	40.05	40.05	-	-	10.35	10.35	50.4	0.02%
Andhra Pradesh	6,509.21	3,182.65	16.97	9,708.83	127.16	1,758.87	2,093.93	3,852.80	13,688.80	4.13%
Arunachal Pradesh	12.35	43.06	-	55.41	-	97.57	104.64	202.21	257.62	0.09%
Assam	187	718.62	-	905.62	-	429.72	34.11	463.83	1,369.45	0.50%
Bihar	2,516.24	-	-	2,516.24	-	129.43	114.12	243.55	2,759.79	1.00%
Central - NLC	100.17	-	-	100.17	-	-	-	-	100.17	0.04%
Central - Unallocated	1,622.35	196.91	-	1,819.26	228.14	-	-	-	2,047.40	0.74%
Central - Unallocated	977.19	290.35	-	1,267.54	129.8	754.3	-	754.3	2,151.64	0.78%
Central - Unallocated	1,523.08	-	-	1,523.08	300.48	-	-	-	1,823.56	0.66%
Central - Unallocated	1,572.07	-	-	1,572.07	-	-	-	-	1,572.07	0.57%
Central - Unallocated	37.5	104.44	-	141.94	-	127.15	-	127.15	269.09	0.10%
Chandigarh	32.54	15.32	-	47.86	8.84	62.32	5.04	67.36	124.06	0.04%
Chhattisgarh	13,193.49	-	-	13,193.49	47.52	120	327.18	447.18	13,688.19	4.96%
Dadra & Nagar Haveli	44.37	27.1	-	71.47	8.46	-	-	-	79.93	0.03%
Daman & Diu	36.71	4.2	-	40.91	7.38	-	-	-	48.29	0.02%
Delhi	5,001.87	2,366.01	-	7,367.88	122.08	822.05	34.71	856.76	8,346.72	3.03%
DVC	7,160.66	90	-	7,250.66	-	193.26	-	193.26	7,443.92	2.70%
Goa	326.17	48	-	374.17	25.8	-	0.05	0.05	400.02	0.14%
Gujarat	16,353.72	6,806.09	-	23,159.81	559.32	772	4,940.00	6,271.32	29,431.13	10.66%
Haryana	6,527.53	560.29	-	7,087.82	109.16	1,456.83	138.6	1,595.43	8,792.41	3.19%
Himachal Pradesh	152.02	61.88	-	213.9	34.08	3,421.51	728.91	4,150.42	4,398.40	1.59%
Jammu & Kashmir	329.32	304.14	-	633.46	77	1,805.21	156.53	1,961.74	2,672.20	0.97%
Jharkhand	2,404.93	-	-	2,404.93	-	200.93	20.05	220.98	2,625.91	0.95%
Karnataka	6,408.46	-	234.42	6,642.88	475.86	3,599.80	4552.48	8,152.28	15,271.02	5.53%
Kerala	1,038.69	533.58	234.6	1,806.87	228.6	1881.5	204.05	2,085.55	4,121.02	1.49%
Lakshadweep	-	-	-	-	-	-	0.75	0.75	0.75	0.00%
Madhya Pradesh	11,126.39	257.18	-	11,383.57	273.24	3,223.66	1,670.34	4,894.00	16,550.81	6.00%
Maharashtra	24,669.27	3,475.93	-	28,145.20	690.14	3,331.84	6,205.65	9,537.49	38,372.83	13.91%
Manipur	15.7	67.98	36	119.68	-	80.98	5.45	86.43	206.11	0.07%
Meghalaya	17.7	105.14	-	122.84	-	356.58	31.03	387.61	510.45	0.19%
Mizoram	10.35	38.29	-	48.64	-	34.31	36.47	70.78	119.42	0.04%
Nagaland	10.7	46.35	-	57.05	-	53.32	29.67	82.99	140.04	0.05%
Odisha	6,753.04	-	-	6,753.04	-	2,166.93	116.55	2,283.48	9,036.52	3.28%
Puducherry	249.32	32.5	-	281.82	52.78	-	0.03	0.03	334.63	0.12%
Punjab	6,444.88	288.92	-	6,733.80	208.04	3,145.13	503.42	3,648.55	10,590.38	3.84%
Rajasthan	9,400.72	825.03	-	10,225.75	573	1,719.30	4,710.50	6,429.80	17,228.55	6.24%
Sikkim	92.1	-	-	92.1	-	174.27	52.11	226.38	318.48	0.12%
Tamil Nadu	10,075.10	1026.3	411.66	11,513.06	986.5	2,182.20	8,423.15	10,605.35	23,104.91	8.37%
Telangana	5,598.47	1,697.75	19.83	7,316.05	148.62	2012.54	62.75	2,075.29	9,539.96	3.46%
Tripura	18.7	538.82	-	557.52	-	62.37	21.01	83.38	640.9	0.23%
Uttar Pradesh	11,677.95	549.97	-	12,227.92	335.72	2,168.30	989.86	3,158.16	15,721.80	5.70%
Uttarakhand	399.5	69.35	-	468.85	22.28	2,441.82	244.32	2,686.14	3,177.27	1.15%
West Bengal	8,083.83	100	-	8,183.83	-	1,248.30	131.45	1,379.75	9,563.84	3.47%
Total	170,737.88	24,473.03	993.53	196,204.44	5,780	42,623.42	37,415.53	80,038.95	282,023.39	100.00%

Source: "Executive summary of month of November 2015" *(PDF). Central Electricity Authority, Ministry of Power, Government of India*

A combination of favourable policies in conjunction with falling prices aided rapid increase in installation of grid-connected RE power in the last decade (see *Figure 2.2: Growth in RE Capacity in India*). The renewable energy capacity in India has grown at CAGR of 20 per cent from 3.1 GW in 2000-01 to a little over 47 GW in December, 2016.

Figure 2.2: Growth in RE Capacity in India

Maximum amount of RE was installed in 2015-16



Estimated from MNRE's Annual Report

B. RE potential

The potential for generating electricity from renewable energy is far higher than the electricity requirements. According to Ministry of New and Renewable Energy (MNRE) estimates, India's solar energy potential is about 748 GW (see *Table 2.2: State-wise Solar Potential*). These are only conservative estimates. The highest potential is in Rajasthan, followed by Jammu and Kashmir and Maharashtra[10].

The potential of wind energy is estimated at 102 GW (excluding off-shore wind) with the largest volume being available in Gujarat, followed by Arunachal Pradesh, Tamil Nadu and Karnataka[11]. However, all estimates are based on certain assumptions around land area, height of wind turbines, level of solar radiations, etc. A change in assumption drastically changes the estimated wind potential. For example, by changing the hub height of wind towers from 80m to 100m, MNRE increased the on-land wind potential in India from 102 GW to 302 GW. Other institutions have estimated the country's wind potential to be as high as 2,541 GW.[12] Essentially, India has enough potential to meet its energy requirements from renewable energy now and in the foreseeable future.

The government has set a target of installing 175 GW of renewable energy in the country by 2022 comprising 100 GW solar energy (40 GW solar rooftop projects, 40 GW utility-scale solar plants and 20 GW ultra-mega solar parks), 60 GW wind energy, 10 GW small hydropower, and 5 GW biomass-based power projects.[13] India will have to install 25 GW RE every year to meet this target {see *Figure 2.3: Current Installed Capacity of RE and Target for 2022 (in MW)*}

10 State-wise solar energy potential, MNRE, 2014, http://mnre.gov.in/file-manager/UserFiles/Statewise-Solar-Potential-NISE.pdf

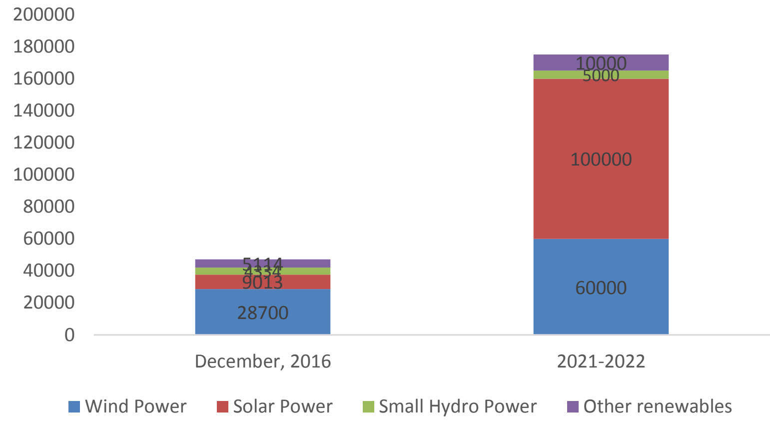
11 State-wise Potential for Renewable Energy in India, data.gov.in, https://data.gov.in/catalog/state-wise-potential-various-renewable-energy-technologies

12 Re-assessment of India's On-shore Wind Power Potential, CSTEP (http://www.cstep.in/uploads/default/files/publications/stuff/c1d1ec51806ba5d1716b15b01d89e4f9.pdf)

13 http://mnre.gov.in/file-manager/annual-report/2015-2016/EN/Chapter%201/chapter_1.htm

Figure 2.3: Current Installed Capacity of RE and Target for 2022 (in MW)

India will have to install 25 GW of renewable energy every year till 2022 to meet the target



Source: http://mnre.gov.in/mission-and-vision-2/achievements/, as viewed on 20 February, 2017

India has also committed in its Intentionally National Determined Contribution (INDC) to the United Nations Framework Convention on Climate Change (UNFCCC) to achieve '40 per cent cumulative electric power installed capacity from non-fossil fuel based energy resources by 2030 with the help of transfer of technology and low cost international finance including from Green Climate Fund (GCF)'.[14]

Can India meet these targets? We will discuss this in subsequent chapters.

14 http://www4.unfccc.int/submissions/INDC/Published%20Documents/India/1/INDIA%20INDC%20TO%20UNFCCC.pdf

CHAPTER 3
MEETING 175 GW TARGET

The policy environment in India at present is conducive for RE. It is the implementation of some of these policies that needs attention. For example, Renewable Purchase Obligations (RPO), the mechanism by which distribution companies (DISCOMs) are obliged to purchase a certain percentage of power from renewable sources, needs to be strictly adhered to. States need to put in place penalties for non-compliance. Similarly, Renewable Energy Certificates (REC) cannot be relied upon in the long run as they will become obsolete once RE achieves grid parity.

The key question is can India meet 175 GW target with the available policies, or other more innovative policy frameworks, like Availability Based Tariffs (ABT), etc. are required.

A. Current Policy Environment

Renewable energy (RE) policy in India has evolved over the past 15 years, starting with the Electricity Act (EA), 2003. Later, the National Electricity Policy (NEP), National Tariff Policy (NTP) and Rural Electrification Policy (REP) created favourable environment for RE.

The Electricity Act established the basis for renewable purchase obligation (RPOs) while the National Electricity Policy and National Tariff Policy paved the way for cost plus preferential/feed-in tariffs.

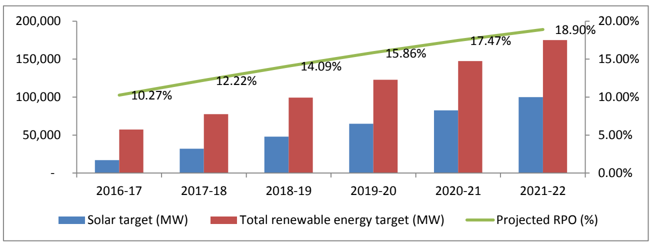
The crux of India's RE policy revolves around the following:

- A preferential tariff and subsidy programme to promote RE
- Concessions, like reduced transmission and distribution charges, power banking, etc., given by various states
- Competitive bidding in allocation of RE projects and procurement of power
- Fixing a minimum percentage of renewable power to be procured by DISCOMs, called Renewable Purchase Obligations
- A mechanism to enable and recognise inter-state RE transactions, for example, Renewable Energy Certificates
- Domestic targets and commitments given to the international community as part of climate change mitigation action

The National Action Plan on Climate Change (NAPCC) committed India to minimum renewable purchase obligation. The target of five per cent RE purchase was set for Financial Year (FY) 2009-10 with increase of one per cent in target each year for the next 10 years. So by 2019-20, 15 per cent of the electricity purchased by DISCOMs in India should be from RE. If India can remain on and achieve its target of 175 GW of RE by 2022, then about 16 per cent of the electricity consumed in the country can be derived from RE by as early as 2019-20 (see *Figure 3.1: RE Target Vs. RPO Target*).

Figure 3.1: RE Target Vs. RPO Target

If India keeps on track to meet its 175 GW target, it will also meet its RPO target under NAPCC



Source: Adopted from presentation made by Tarun Kapoor, Jt. Secretary, MNRE on 13 May, 2015

1. Tariff and subsidies

Tariff is the primary vehicle through which RE has been pushed in India. As per the provisions of NTP, State Electricity Regulatory Commissions (SERCs) notify preferential tariff for different RE sources. The preferential tariff is based on a cost plus formula that allows generators a reasonable rate of return on their investments.

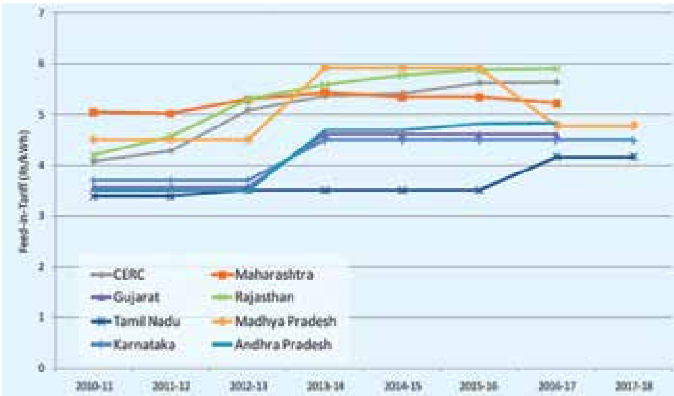
Wind power in India developed primarily on the basis of preferential tariff. Preferential tariff announced by SERCs is paid by DISCOMs to purchase wind power and this in turn incentivises developers to install more wind power plants.

SERCs in some states have adopted a single state-wise wind tariff (Gujarat, Tamil Nadu, Madhya Pradesh) while in states like Maharashtra a zone-wise tariff model is being used. The preferential tariff varies greatly from one state to another, ranging from Rs 4-6/kWh.

Wind power tariffs have been increasing slowly over the past few years (see *Figure 3.2: Preferential Tariff for Wind*).

Figure 3.2: Preferential Tariff for Wind

Wind tariffs have increased in the last few years

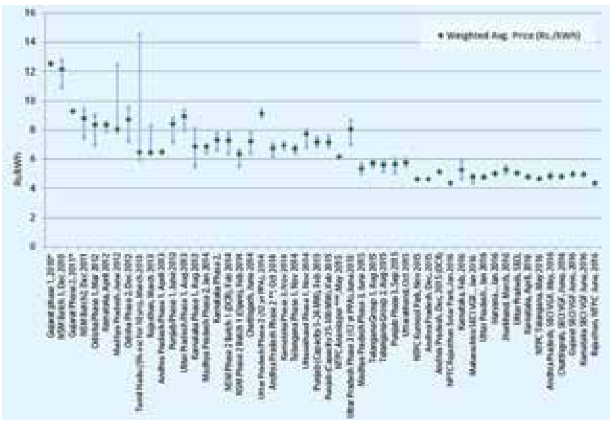


Source: Prayas (Energy Group), 2016, October: *India's journey towards 175 GW Renewables by 2022*

Unlike wind power, solar power in India has followed the route of competitive bidding to determine tariff (see *Figure 3.3: Solar Tariff through Competitive Bidding*). Competitive bidding has allowed the tariff of solar power to come down from Rs 12/kWh in December, 2010 to just above Rs 4/kWh in June, 2016. The tariff of utility connected solar power has therefore reduced by a CAGR of 20 per cent in the last six years in the country.

Figure 3.3: Solar Tariff through Competitive Bidding

Solar tariff has reduced at CAGR of 20% in last 6 years



Source: Prayas (Energy Group), 2016, October: *India's journey towards 175 GW Renewables by 2022*

Lately, there is a growing demand from RE companies to switch to Availability Based Tariff (ABT) structure. ABT is a frequency based tariff system centred on the readiness of a generator to make power available as a ratio of its rated capacity; in other words, a power plant gets paid for being available for generation. ABT is likely to improve forecasting and scheduling of RE and therefore assist its integration into the grid (see *Chapter 5: Can India's Grid Absorb High Proportion of Renewable Energy?*).

Apart from preferential tariffs, India offers a number of other financial incentives to renewable energy projects. These include tax holidays of up to 10 years and accelerated depreciation of up to 80 per cent in the first year. There are excise and custom duty exemptions for most of the imported equipment, machinery, etc. Then there are source based incentives for renewable energy projects.

The central bank has also categorised renewable energy as a priority sector for lending (commercial banks are obligated to lend to certain priority sectors). Although this means that more debt capital will be available for renewable energy projects, the mechanism caps individual loans at Rs 15 crore, which may not be enough for large-scale solar projects[15].

For open access renewable energy projects – where RE power can be sold to any customer – concessions have been granted on transmission and distribution charges. Concessions vary from state to state, but in general, concessions are in the form of reduced transmission or cross-subsidy charges, energy banking, etc. CERC has fully waived inter-state transmission charges and losses for solar projects commissioned until June, 2017 and for wind projects commissioned until March, 2019 – applicable only to projects selected through competitive bidding.[16]

2. RPOs

Renewable Purchase Obligation (RPO)[17] is a percentage of the energy consumption in each state (for three designated consumers – DISCOMs, open access consumers and captive consumers) that has to be met from RES.

The National Action Plan on Climate Change (NAPCC) has set an ambitious target of 15 per cent RPOs by 2020 for the country. In July, 2016 the ministry of power (MoP) issued new RPO targets to be met by states for 2016-17, 2017-18 and 2018-19 (see *Table 3.1: RPO Targets*). The RPO target for 2018-19 is 17 per cent, which is three per cent higher than what was declared in 2010 in NAPCC. NTP has set a target of eight per cent solar RPO by 2022; this means by 2022 eight per cent of electricity consumption has to be solar power.

Table 3.1: RPO Targets

RPO targets have been revised upwards recently

	Non-Solar RPO	Solar RPO	Total RPO
2016-17	8.75%	2.75%	11.50%
2017-18	9.50%	4.75%	14.25%
2018-19	10.25%	6.75%	17%

Source: Ministry of Power, 2016

The RPO targets mentioned above should ideally get translated into RPO targets for each state, but unfortunately, this has not happened so far. For 2016-17, the weighted average of total (solar and non-solar) RPO targets of states is around 6.6 per cent, considerably less than 12 per cent as was expected under NAPCC. Only two states have met, or exceeded, their respective RPO targets.

15 Renewable Energy Transformation, PwC, 2015 http://www.pwc.in/assets/pdfs/publications/2015/renewable-energys-transformation.pdf

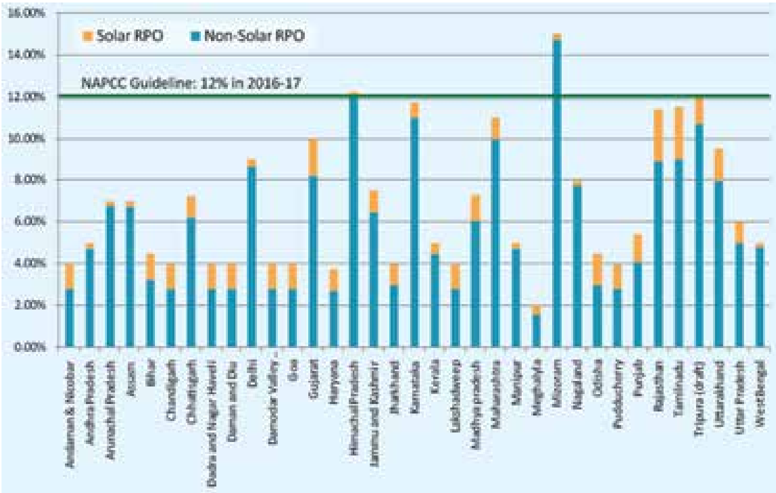
16 Prayas (Energy Group), 2016, October: *India's journey towards 175 GW Renewables by 2022*

17 Legally, RPO means the requirement specified by the State Commissions under clause (e) of sub-section (1) of section 86 of the Electricity Act, for the obligated entity to purchase electricity from renewable energy sources.

Solar RPOs, as specified by SERCs, are significantly lower than what NTP suggests. Of the large states, only Gujarat, Rajasthan and Tamil Nadu have a sizeable solar RPO target, at 1.75 per cent, 2.5 per cent and 2.5 per cent, respectively for 2016-17 (see *Figure 3.4: Solar and Non-Solar RPOs for 2016-17*). Tamil Nadu has set its solar RPO to an ambitious five per cent for 2017-18. The weighted average of all state solar RPOs for 2016-17 is only 1.2 per cent, and will need significant upward revision to eight per cent by 2022 in order to meet the targets set under NTP

Figure 3.4: Solar and Non-Solar RPOs for 2016-17

States have far lower RPOs than what is required to meet NAPCC targets



Source: Prayas (Energy Group), 2016, October: *India's journey towards 175 GW Renewables by 2022*

Not having a high enough RPO target is not the only problem. Compliance with RPOs announced by SERCs is also a major concern.

First of all, there is no up-to-date data of the status of RPOs in different states; SERCs have not put out data on RPO compliance. Whatever data is available indicates very poor compliance in a large number of states. For example, most states are not meeting solar RPOs even when SERCs have set solar RPOs targets as low as 0.25 per cent to one per cent.[18] SERCs of many states have reduced or have not increased the RPO target for the past few years in contravention to the provisions of NAPCC wherein the RPO target has to increase by one per cent every year till 2020. States like Bihar, Odisha, Jharkhand, Assam, Tamil Nadu, Uttar Pradesh, etc., all fall in this category.[19]

SERCs too do not enforce RPOs strictly nor penalise non-compliance. In fact, SERCs have waived the penal provision whenever they have recorded non-compliance. According to a recent report by the Comptroller and Auditor General of India on India's renewable energy sector, many states have not prescribed any penalty for non-compliance, except for a token penalty collected by Uttarakhand.[20]

Part of the reason is that the SERCs are sympathetic of the financial difficulties that most DISCOMs find themselves in for various reasons. They, therefore, are reluctant to push DISCOMs into further financial difficulties by strictly enforcing RPO targets. However, RPO enforcement received a major boost in 2015 when the Supreme Court of India made it mandatory for designated consumers to meet RPO targets.[21] The ministry of new and renewable energy (MNRE) is now demanding strict enforcement of these targets by SERCs.

18 Vinay Rustagi, managing director, Bridge to India, *Solar RPO Compliance: Challenges and Progress*
19 ERC regulations of Bihar, Uttar Pradesh, Tamil Nadu, Assam, Jharkhand
20 http://www.cag.gov.in/sites/default/files/audit_report_files/Union_Civil_Performance_Renewable_Energy_Report_34_2015_chap_2.pdf
21 http://www.business-standard.com/article/companies/sc-order-upholding-rpo-big-boost-for-renewable-energy-trading-115051900544_1.html

It is clear that enforcement of RPOs is key to meeting India's 175 GW target. Once this target is met, it will not be difficult to meet other targets, like the one to install 40 per cent cumulative electric power installed capacity from non-fossil fuel based energy resources by 2030.

3. Renewable Energy Certificates (RECs)

REC mechanism was instituted in 2010 to allow states with lower renewable energy potential to meet their RPO targets. In this mechanism, one REC is issued to the RE generator for one MWh electricity fed into the grid. The electricity is treated in the same way as conventional electricity, and the generator is assumed to be compensated at the pooled cost of power purchased by the DISCOM or any other designated entity. The REC is the environmental attribute and is to be compensated at a market-determined price by trading these on the power exchanges within a price band determined by the CERC, which ensures sufficient compensation to the generator.

The RE generator could sell electricity to a DISCOM and associated RECs also to the DISCOM or any other designated entity within or outside the state. Two categories of RECs, solar and non-solar (which include wind, biomass, bagasse, small hydropower) were instituted in 2010 when the cost of solar was 2-3 times non-solar RE.

The REC market started with much excitement in 2011 with the solar REC selling at an average price of Rs 12,740/REC in 2012. The selling price of non-solar REC was also more than Rs 2,100. This was the period when many developers set up renewable energy projects for the REC market. Then the market started to collapse on the back of poor demand for RECs, largely due to non-compliance with RPO targets by states. By 2015, millions of solar and non-solar RECs remained unsold and the prices crashed. CERC reduced the floor price considering the rapid decline in the cost of RE projects. Since 2015, the selling price of solar and non-solar RECs has been at the floor price of Rs 3,500/ REC and Rs 1,500/ REC, respectively.

The worst seems to be over, though, as there are signs of the REC market reviving. January 2017 recorded the sale of the highest number of solar and non-solar RECs in a month since 2011 (see *Table 3.2: Average Monthly Trading in RECs*). Pressure on SERCs to enforce RPO targets seems to be increasing demand in the REC market. But this is likely to be a short-term surge because the situation today is very different from 2011, when the REC market was conceived.

Table 3.2: Average Monthly Trading in RECs

Signs of revival or the end?

		Buy Bids (nos.)	Sell Bids (nos.)	Cleared Volume (nos.)	Cleared Price (Rs/REC)
2011	Solar	4,366	-	-	-
	Non-Solar	1,18,438	65,891	40,286	2,261
2012	Solar	3,029	639	473	12,740
	Non-Solar	2,44,671	4,67,068	1,65,218	2,127
2013	Solar	6,970	21,646	3,264	10,600
	Non-Solar	1,00,049	18,25,331	1,00,049	1,500
2014	Solar	2,037	1,63,716	2,037	9,300
	Non-Solar	87,200	37,27,893	87,200	1,500
2015	Solar	30,881	15,72,901	30,881	3,500
	Non-Solar	2,24,459	71,36,338	2,24,459	1,500
2016	Solar	33,175	23,43,628	33,175	3,500
	Non-Solar	2,14,665	76,37,682	2,14,665	1,500
Jan-17	Solar	39,572	32,51,453	39,572	3,500
	Non-Solar	12,48,242	91,99,168	12,48,242	1,500

Source: REC Data, India Energy Exchange; https://www.iexindia.com/marketdata/recdata.aspx, as viewed on 21 February, 2017

The REC market faces many issues today. First, with the price of solar power falling below that of wind power, there is a serious question mark on the need for solar and non-solar RECs. Second, MNRE and Power Trading Corporation of India (PTC) are together developing a trading platform exclusively for renewables, wherein states can buy, sell and trade RE power.[22] If such a platform comes up, the relevance of REC reduces significantly as consumers would prefer trading in RE electricity than in two commodities – electricity and REC. Essentially, once the cost of RE reaches grid-parity, RECs cease to be relevant. The end seems near.

Overall, policies in India have been quite favourable for the development of RE so far. However, certain issues, like the availability of finance, grid stability, forecasting and scheduling of RE, changes in grid infrastructure, etc., will become important factors to meet 175 GW target.

Box 3.1
Promoting Small hydropower

MNRE has the responsibility of developing small hydropower (SHP) projects in the country. The potential of such projects is pegged at 20,000 MW with most of them located in Himalayan states (Arunachal Pradesh, Uttarakhand, Jammu and Kashmir, etc.) as river-based projects (mostly without a dam). MNRE aims to tap at least 50 per cent of this potential in the next 10 years[23]. There are estimates that renovation of old projects will result in an increase of about 35 per cent electricity generation[24]. The current installed capacity is 4,334 MW.[25]

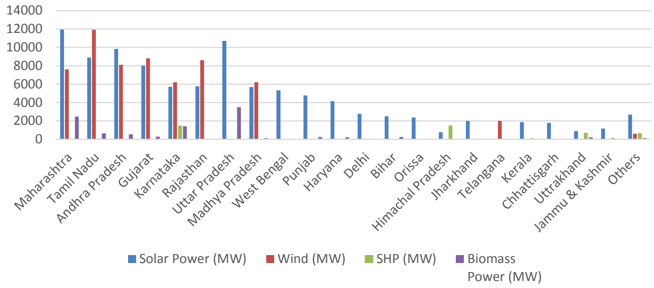
These hydro projects are classified into micro hydro (up to 100 kW), mini hydro (101 to 2,000 kW) and small hydro (2,001 and 25,000 kW). Under the MNRE scheme, these projects are provided financial support for estimating the potential of hydropower and identification of new potential sites and preparation of detailed project reports. The sector has a lot happening at present. Recently, MNRE has engaged an advisory firm to evaluate the small hydro programme and the constraints. There is also a discussion on within MNRE at present on doing away with the divide between small and large hydro and perhaps including the latter as renewable projects. MNRE has recently issued draft guidelines for tariff-based competitive bidding for grid connected small hydro projects.

B. The 175 GW target

Over the past few years, MNRE has come out with a broad plan to implement the 175 GW target, issuing tentative state-wise targets. These targets are highly concentrated as 83 per cent of the 175 GW of renewable power has been planned to be installed in 10 states – Maharashtra, Tamil Nadu, Andhra Pradesh, Gujarat, Karnataka, Rajasthan, Uttar Pradesh, Madhya Pradesh, West Bengal and Punjab – by 2022 (see *Figure 3.5: State-wise Breakup of 175 GW Target*).

Figure 3.5: State-wise Breakup of 175 GW Target

Top 10 states will install more than 80% of the target



Source: Annual Report 2015-16, MNRE

22 http://www.business-standard.com/article/economy-policy/renewable-energy-to-soon-get-a-separate-trading-platform-116062700265_1.html, as viewed on 21 February, 2017
23 http://mnre.gov.in/schemes/grid-connected/small-hydro/ as viewed on 30 September, 2016
24 http://indianexpress.com/article/india/india-others/govt-turns-to-small-hydro-projects-to-meet-power-needs/ as viewed on 30 September, 2016
25 http://mnre.gov.in/mission-and-vision-2/achievements/

- All states and UTs have been given targets to install solar power, ranging from 12 GW to Maharashtra to 4 MW to Lakshadweep. However, top 10 states have been given a target to install 77 GW solar power by 2022.
- In case of wind power, the targets are even more concentrated. Only seven states – Tamil Nadu, Gujarat, Maharashtra, Madhya Pradesh, Rajasthan, Karnataka and Andhra Pradesh – will have more than 95 per cent of the total wind power capacity.
- Biomass power is also concentrated in eight states – Uttar Pradesh, Tamil Nadu, Gujarat, Maharashtra, Madhya Pradesh, Karnataka, Punjab and Andhra Pradesh. These states will install 9.2 GW out of the target of 10 GW for biomass power. As biomass availability is widespread, this concentration in just a few states seems unjustifiable.
- In small hydropower, four states – Karnataka, Himachal Pradesh, Uttarakhand and Arunachal Pradesh – will account for 4.2 GW of the targeted 5 GW capacity.

The state-wise targets could have been made broader as many northern and eastern states have relatively smaller targets.

1. Year-wise targets

A tentative year-wise plan comprising annual targets has been announced by MNRE. Starting with 5.3 GW installation in 2015-16, MNRE plans to install 27.5 GW in 2021-22 (see *Table 3.3: Year-wise plan for 175 GW Target*).

Table 3.3: Year-wise plan for 175 GW Target

India targets to install 139.5 GW RE power in seven years

	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	TOTAL (GW)	Already commissioned capacity by 2014-15 (GW)
Solar	2	12	15	16	17	17.5	17.5	**97**	3.0
Wind	3.2	3.6	4.1	4.7	5.4	6.1	8.9	**36**	24.0
Small hydro	0.14	0.14	0.14	0.14	0.14	0.14	0.14	**0.95**	4.1
Biomass	0.0	0.9	0.9	0.9	0.9	0.9	0.9	**5.58**	4.4
Total (GW)	**5.3**	**16.7**	**20.2**	**21.8**	**23.5**	**24.7**	**27.5**	**139.5**	**35.5**

Source:http://mnre.gov.in/file-manager/grid-solar/100000MW-Grid-Connected-Solar-Power-Projects-by-2021-22.pdf

As of December, 2016 the installed capacity of RE in India reached 47 GW. This means an additional 128 GW of capacity is required in the next five years to meet the target of 25.6 GW capacity addition per year. This will require a CAGR of 30 per cent in RE installation for the next five years. This is going to be a tall order considering that:

- The maximum RE that India has installed in any one year is about 7 GW. This is less than a third of the annual target.
- The CAGR of RE in India in the last decade has been about 20 per cent.
- It has taken India about 15 years to install 43.5 GW of RE capacity (3.5 GW in 2001-02 to 47 GW in December 2016). The country now wants to install three times the amount (128 GW) in just one-third the time (5 years).

In 2015-16, against a target of 5.3 GW installation, close to 7 GW of RE was installed. In 2016-17, however, the progress has not been up to the mark. Against a target of 16.7 GW, only about 4.3 GW was installed till December, 2016 – mere one-fourth of the target (see *Table 3.4: Targets Vs. Achievements*). Even if, several projects are installed between January and March, 2017, meeting the 16.7 GW target seems impossible.

Table 3.4: Targets Vs. Achievements

Only about one-fourth of 2016-17 targets have been met till December, 2016

	2015-16		2016-17	
	Target (in GW)	Achievements (in GW)	Target (in GW)	Achievements* (in GW)
Wind	3.2	3.3	4	1.92
Solar	2	3.1	12	2.15
Small hydro	0.14	0.2	0.25	0.6
Biomass	0	0.4	0.04	0.1

Source: http://mnre.gov.in/mission-and-vision-2/achievements/

As can be seen, India will have to use all available policy levers and resources to meet the 175 GW target. The only factor, apart from favourable policy environment, that can allow such large-scale installation is a significant drop in prices.

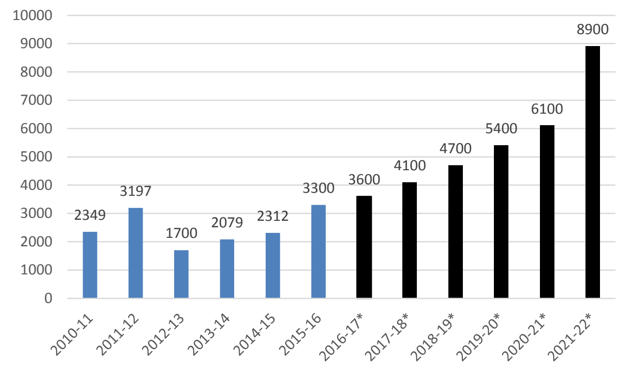
C. Meeting 60 GW wind power target

MNRE has set a target of 60 GW wind power installation by 2022. As per MNRE, the annual target for wind power increases progressively, from 3.2 GW in 2015-16 to 8.9 GW in 2021-22.

The installed capacity of wind power reached 28.7 GW in the country (as of December, 2016). So, in the next five years India will have to install 31.3 GW wind power capacity, or around 6 GW of wind power every year, to meet the target (see *Figure 3.6: Annual Wind Power Installation and Target*). In the past, the maximum capacity of wind power installed in any given year has been 3.3 GW in 2015-16.

Figure 3.6: Annual Wind Power Installation and Target

Maximum amount of wind power installed in a year has been 3300 MW



Source: MNRE, 2016

* Targets set by MNRE for 60 GW wind power installation by 2022

Though doubling the annual installation of wind power is certainly feasible, the problem is that wind power is now more expensive than ground-mounted solar power. Also, as solar power is gaining more attention from governments across the country, the chances of investors moving from wind to solar are high.

The average tariff of wind power, without accelerated depreciation (AD) announced by SERCs is in the range of Rs 4-5/kWh. The lowest tariff is Rs 3.82/kWh for the wind turbines installed in the best wind conditions (wind zone 4) in Maharashtra.[26] Solar tariff on the other hand has dipped below Rs 3/kWh.[27]

26 http://www.mercindia.org.in/pdf/Order 58 42/Order-45 of 2016-29042016.pdf
27 http://www.livemint.com/Industry/zW5Lf1okn054cFug5yKGsL/Madhya-Pradesh-solar-bids-hovering-at-Rs3-per-unit-in-revers.html

The wind industry in India has grown on the back of subsidies, incentives and tax exemptions. Under the income tax law, wind power developers can avail 80 per cent AD if the project is commissioned before 30 September and 40 per cent if commissioned after that date in a financial year. It essentially allows the investor to recover its equity contributions by reducing the amount of tax that they pay in the first year of operations. Those who do not want to avail of AD get a Generation Based Incentive (GBI) of Rs 0.50/kWh of wind power supplied to the grid over and above the preferential tariff paid by DISCOMs.

The government has proposed to end GBI and reduce the AD benefits to 40 per cent from the current 80 per cent. In such a scenario investments are likely to shift from wind to solar energy. This is already happening. According to reports, clean energy companies, which were predominantly focused on wind, are now entering the solar energy market.[28]

In a nutshell, the installation of wind power is dependent on how cost competitive it is in comparison to solar power. To remain cost competitive, more and more wind energy projects will need to be installed in high wind zones. Also, some of the windiest places, where older and small capacity turbines are currently installed, are likely to be repowered to larger turbines of higher hub heights. The central government has announced a repowering policy under which repowered projects will get an interest rate rebate of 0.25 per cent in addition to all the other subsidies that a new wind project is entitled to.[29]

D. Meeting 100 GW solar target

The solar target is the stiffest to meet. From 9 GW installed capacity in December, 2016, solar installed capacity has to reach 100 GW by March, 2022. This means an installation of 18 GW of solar power every year. MNRE has come out with a detailed plan to meet this target (see *Figure 3.7: Tentative Year-wise Target for 100 GW Solar Energy*).

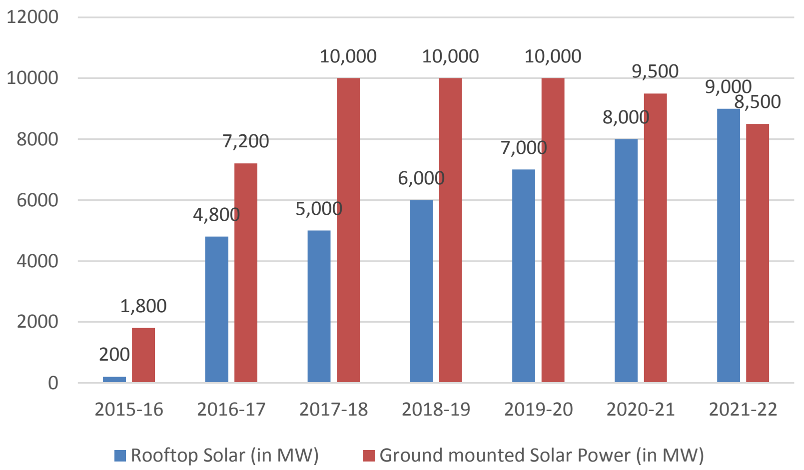
Solar projects have been divided into two categories:

i. Large-scale projects with a target of 60 GW. This is further divided into:
   - Inside solar park (20 GW)
   - Outside solar park (40GW)

ii. Rooftop solar projects with a target of 40 GW

Figure 3.7: Tentative Year-wise Target for 100 GW Solar Energy

40 GW of solar rooftops and 60 GW of larger projects have been planned



Source:http://mnre.gov.in/file-manager/grid-solar/100000MW-Grid-Connected-Solar-Power-Projects-by-2021-22.pdf

28 http://www.livemint.com/Home-Page/gV4ucPd83M4Zc9yr6l6NPO/Wind-energy-sector-feels-the-heat-as-solar-steals-limelight.html

29 http://mnre.gov.in/file-manager/UserFiles/Repowering-Policy-of-the-Wind-Power-Projects.pdf

Of the 60 GW target for large-scale solar projects, 8.7 GW was installed as of December, 2016. The remaining 51.3 GW has to be installed in the next five years.

The large-scale projects have been divided into three categories:

- 20 GW installation in solar parks and ultra-mega solar power projects (UMPP)
- 20 GW installation as 0.5 MW to 5 MW power plants for unemployed youth, gram panchayats and micro, small and medium enterprises (MSME). This scheme is to generate employment for 20,000 unemployed youths.
- 11.3 GW grid-connected solar plants through bundling, reverse bidding and viability gap funding (VGF).

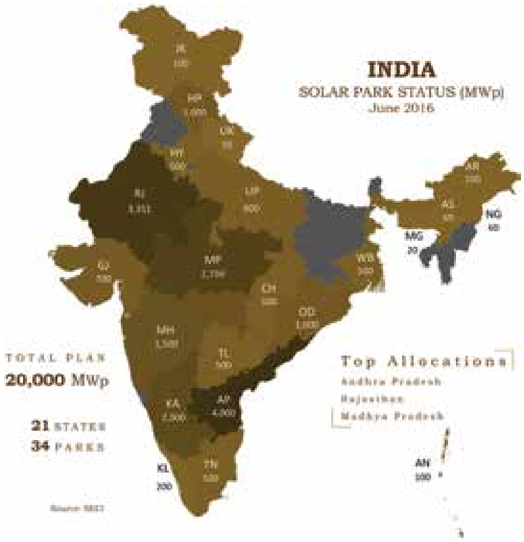
1. Solar parks and UMPPs

The scheme for "Development of Solar Parks and Ultra Mega Solar Power Projects" was introduced by MNRE in December, 2014 mostly with the objective of bringing in economies of scale that can help reduce the cost of generation for solar power[30].

The scheme proposed setting up a minimum of 25 projects with a total capacity of 20 GW by 2020. Till now, 34 parks have been identified across 21 states with a capacity of 20 GW (see *Figure 3.8: Status of Solar Parks*). A total of Rs 539.79 crore have been sanctioned by MNRE for implementation of these solar parks as part of the MNRE financial support through viability gap funding (VGF) of Rs 20 lakh per MW, or 30 per cent of the cost of developing the park whichever is lower[31].

Figure 3.8: Status of Solar Parks

A total of 34 parks in 21 states have been approved



Source: Ministry of New and Renewable Energy, 2016

On 22 February, 2017 the capacity of solar parks and UMPPs was enhanced to 40 GW from 20 GW. The enhanced capacity will ensure setting up of at least 50 solar parks each with a capacity of 500 MW and above in various parts of the country. The Solar Parks and Ultra Mega Solar Power Projects will be set up by 2019-20 with Central Government financial support of Rs 8,100 crore.[32] It is not clear whether this 20 GW enhancement is over and above the 100 GW target or part of the target. If it is part of the target, then most probably the target for solar rooftops has been reduced from 40 GW to 20 GW.

30 Ministry of New & Renewable Energy (Dec 2014), Implementation of a Scheme for Development of Solar Parks and Ultra Mega Solar Power Projects in the country commencing from 2014-15 and onwards (i.e., from the year 2014-15 to 2018-19), Ministry of New and Renewable Energy, Government of India, New Delhi

31 Press Information Bureau (May, 2016), Fact Sheet on Scheme for Development of Solar Parks and Ultra Mega Solar Power Projects, Ministry of New and Renewable Energy, Government of India, New Delhi, http://pib.nic.in/newsite/Printrelease.aspx?relid=145542 as accessed on 21 February, 2016

32 http://pib.nic.in/newsite/PrintRelease.aspx?relid=158621

2. 20 GW for unemployed youth

Under this scheme, MNRE plans to install 20 GW worth of solar plants of 0.5 MW to 5 MW capacity in the next five years. These plants will be installed at sub-stations where spare capacity is available for injection of solar power. The first priority for allocation will be given to unemployed youth, but Panchayats, municipal bodies and MSMEs are also eligible. The unemployed youth can set up the power projects on their own or in partnership with companies and societies.

As per the methodology laid down for allocation of projects to unemployed youth, applications received will be shortlisted on the basis of eligibility criteria.

The shortlisted applicants will be trained by the National Institute of Solar Energy (NISE), Gurgaon, Haryana. A second stage of short-listing will be carried out wherein applicants will be selected on the basis of their preparedness to take up the project, such as availability of land for the project and financial closure.

DISCOMs will buy power from these projects at the rate decided by SERCs. MNRE has proposed a VGF of Rs 65 lakh/MW for installing such projects. A Rs 2,000 crore Risk Guarantee Fund has also been proposed to ensure than the projects get paid on time for the electricity sold to DISCOMs.

There is no update on the status of implementation of this scheme.

3. 11.3 GW Solar power plants through bundling, reverse bidding and VGF

A combination of schemes has been introduced to install the 11.3 GW grid connected solar power plants.

- ***Bundling scheme:*** 3,000 MW capacity is planned to be installed under the bundling scheme. Under this scheme, projects will be auctioned through reverse bidding. The solar power will be purchased by the National Thermal Power Corporation (NTPC), National Vidyut Vyapar Nigam Ltd. (NVVN) and bundled with cheap coal power in the ratio of 2:1 and sold to the DISCOMs. Bundling was successfully used under Phase I of the National Solar Mission to bring down the cost of solar power. But with cost of solar going below Rs 3.0/kWh[33], bundling with coal may not be required.
- ***Defence and PSUs*:** MNRE has roped in defence departments and public sector undertakings (PSUs) to install grid-connected solar power. Defence has been allocated 300 MW solar capacity and are being given a VGF of Rs 1.5-2.5 crore/MW under various categories. Similarly, PSUs have been provided a VGF of Rs. 0.5-1.0 crore/MW to install 1,000 MW worth of solar power plants by 2016-17.
- ***7,000 MW under VGF scheme:*** MNRE plans to auction 2,000 MW solar plants, from 2015-16 to 2016-17, and 5,000 MW, from 2016-17 to 2020-21, under the VGF scheme. Based on reverse bidding, a maximum VGF of Rs 1-1.3 crore/MW will be provided. Projects that will meet the domestic content requirement will get a higher VGF of Rs 1.3 crore/MW.

Overall, MNRE seems to have a reasonably good plan in place to meet the 60 GW ground mounted solar power project target. However, grid issues like forecasting and scheduling, constructing transmission lines to evacuate power, etc., will have to be addressed to meet this target (see *Chapter 5: Can India's Grid Absorb High Proportion of Renewable Energy?*).

E. Rooftop solar

India has set a target to install 40 GW worth of rooftop solar projects by March, 2022. Most of these will have to be installed in the next five years.

The major advantage of rooftop solar units is that these don't require land or new transmission infrastructure. Rooftop projects don't have to pay for the cost of land, civil works and power evacuation which constitute around 20 per cent of the capital cost of a ground mounted solar power plant[34]. Rooftop PV systems can also tap into the existing distribution systems. Power plants can utilise within short distances the excess power that rooftop units feed into the grid thereby reducing transmission and distribution (T&D) losses.

---

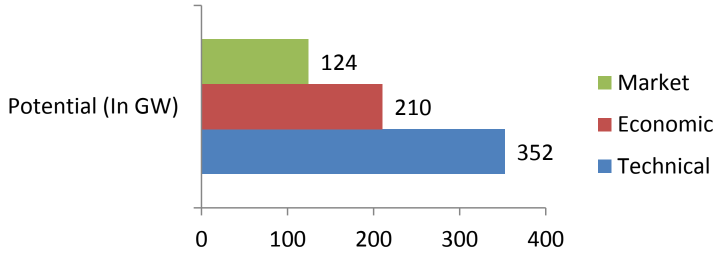
33 http://www.livemint.com/Industry/zW5Lf1okn054cFug5yKGsL/Madhya-Pradesh-solar-bids-hovering-at-Rs3-per-unit-in-revers.html

34 CERC Order dated 23 March 2016, on benchmark capital cost determination for Solar PV projects 2016-17

The technical potential for rooftop solar in the country is more than 350 GW and the market potential is 124 GW (see *Figure 3.9: Potential of Solar Rooftops in India*). However, with growing building stock and fast development of building integrated solar technologies, the potential of solar rooftops is likely to increase manifold in the future.

Figure 3.9: Potential of Solar Rooftops in India

Potential is three times the target set

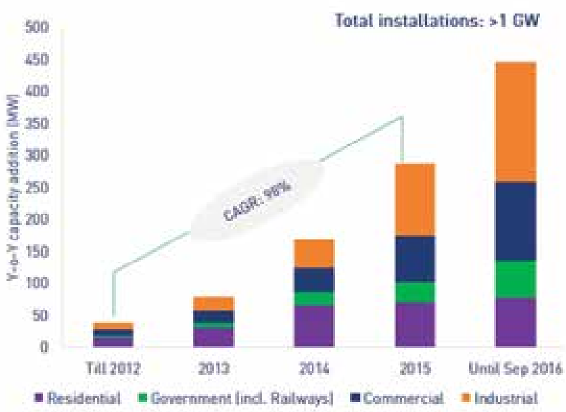


Source: Adopted from presentation made by Tarun Kapoor, Jt. Secretary, MNRE on 13 May, 2015

The pace of installation of solar rooftop projects has increased in the last two years. Estimates by consultancy firm, Bridge to India, indicates that more than 1 GW capacity has been installed (see *Figure 3.10: Solar Rooftop Installation in India*). A significant proportion of installation is taking place in the commercial and industrial sectors. And, this is likely to grow in the future.

Figure 3.10: Solar Rooftop Installation in India

Total installation of solar rooftops exceeds 1 GW



Source: Bridge to India, 2016

1. Policies and Prices

There are policies to support installation of solar PV plants both at the Centre and at the state level. At present, 13 states have a solar policy supporting grid connected rooftop systems.

MNRE provides capital subsidy equivalent to 30 per cent of the benchmark cost, which is Rs 80,000 per KW (cost) for grid connected rooftop projects[35]. This subsidy is only for residential, institutional and social sector systems that are installed for personal consumption. Although there is no capital subsidy for the commercial and industrial sector, their installations are eligible for accelerated depreciation benefits.

The capital subsidy for residential, institutional and social sector systems installed for personal consumption is 70 per cent of the benchmark cost for special category states, i.e., northeastern states including Sikkim, Uttarakhand, Himachal Pradesh, Jammu and Kashmir, Lakshadweep and Andaman and

35 Ministry of New and Renewable Energy (Nov 2015),Installation of Grid connected solar rooftop power - CFA regarding, New Delhi

Nicobar Islands[36]. The Central Government allocated Rs 5,000 crore in December, 2015 for supporting 4,200 MW worth of solar rooftop plants[37]. This, the government hopes, will create the market, build the confidence of consumers and will enable the balance capacity through market mode to achieve the target of 40,000 MW by 2022.

In addition to capital subsidy, the Centre also provides other benefits like custom duty concessions, excise duty exemptions and soft loans from various banks. Several major banks of India have come forward to include rooftop solar PV as part of their home loan/home improvement loan[38].

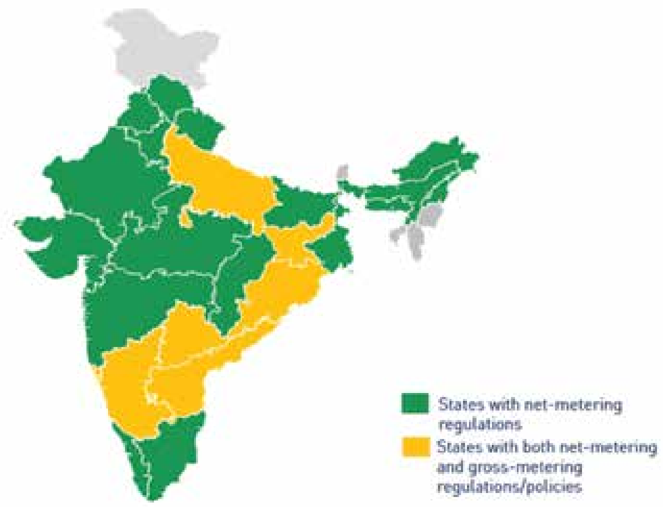
The Central government is also pushing all departments and ministries to install rooftop solar. It has come out with a policy that will allow installation of 6 GW of solar rooftop projects on government buildings. A capital subsidy scheme has been released in this regard.

Solar rooftop projects can be installed for captive use or can be connected to the grid. For those connected to the grid, Indian DISCOMs offer two types of metering: net and gross metering.[39] Around 23 states in India have come out with regulations on net metering (see *Figure 3.11: Status of Net and Gross Metering Policy)*. Six states have implemented both net and gross metering.

DISCOMs, though, are not thrilled about solar rooftop plants as these are likely to eat into their revenue and profitability. Some DISCOMs are also not confident about the impact of solar rooftops on the local grid. They have, therefore, put restrictions on the amount of solar rooftop plants that can be installed (see *Box 3.2: Restricting Solar Rooftops*). The DISCOM issues will have to be resolved for large-scale installation of solar rooftop plants (see *Chapter 4: What Ails India's DISCOMs?*).

Figure 3.11: Status of Net and Gross Metering Policy

Barring few states, all states allow net metering



Source: Bridge to India, 2016

Rooftop solar projects are generally more expensive than ground mounted large solar PV projects.

36 Ministry of New and Renewable Energy (Nov 2015),Installation of Grid connected solar rooftop power - CFA regarding, New Delhi

37 PIB ID: 134027, titled "Cabinet approves Rs 5,000 crore for promotion of Solar Rooftops in the country"

38 Ministry of New and Renewable Energy (Nov 2014), Financing Solar Rooftop, http://mnre.gov.in/file-manager/UserFiles/financing-of-Solar-Rooftop.pdf, as accessed 25 February 2016

39 In the net metering system, the electricity meter operates in both directions. The electricity produced by the solar rooftop plant is consumed by the consumer and the surplus power, if any, is fed into the grid. If required, consumers can also import from the grid. The net meter will measure both electricity exported and imported. By the end of the billing period, the net power is calculated. If the net energy is negative (i.e., import is higher than the export), the consumer will pay the DISCOM for the net units as per the tariff band. If it is positive, the DISCOM may pay the customer, adjust during the next billing period, or not pay the customer.

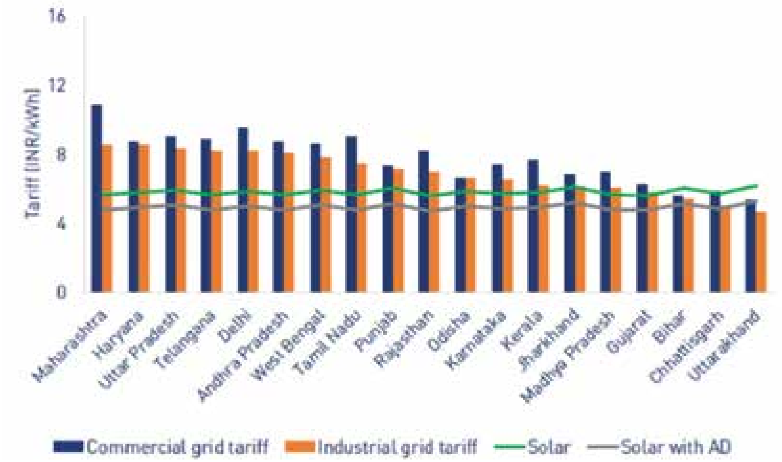
In gross metering, the generated power is not linked to consumption. Two separate meters are installed. The electricity generated by the solar plant and the electricity imported are measured independently. The power generated by the solar rooftop plant is directly fed into the grid, which is measured through an export meter and power from grid is imported through an import meter. By tracking the total units generated and the total units consumed separately the DISCOM has the flexibility to charge the two at different rates.

This is because of the higher cost of the balance of the system like inverter, meters, etc. But over the last few years, the cost of rooftop solar has reduced significantly. The benchmark cost of rooftop plants released by MNRE for the purpose of giving capital subsidy has reduced from Rs 130/Watt peak (Wp) in 2012-13 to Rs 75/Wp in 2016.[40] The Solar Energy Corporation of India has been regularly conducting competitive bidding for rooftop solar projects. The price under these biddings settled at Rs 70-75/Wp.[41]

At these prices, solar rooftop projects supply power cheaper than the average tariff of power from the grid for the commercial and industrial sectors (see *Figure 3.12: Rooftop Solar Prices vs. Grid Tariff for Commercial and Industrial Consumers* and *Figure 3.13: Rooftop Solar Prices vs. Grid Tariff for Residential Sector*). In other words, solar rooftop plants have achieved grid parity for the commercial and industrial sectors. Rooftop solar is likely to reach grid parity for the residential sector by 2018.[42]

Figure 3.12: Rooftop Solar Prices vs. Grid Tariff for Commercial and Industrial Consumers

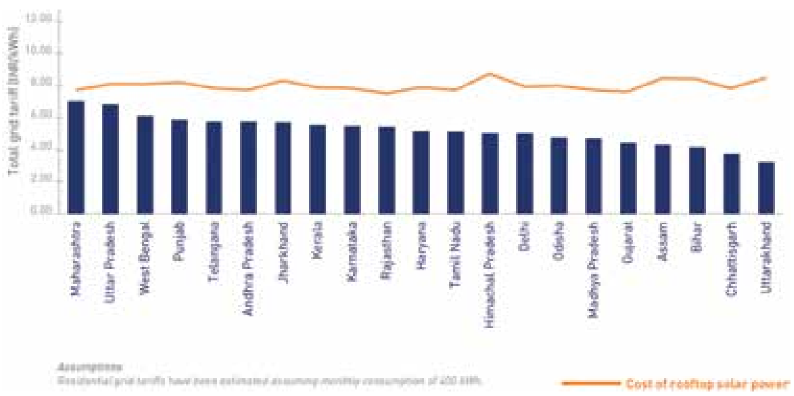
In most states solar rooftop projects are economically lucrative for commercial and industrial consumers



Source: Bridge To India, 2016; as presented at the conference organised by Centre for Science and Environment, on replacement of DG sets with solar rooftop systems on 10 January, 2016 in New Delhi

Figure 3.13: Rooftop solar prices vs. grid tariff for residential sector

Presently rooftop solar plants have not achieved grid parity for residential consumers



Source: India's Solar Rooftop Map 2016, Bridge to India

40 Prayas (Energy Group), October, 2016: *India's Journey towards 175 GW Renewables by 2022*
41 Ibid
42 India's Solar Rooftop Map 2016, Bridge to India

With solar rooftop achieving grid parity for all segments of consumers in the next few years, and a Rs 5,000 crore subsidy to galvanise the market, meeting the 40 GW target, though stiff, can be achieved within few years of 2022.

Box 3.2
Restricting Solar Rooftops

It has been seen that DISCOMs are generally not in favour of rooftop solar systems. One of the main concerns of most DISCOMs is the fear of losing their most profitable customer base, the commercial and industrial consumers. DISCOMs are also not sure of the stability of the grid due to large-scale installation of rooftop solar. They are, therefore, imposing restrictions.

In the net metering system, DISCOMs have restricted the amount of energy that can be injected into the grid in a year. The restriction is linked to either the sanctioned load (fixed at the time of getting the connection) or the annual consumption of a consumer. The electricity injected into the grid through solar rooftop is often capped by many states to 90 per cent of the annual consumption of the consumer. The excess energy exported to the grid is treated lapsed at the end of a settlement period.

At the local distribution level, the total capacity of rooftop PV systems connected to the grid is restricted in proportion to the rated capacity of the distribution transformer. The reason for this limitation is the uncertainty of any negative impacts the grid may face due to reverse flow of electricity. Different states have different levels of restriction. Most of the states have kept the restriction at 15-30 per cent of the distribution transformer capacity. For instance, if the transformer's capacity is 200 kVA, a total of 54 kW (i.e., 30 per cent of rated capacity) rooftop PV systems can be connected to the grid. However, many states allow much higher capacity – Gujarat (60 per cent), Kerala (80 per cent) and Karnataka (80 per cent).

Although the rooftop solar sector is still in its early stage, it will not be long before some DISCOMs reach their restriction levels. The DISCOM issues will have to be resolved and restrictions removed to allow for large-scale installation of solar rooftop plants.

F. Financing 175 GW target

Most analysts believe that the key impediment for the large-scale expansion of renewable energy in India is non-availability of low cost finance. This is because, even though the cost of renewable energy has reduced, the total quantum of finance required to meet 175 GW target is high.

- According to a report by Bloomberg New Energy Finance, India will need around $100 billion (approximately Rs 6,50,000 crore) asset finance during 2016-22, including $30 billion (approximately Rs 1,95,000 crore) in equity capital, to put the nation on the track to reach 135 GW of utility-scale renewable energy by 2022. In addition, $50 billion (approximately Rs 3,25,000 crore) would be required to install 40 GW of solar rooftop projects.[43] So, about Rs 10,00,000 crore will be required to meet the 175 GW RE target and this excludes the finance required for the transmission infrastructure.
- According to Climate Policy Initiative, a consulting organisation, in order to meet the target of 175 GW by 2022, the renewable energy sector in India will require $189 billion (Rs 12,28,500 crore) in additional investment during 2016-2022 period, which includes $57 billion (Rs 3,70,500 crore) in equity, and $132 billion (Rs 8,58,000 crore) in debt.[44]
- According to the draft National Electricity Plan (Vol. 1), Generation, during 2017-12, an estimated Rs 8,59,369 crore would be required to set up generation plants. This includes approximately Rs 6,50,000 crore required to set up 1,15,326 MW from RE sources.[45] According to the draft National Electricity Plan (Vol. 2), Transmission, an expenditure of Rs 2,60,000 crore will be incurred during 2017-22 for the transmission system addition required in the country.[46]
- According to the Report of the Expert Group, constituted by Niti Aayog, on 175 GW RE by 2022, the cost for transmission strengthening to integrate large-scale RE into the grid is estimated at around Rs 1.0 crore/MW. About half of this cost – Rs 50 lakh/MW – will be required for inter-state transmission

43 Financing India's clean energy transition, Bloomberg new energy finance, 2016
44 Reaching India's Renewable Energy Targets: The Role of Institutional Investors, Climate Policy Initiative, December 2016
45 draft National Electricity Plan (Vol. 1) Generation, CEA, 2016
46 draft National Electricity Plan (Vol. 2), Transmission, CEA, 2016

network and the remaining half for strengthening the intra-state transmission network. Considering an addition of about 120 GW RE till 2022, an estimated Rs 1,20,000 crore will be required for transmission infrastructure.

The authors of this report have also made estimates on the quantum of finance required to meet the 175 GW target (see *Table 3.5: Estimated Finance Required for 175 GW Target*).

Table 3.5: Estimated Finance Required for 175 GW Target

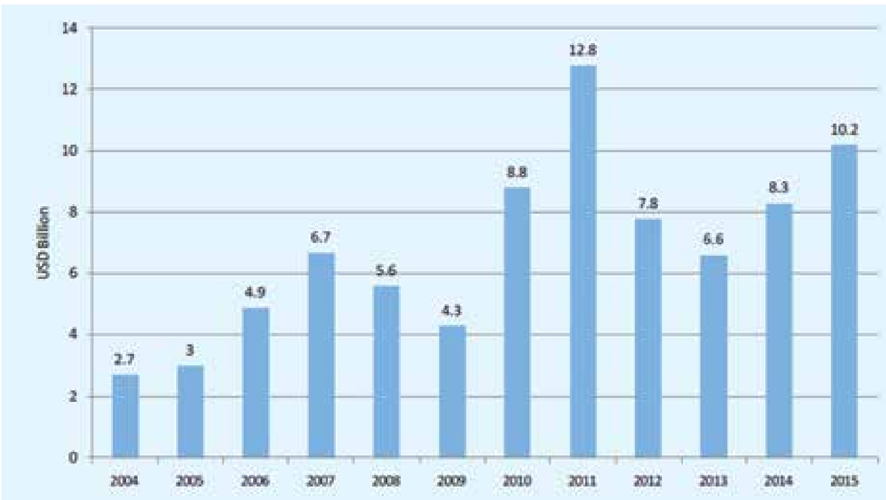
For the remaining 138 GW RE installation

Energy Source	Capacity in GW (up to March 2022)	Per MW cost (in crore)	Total (in crore)
Solar utility-scale	**51.3**	**5.0**	**2,56,500**
Solar rooftop	**39**	**6.0**	**2,34,000**
On-shore Wind	**31.3**	**5.5**	**1,72,150**
Biomass	**4**	**12**	**48,000**
Solar PV+ Distributed PV	**57**	**6**	**342,000**
Solar CSP	**11**	**12**	**132,000**
Small hydro	**0.7**	**7**	**4,900**
Others (include waste to energy, biomass etc.)	**4.9**	**5.7**	**27,930**
Transmission infrastructure	**120**	**1**	**1,20,000**
Total			13,37,480 or $205 billion

In the last 10 years, the maximum investment in any one year in the renewable energy sector has been about $12.8 billion (see *Figure 3.14: Estimated Renewable Energy Investments in India*). However, to meet the 175 GW target about $200 billion will be required over the next five years or, on an average, $40 billion per year. This is at least three times the investments in the past. This makes the availability of adequate finance a very important factor in deployment of large-scale renewable energy in India.

Figure 3.14: Estimated Renewable Energy Investments in India

In 2015, about $10 billion was invested in the renewable energy sector in India



Source: Prayas (Energy Group), October, 2016: *India's Journey towards 175 GW Renewables by 2022*

1. Availability of finance

Since the announcement of the 175 GW target, domestic and foreign investors, including banks and multilateral agencies, have shown a great deal of interest in investing in the renewable sector in India.

During the RE-Invest meet in February, 2015, 40 major banks and Non-Banking Financial Companies committed to finance 78 GW of RE capacity over the next five years. The state-owned State Bank of India (SBI) alone committed to lend Rs75,000 crore towards 15,000 MW of projects.[47]

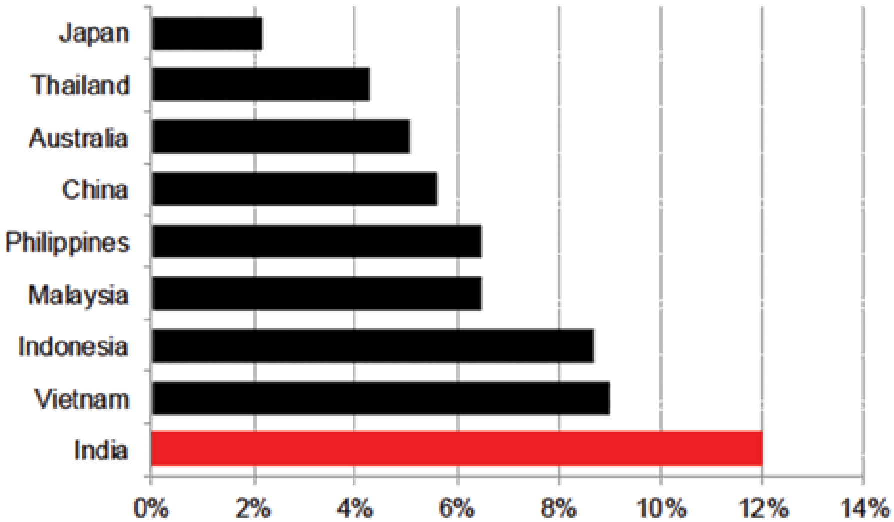
There has been growing interest from foreign investors as well. Japan's Soft Bank has pledged to invest at least $20 billion in solar energy projects in India.[48] World Bank has signed an agreement to invest $1.0 billion in Indian solar energy projects.[49] KfW, the German development bank, is also in the final stages of negotiations with MNRE to invest $1 billion for installation of rooftop panels. Apart from KfW, US EXIM Bank has already pledged $1 billion. The Asian Development Bank (ADB) will invest $500 million for solar rooftop projects and $1.0 billion for transmission of renewable energy.[50]

Although these are encouraging trends, India needs to improve the investment climate to raise low-cost finance from both domestic and foreign sources. This will boost the RE sector.

Currently, the cost of debt is high in India due to the macro-economic scenario (high inflation and high government borrowing) and there are many risks associated with renewable energy projects as well, including the poor financial health of utilities (see *Figure 3.15: Cost of Debt for Solar Projects*). The expectation on the rate of return on equity is also high because of the perceived high risk. Additionally, the equity requirement for the procurement of debt funding in India is also higher than the finance available in developed countries – the debt to equity ratio in India is estimated at about 70:30 as compared to 85:15 in countries like Germany, which have globally, among the highest penetration of renewable energy in their electricity sector (see *Figure 3.16: Cost of Equity for Solar Projects*). The high cost of capital increases the cost of renewable energy by 24-32 per cent compared with similar projects in developed countries.[51]

Figure 3.15: Cost of Debt for Solar Projects

Cost of debt in India is more than double of China



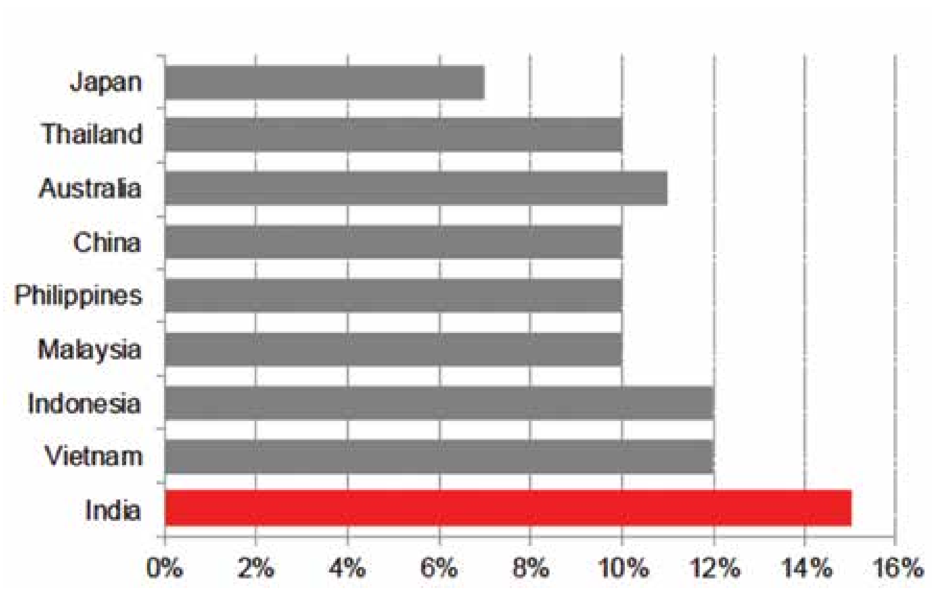
Source: Financing India's clean energy transition, Bloomberg New Energy Finance, 2016

* nominal rates for local currency debt

47 http://www.livemint.com/Industry/nMlGobKsiSAwxW0Luw3LtK/Firms-pledge-investments-to-back-renewable-energy-push.htm
48 http://www.livemint.com/Companies/VXBRbs9HVdDbEIJJeB5NYP/Softbank-to-double-India-investment-to-20bn.html
49 http://www.business-standard.com/article/economy-policy/indian-solar-energy-to-get-1-bn-from-world-bank-116063000413_1.html
50 https://www.adb.org/news/adb-lends-1-billion-renewable-energy-transmission-grid-expansion-india
51 Solving India's Renewable Energy Financing Challenge: Instruments To Provide Low-Cost, Long Term Debt, Climate Policy Initiative, 2014

Figure 3.16: Cost of Equity for Solar Projects

Cost of equity in India is 1.5 times China's



Source: Financing India's clean energy transition, Bloomberg New Energy Finance, 2016

* nominal rates for local currency equity

So far in India, private investors and corporates have put in equity while debt has been provided by domestic and foreign banks, including multilateral agencies. Very few companies have raised finance from the public.

Raising low-cost finance from the market and from domestic and foreign investors is key to meeting the finance requirements. Low-cost finance can be raised by reducing risks for foreign and domestic investors and by raising funds from the market.

2. Low-cost finance from foreign investors

Financing renewable energy growth in India has its own bag of risks. For foreign investors, like insurance companies and pension funds, the biggest risk is from off-takers and from the currency market. Investors always run the risk of DISCOMs not fulfilling their contractual obligations and making delayed or incomplete payments. As most DISCOMs have poor financial health, off-takers' risk makes the return on investments uncertain. This risk can be mitigated by putting in place a payment security mechanism that will ensure that the investor is paid for the amount of energy fed into the grid even if the DISCOM defaults.

MNRE can set up such a payment security mechanism from the Central Government's funds or by raising funds from multilateral institutions like the Green Climate Fund. Recently, in 20 GW solar programme for unemployed youth, MNRE proposed a Risk Guarantee Fund to ensure that project developers are paid even if DISCOMs default on payments.

The other risk factor for investors arises out of unexpected and volatile fluctuations in foreign exchange rates. To guard against such currency risk, a certain percentage is added to the cost of capital. This is called currency hedge. Market-based currency hedging in India is expensive, adding approximately seven percentage points to the cost of debt. This makes fully-hedged foreign debt nearly as expensive as domestic debt, and renders investments from foreign investors, including institutional investors, less competitive against domestic investment. A government-sponsored foreign exchange hedging facility can exercise greater control over risk exposure and reduce the hedging cost by nearly 50 per cent.[52] Here also, Green Climate Fund can be tapped to set up a foreign exchange hedging facility.

Instituting a payment security mechanism and a foreign exchange hedging facility, together with keeping the policy and regulatory environment stable – like continuity of certain government incentives – will reduce the cost of capital from foreign investors.

3. Low-cost finance from domestic investors

Domestic institutional investors – domestic insurance companies and pension funds – have the ability to provide sufficient finance for the RE sector. At present, domestic institutional investors view RE sector as risky. To encourage domestic institutional investors, their understanding of the sector will have to be improved. In addition, RE will have to become like any other infrastructure sector with proper credit ratings of RE companies.

Policy and regulatory certainty will give confidence to domestic investors. Similarly, partial credit guarantees can improve the credit rating of the debt of operational renewable energy projects, and make them attractive to institutional investors.[53]

A payment security mechanism will help domestic investors as well. There are also proposals to set up infrastructure debt funds to enable institutional investment in the renewable energy sector by providing a more liquid investment option.

4. Raising money from the market

RE companies will have to get listed, get proper credit rating (possibly with the help of partial credit guarantees) and raise money from the market. Green bonds are emerging as a viable option to raise finance from the market. In 2015, the size of green bonds was about $45 billion globally.[54]

Green bonds can be labelled (and hence certified as green) or unlabelled but clearly linked to 'green' projects. Indian firms involved in RE sector have issued unlabelled green bonds in the past. Since 2015, Indian companies have issued number of labelled green bonds. Yes Bank issued India's first 'Green Infrastructure Bond', and since then at least three more companies have issued labelled green bonds.

Considering the rise in green bonds, in January 2016, the Securities and Exchanges Board of

India (SEBI) issued disclosure requirements for issuance and listing of green bonds. This is likely to help the green bond market further.

It is quite clear that there is a great deal of interest among domestic and foreign investors to invest in RE projects. Further, by putting in place risking mitigating instruments, like payment guarantee mechanism and by providing policy and regulatory certainty, more low-cost finance can be attracted. Also, as the cost of RE reduces further, more and more investors are expected to move into this sector. For rooftop solar projects, individuals, industries and institutions would be willing to put their own money or raise balance-sheet loans to offset the high cost of grid power.

Overall, with certain policy reforms, finance is not likely to be an impediment for meeting the 175 GW target.

The issue is how quickly these reforms can be institutionalised.

---

52 Reaching India's Renewable Energy Targets Cost Effectively: Foreign Exchange Hedging Facility, Climate Policy Initiative, 2015

53 Reaching India's Renewable Energy Targets: The Role of Institutional Investors, Climate Policy Initiative, December 2016

54 Financing India's clean energy transition, Bloomberg new energy finance, 2016

CHAPTER 4

WHAT AILS INDIA'S DISCOMS?

Distribution companies (DISCOMs) have long faced financial unsustainability on account of below-cost tariffs for different consumer groups; supply of un-metered, free electricity to agriculture; and high aggregate technical and commercial (AT&C) losses. The weakened finances of state utilities have lowered their ability to invest in upgradation and expansion of the distribution infrastructure. Today they rely heavily on government support for both investment and working capital.

There is a fear that higher cost of renewables could further jeopardise the financial position of DISCOMs. Decentralised renewables, like the solar rooftop, poses a major challenge. Consumers who are paying higher tariff for electricity are likely to shift to solar rooftop and other decentralised systems. This could significantly reduce the sales volume and revenue for DISCOMs, thereby worsening their operational and financial health. DISCOMs, therefore, could view renewables as a major threat and resist its large-scale use.

In this chapter, we will discuss the status of DISCOMs and the reasons for their poor operational and financial position, the risk they pose to the penetration of renewable energy and the actions required to reboot DISCOMs for wider integration of renewable energy.

A. Status of DISCOMs[55]

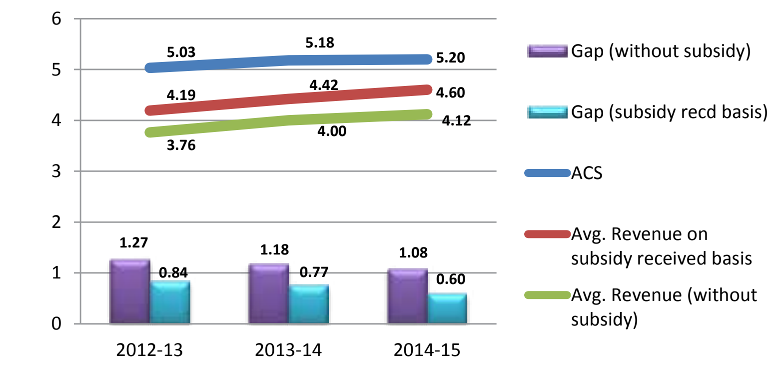
DISCOMs in India are largely state owned. They have been under financial stress for a long time. Their situation has worsened in the last decade despite a series of specific reform measures and financial bailouts for the sector. Why have these reforms not worked? Let us examine the financial and operational performance of DISCOMs to understand the fundamental problems plaguing them.

1. Cost of supply and revenue realised

Utilities that are selling directly to consumers are unable to recover the cost of supplying power. The gap between the average cost of supply (ACS) and average revenue realised (ARR) was about 20 per cent in 2014-15 (see *Figure 4.1: ACS and ARR*). This gap has been reduced by subsidy from the states. Even then the gap is about 12 per cent now.

Figure 4.1: ACS and ARR

The gap has reduced narrowly in the last few years, but still remains high



Source: Power Finance Corporation Ltd.
Unit: Rs/kWh

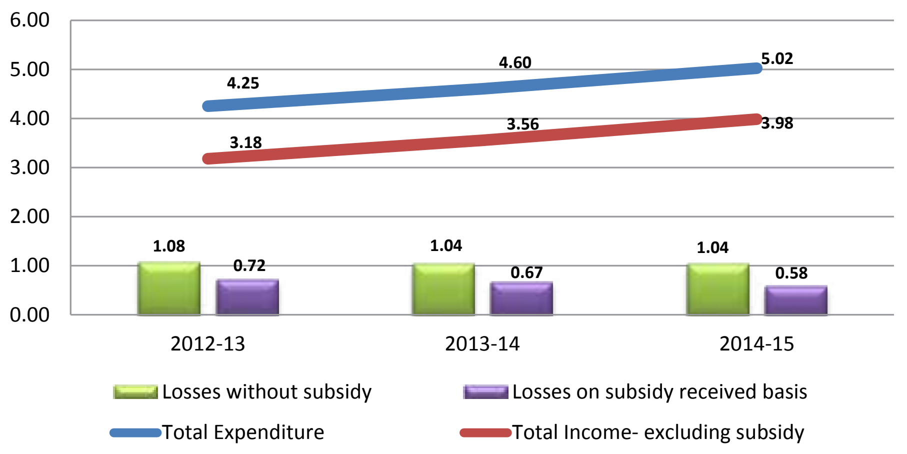
55 This entire section has sourced data from the report titled, "The Performance of State Power Utilities for the years 2012-13 to 2014-15", by the Power Finance Corporation Ltd. The year 2014-15 is the latest year for which data on the performance of DISCOMs is available.

2. Income, expenditure and losses

DISCOMs incur heavy losses every year. Although, losses (without subsidy) remained almost the same (Rs 1 lakh crore, or $US 16 billion, every year at the current exchange rate) from FY 2012-13 to FY 2014-15, losses (with subsidy) came down narrowly in the same period due to increase in subsidy from state governments (see *Figure 4.2: Income, Expenditure and Losses*). The percentage of loss, however, reduced from 25 per cent in FY2012-13 to about 20 per cent in FY2014-15, which is a positive trend.

Figure 4.2: Income, Expenditure and Losses

Losses without subsidy has remained at Rs 1 lakh crore



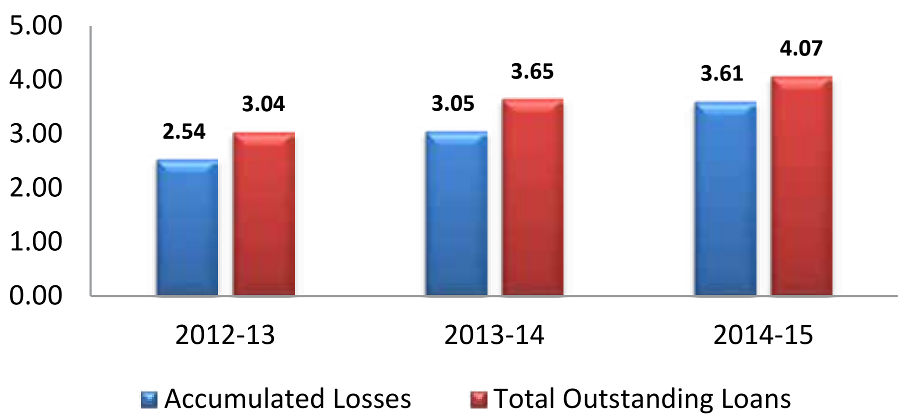
Source: Power Finance Corporation Ltd.
Unit: Rs Lakh Crore

3. Accumulated losses and outstanding debt

The total outstanding debt and accumulated losses of DISCOMs increased continuously from 3.04 and 2.54 lakh crore in FY2012-13 to 4.07 and 3.61 lakh crore in FY2014-15 (see *Figure 4.3: Accumulated Losses and Total Outstanding Debt*).

Figure 4.3: Accumulated Losses and Total Outstanding Debt

Losses have been continuously increasing over the years

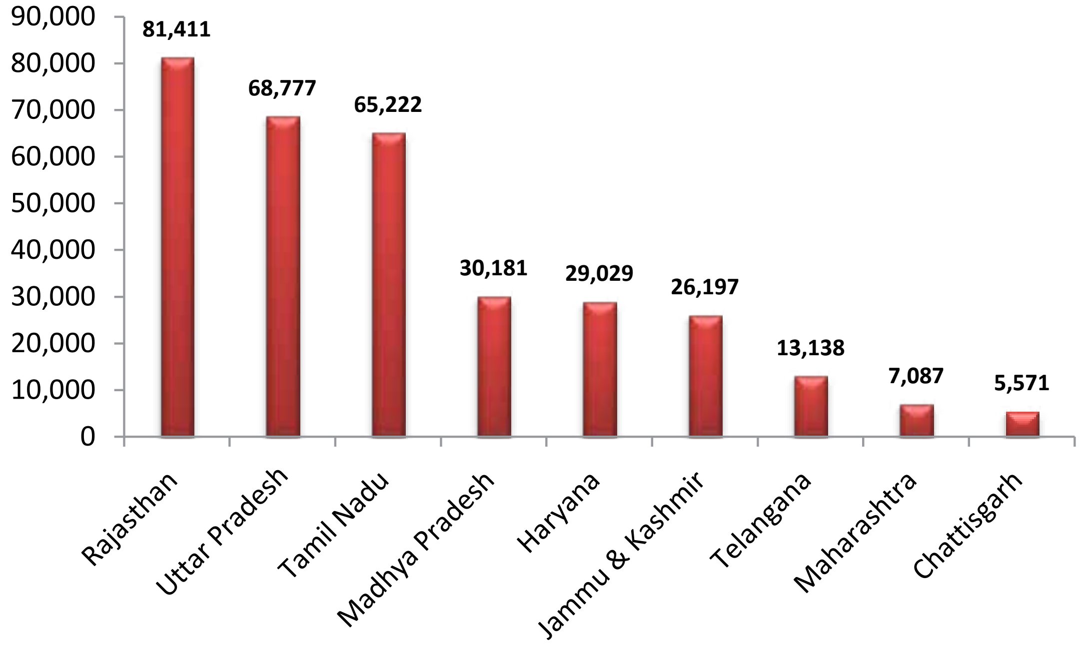


Source: Power Finance Corporation Ltd.
Unit: Rs Lakh Crore

Majority of the accumulated losses – 90 per cent of the total – are in Rajasthan, Uttar Pradesh, Tamil Nadu, Madhya Pradesh, Haryana, Jammu and Kashmir, Telangana, Maharashtra and Chhattisgarh (see *Figure 4.4: Accumulated Losses – State-wise, 2014-15*). Interestingly, Rajasthan has the highest potential of solar power in the country (see *Box 4.1: States with High Renewable Energy Target have DISCOMs with Poor Financial Health*).

Figure 4.4: Accumulated Losses – State-wise, 2014-15

9 states constitute 90 per cent of the total accumulated losses in India

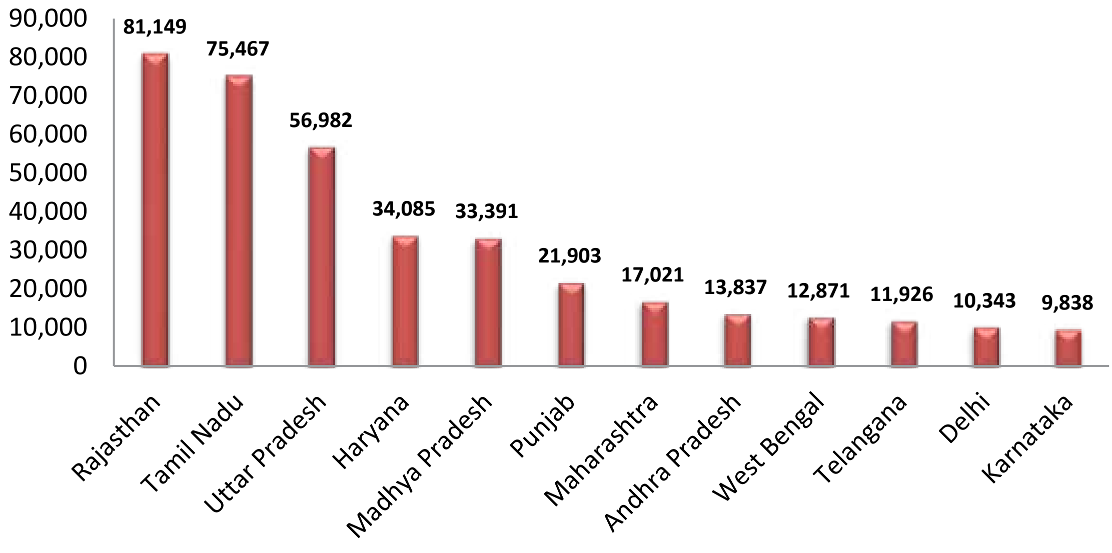


Source: Power Finance Corporation Ltd.
Unit: Rs. Crore

Similarly, 93 per cent of the outstanding debt is with 12 states (see *Figure 4.5: Outstanding Debt – State-wise, 2014-15*). Rajasthan again has the largest debt.

Figure 4.5: Outstanding Debt – State-wise, 2014-15

12 states constitute 93 per cent of the total outstanding debt in India

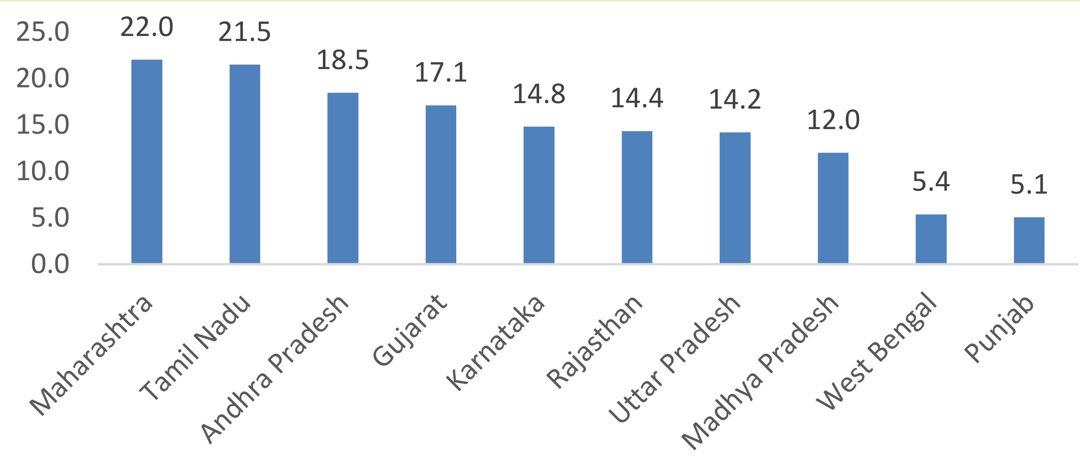


Source: Power Finance Corporation Ltd.
Unit: Rs Crore

Box 4.1
States with a High Renewable Energy Target have DISCOMs with Poor Financial Health

The Ministry of New and Renewable Energy (MNRE) has projected state-wise breakup of Renewable Power target to be achieved by 2022. Most of the renewable power – 83 per cent of the 175 GW –has to be installed in 10 states by 2022.

Top 10 states for installation of power by 2022
Of the 175 GW renewable power to be installed by 2022, 145 GW has to be installed in 10 states



Though most DISCOMs in India have poor financial health, the interesting thing to note is that these top 10 states are also some of the largest consumers of electricity and account for the lion's share of poor balance sheet of DISCOMs in India.

- *According to the latest data released by the Ministry of Power on power supply position in India, 70 per cent of the energy requirement and 78 per cent of peak load requirement come from these 10 states.*[56]
- *In 2014-15, of the Rs 1,04,387 crore loss incurred by all DISCOMs, Rs 74,429 crore loss (71.3 per cent of the total) was incurred by utilities in these 10 states.*
- *Till March, 2015, of the total accumulated losses by all DISCOMs, 73.5 per cent of the accumulated losses were accounted by DISCOMs of these states.*
- Till March, 2015, 80% of the total outstanding debt of Rs 4,06,825 crore was accounted by DISCOMs of these 10 states.

These top states, other than West Bengal, also have a significant share of the total agricultural consumers and subsidise them substantially.

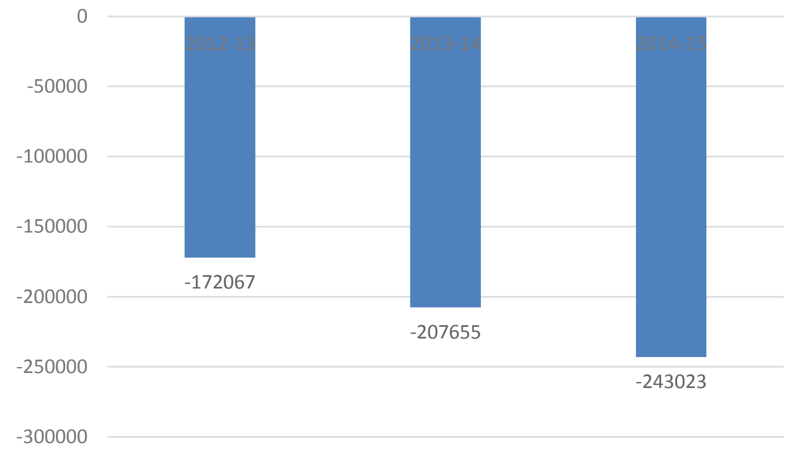
56 Region/State-wise Power Supply Position in India – 2016-17, Ministry of Power

4. Net worth

The net worth of utilities directly selling power to consumers is negative. Net worth declined from negative Rs 2,07,655 crore, as on March 31, 2014, to Rs 2,43,023 crore, as on March 31, 2015 (see *Figure 4.6: Net Worth of Utilities*).

Figure 4.6: Net Worth of Utilities

Most utilities have a negative net worth



Source: Power Finance Corporation Ltd.
Unit: Rs Crore

Overall, DISCOMs in India are bankrupt. If DISCOMs were a private company, there is no way they would continue to exist with such poor financial health.

B. Reasons for poor financial health

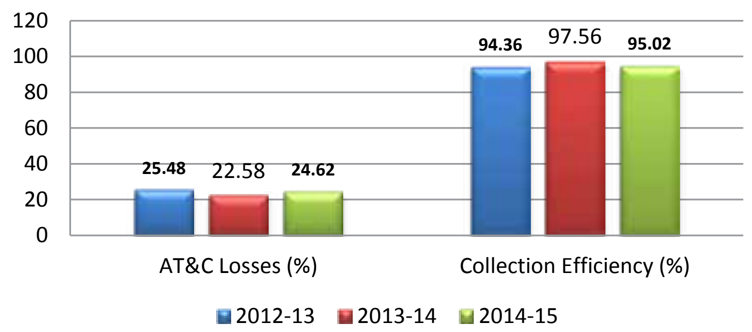
1. High AT&C losses

AT&C losses have two components – technical and commercial. Technical losses occur due to flow of power in the transmission and distribution system and are generally inevitable. Normally, transmission and distribution (T&D) losses are in the range of 8-10 per cent. Commercial losses occur due to theft of electricity, faulty metering system, collection inefficiencies, etc.

Although all-India AT&C losses are in the range of 24-25 per cent, some states in India have AT&C losses as high as 60-70 per cent. The overall AT&C losses for utilities selling directly to consumers increased from 22.58 per cent in 2013-14 to 24.62 per cent in 2014-15 (see *Figure 4.7: AT&C Losses and Collection Efficiency*). Northern and eastern states have some of the highest AT&C losses (see *Figure 4.8: State-wise AT&C Losses*).

Figure 4.7: AT&C Losses and Collection Efficiency

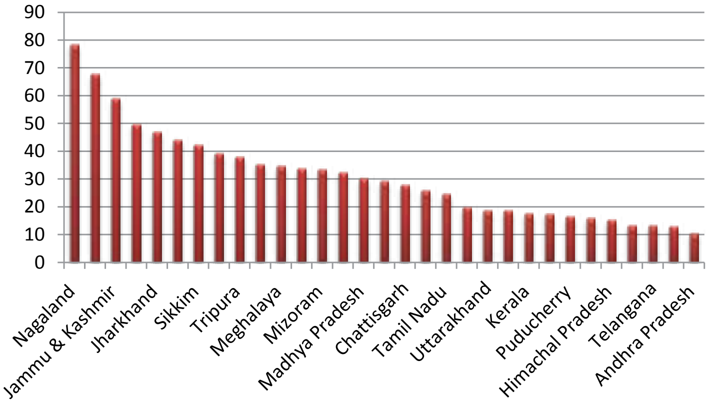
AT&C losses remain very high



Source: Power Finance Corporation Ltd.

Figure 4.8: State-wise AT&C Losses

Northern and eastern states have some of the highest AT&C losses



Source: Power Finance Corporation Ltd.
Unit: Percentage (%)

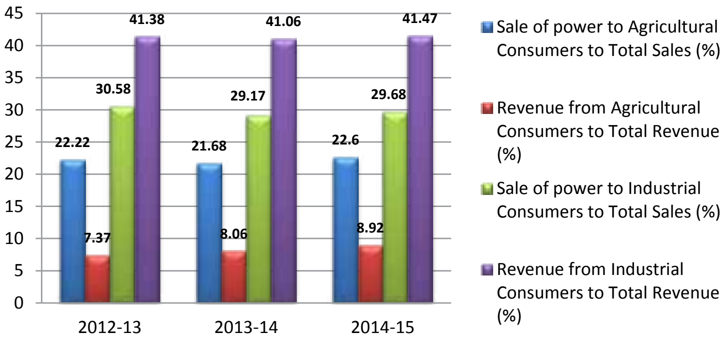
2. Supply of low-cost electricity to agricultural consumers

For political reasons, DISCOMs in India are forced to supply either low-cost or free electricity to agricultural consumers leading to huge revenue losses.

The share of energy sold to agricultural consumers was approximately 23 per cent in 2014-15 while the share of revenue from them was only nine per cent (see *Figure 4.9: Sale of Power and Revenue from Different Consumers)*. States like Haryana, Punjab, Andhra Pradesh, Tamil Nadu and Telangana do not recover even 10 per cent of the cost of supply from agricultural consumers. In Gujarat and Maharashtra, the revenue realisation is about half of the cost of supply.

Figure 4.9: Sale of Power and Revenue from different Consumers

The revenue from agricultural consumers has been low



Source: Power Finance Corporation Ltd.

At present, commercial and industrial users, and a small segment of affluent consumers (falling in the highest tariff slab), pay more than the cost of supply to cross-subsidise other categories of consumers such as low-income households, agricultural consumers, etc. This is clear when we look at the share of electricity sold and revenue realised from industrial consumers. The share of energy sold to industrial consumers was approximately 30 per cent in 2014-15 while the share of revenue was approximately 41 per cent (see *Table 4.1: State-wise Sale of Power and Revenue from Agricultural Consumers*). It is possible that in the near future these consumers will partly or wholly offset their electricity needs through captive generation, including solar rooftops.

Table 4.1: State-wise Sale of Power and Revenue from Agricultural Consumers

State	Agricultural (% of total energy sold)	Agricultural (% of total revenue)
Karnataka	36%	23%
Rajasthan	40%	36%
Punjab	26%	Nil
Andhra Pradesh	26%	2%
Maharashtra	28%	14%
Gujarat	25%	13%
Tamil Nadu	19%	Nil
Madhya Pradesh	39%	16%
Uttar Pradesh	18%	7%
West Bengal	5.5%	3.3%

Source: Power Finance Corporation Ltd.

C. Reforms in Distribution Segment

Keeping in view the poor performance of the DISCOMs, the Indian government introduced a series of reforms for the sector, like Accelerated Power Development Programme (APDP) in 2000-2001, Accelerated Power Development and Reforms Programme (APDRP) in 2002-03, Restructured Accelerated Power Development and Reforms Programme (R-APDRP) in 2008, One Time Settlement Scheme and Financial Restructuring Plan (FRP) in 2012.

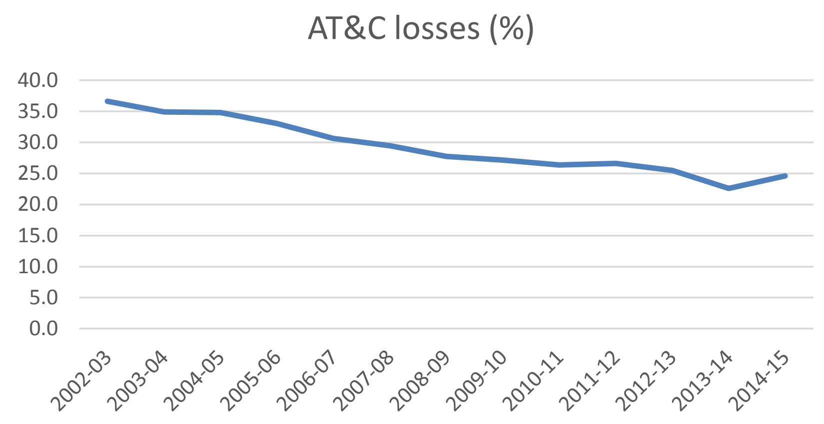
All these schemes were designed to reduce the debt burden of DISCOMs, reduce the gap between cost of supply and revenue realisation and reduce AT&C losses. They planned to do so by:

- Restructuring/rescheduling loans to reduce the burden of interest
- Shifting liabilities of the DISCOMs to the state governments
- Upgradation of metering infrastructure and increase in collection efficiency
- Incentivising reduction in AT&C losses
- Incentivising regular revision in tariff, etc.

However, all these schemes failed to fulfil their objectives because the DISCOMs were not able to reduce AT&C losses, subsidies to certain segment of consumers continued and there was inadequate tariff hike. Still, there have been improvements in the distribution segment. For instance, AT&C losses have reduced from 36.6 per cent in 2002-2003 to 24.6 per cent in 2014-15 (see *Figure 4.10: Ten Years of AT&C losses*). But this is not sufficient; more needs to be done.

Figure 4.10: Ten Years of AT&C losses

AT&C losses have reduced by about one-third since 2002-03



1. New reform policies and programmes

With poor financial condition of DISCOMs affecting the whole power and banking sector and economy at large, the Government of India has introduced some key programmes for the turnaround of DISCOMs. These are:

- ***Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY)***
  DDUGJY is a programme to electrify all villages. The scheme includes metering of connections and improvement of sub-transmission and distribution network to improve the quality and reliability of supply. Another important objective of this programme is to reduce the subsidy given to agricultural consumers and improve supply of power to other rural consumers. This it plans to do by separating the feeder that supplies electricity to agriculture and those that supply power to other rural consumers like domestic, commercial and industrial.

- ***Integrated Power Development Scheme (IPDS)***
  IPDS is a continuation of Accelerated Power Development and Reforms Programme (RAPDRP) to improve consumer database, metering practices and distribution infrastructure. The scheme has three components:

  - Strengthening of sub-transmission and distribution network in urban areas
  - Metering of distribution transformers/feeders/consumers in urban areas
  - IT enablement of distribution sector and strengthening of distribution network

  The scheme will help reduce AT&C losses, establish IT enabled energy accounting/auditing system, improve billed energy based on metered consumption and improve collection efficiency.

- ***Domestic Efficient Lighting Programme (DELP)***
  DELP is a programme to replace household and streetlight incandescent bulbs with LED bulbs. As of February, 2017 a little over 200 million LED bulbs have been distributed which will lead to 27 billion kWh saving in energy consumption and 5,400 MW reduction in peak load.[57]

D. Ujwal DISCOM Assurance Yojana

UDAY is a continuation of past programmes like ARDRP and FRP for improving the operational and financial health of DISCOMs. It aims to achieve this through the following initiatives:

- Reduction in interest rates for DISCOMs
- Improving operational efficiencies of DISCOMs
- Reduction in cost of power purchase
- Enforcing financial discipline on DISCOMs through alignment with state finances

1. Reduction in interest cost of DISCOMs

To reduce the rising debts and interest cost of DISCOMs, the scheme proposes that states take over 75 per cent of DISCOM debt within two years of signing the scheme – 50 per cent debt takeover in the first year and 25 per cent in the second. For this debt, the states will issue non-SLR[58] including SDL bonds in the market or directly to the respective banks/financial institutions (FIs).

The remaining 25 per cent debt (not taken over by states) is to be converted by banks/FIs into loans or bonds with interest rate not more than the bank's base rate plus 0.1 per cent. Alternatively, this debt may be fully or partly issued by the DISCOM as state guaranteed DISCOM bonds at the prevailing market rates which shall be equal to or less than bank base rate plus 0.1 per cent.

To further reduce the interest burden, most states will transfer the borrowings through bonds to DISCOMs in the form of grant, equity and loans (as per MoUs signed). Overall, this financial restructuring will bring down the interest rate from as high as 14-15 per cent to 8-9 per cent.

States will be exempted for the first two years to include the DISCOMs' debt in the calculation of fiscal

---

57 http://www.ujala.gov.in/; as seen on 11 February, 2017
58 SLR – Statutory Liquidity Ratio

deficit. Under the Fiscal Responsibility and Budget Management (FRBM) Act, states are required to maintain a fiscal deficit of three per cent of state GDP. Further, states will have to take over and fund the future losses of DISCOMs in a graded manner.

2. Improving operational efficiency

The scheme aims to improve the operational efficiencies of DISCOMs through targeted improvements in distribution infrastructure, metering infrastructure, demand-side management, energy efficiency and regular tariff revision (see *Table 4.2: Activities for Improving Operational Efficiency*). The idea is to bring down the AT&C losses of all DISCOMs to 15 per cent and a reduction in gap between ACS and ARR to zero by the end of 2018-19.

States achieving operational milestones will be given additional/priority funding through DDUGJY, IPDS, Power Sector Development Fund or other such schemes of MoP and MNRE. In case of non-compliance, the states will have to forfeit their claims on IPDS and DDUGJY grants.

Table 4.2: Activities for Improving Operational Efficiency

Activity	Benefits
Compulsory feeder and Distribution Transformer (DT) metering by states Completion target: Feeders by 30 June, 2016; DTs by 30 June, 2017	Ability to track losses at the feeder and DT level for corrective action
Consumer Indexing & GIS Mapping of losses by 30 September, 2018	Identification of loss making areas for corrective action
Upgrade or change transformers, meters etc., by 31 December, 2017	Reduce technical losses and minimise outages
Smart metering of all consumers consuming above 200 units / month Completion target: Consumption above 500 units / month by 31 December, 2017; Others by 31 December, 2019	Smart meters will be tamper proof and allow remote reading thus helping reduce theft, implementation of DSM activities and consumer engagement
Demand Side Management (DSM) which includes energy efficient LED bulbs, agricultural pumps, fans & air conditioners and efficient industrial equipment through PAT (Perform, Achieve, Trade) scheme	Reduce peak load and energy consumption
Quarterly tariff revision, particularly to offset fuel price increase, to be permitted	Will reduce the gap between ACS and ARR
Assure increased power supply in areas where the AT&C losses reduce	Encourage local participation to reduce losses

Source: Ministry of Power

3. Reduction in cost of power

The scheme also aims to reduce the cost of power purchase for DISCOMs, which constitutes the major portion (70-80 per cent) of total cost of supply of DISCOMs, by bringing down the cost of power generation.

It proposes to achieve the reduction in cost of power through initiatives such as increased supply of cheaper domestic coal, coal linkage rationalisation, liberal coal swaps from inefficient to efficient plants, coal price rationalisation based on GCV (Gross Calorific Value), supply of washed and crushed coal and faster completion of transmission lines.

4. Will UDAY succeed when similar other programmes have failed?

The success of UDAY is critical for improving the financial and operational performance of DISCOMs. If we consider the current status of implementation, UDAY certainly is attracting far more interest from the states than previous programmes.

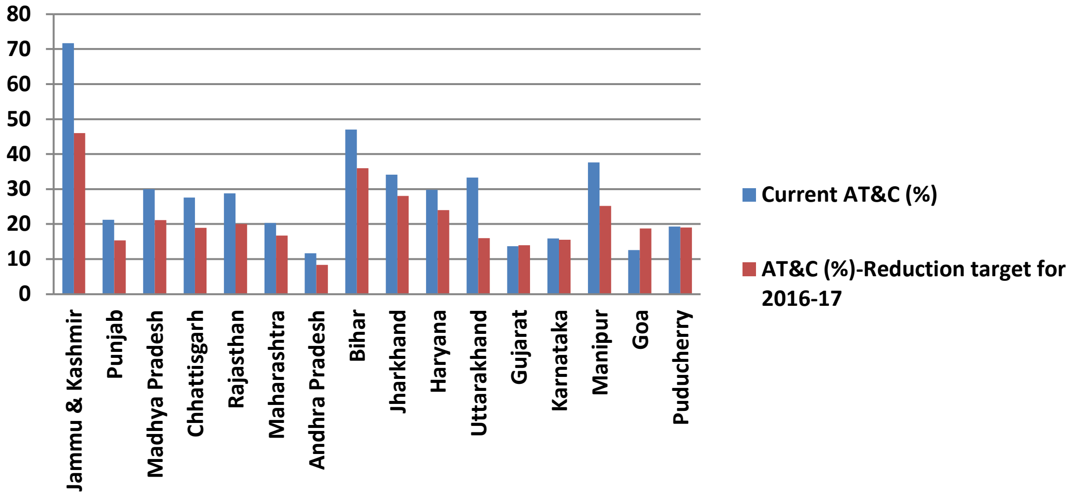
So far 21 states have signed into the scheme, covering almost 92 per cent of total DISCOM debt. Unlike the past programmes, UDAY is able to get states take over the debt of DISCOMs and issue them as bonds. As UDAY bonds have an implicit guarantee from the issuing state and the interest and principal amount are part of the state government's budget, there is an increasing interest from insurance and other companies to park funds in these bonds.[59] So far, 71 per cent of the total bonds have been issued. Also, 15 out of 21 states have issued tariff revisions.[60]

The planned improvements in metering, distribution infrastructure, etc., are also reported to be progressing well. Feeder metering has been completed at all rural and urban feeders; about 45per cent of the Distribution Transformer metering has been completed, and close to 70 per cent of feeder separation for agriculture consumers have been achieved.[61]

But like the past programmes, most of the states have fallen short of their targets in reducing AT&C losses. Except Gujarat, Puducherry and Goa which already had low AT&C losses, others have failed in achieving the reduction target (see *Figure 4.11: Meeting the AT&C Reduction Targets under UDAY)*. Also, the gap between ACS and ARR is still very high – about Rs 0.67/ kWh.

Figure 4.11: Meeting the AT&C Reduction Targets under UDAY

Most states have failed to meet 2016-17 target



Source: www.uday.gov.in; as seen on 11 February, 2017
Reduction target data collected from individual MoUs signed between GoI, State governments and DISCOMs. Data not available for Uttar Pradesh, Tamil Nadu, Telangana, Himachal Pradesh and Assam

The reason for failure in reducing AT&C losses is that the targets are too stiff. UDAY targets to reduce the AT&C losses from 24-25 per cent to 15 per cent by 2018-19. It also has a target to reduce the gap between ACS and ARR to zero by the end of 2018-19. Both these targets are not likely to be met.

It took 12 years to reduce AT&C losses by 10 percentage points, from 35 to 25 per cent. The target to reduce losses by nine percentage points (24% to 15%) in three years is way too ambitious.[62] Similarly, the gap between ACS and ARR can be brought to zero only if the cost of power can be reduced; tariff increase are allowed to reflect the cost of supply and AT&C losses are reduced significantly. All this is not likely to happen to the extent that UDAY envisages.

The cost of power is not likely to be reduced because of many factors including decreasing PLF of coal power plants and increasing penetration of renewable energy. Similarly, absolute level of subsidies might not reduce because of the improvements in access of electricity to the poor and increasing use of electricity in rural areas, including for agriculture. AT&C losses can be realistically reduced to 20 per cent by 2018-19 and not 15 per cent as envisaged by UDAY. All this means that the cost of power supplied by the DISCOMs for commercial, industrial and high consuming residential sector would

59 http://economictimes.indiatimes.com/markets/bonds/attractive-uday-bonds-a-good-place-to-park-funds/articleshow/53037987.cms
60 https://www.uday.gov.in/home.php, as seen on 11 February, 2017
61 ibid
62 Assuming that AT&C losses reduced to 24 per cent in 2015-16

keep increasing, creating a conflict between DISCOMs and penetration of renewable energy especially decentralised renewables like solar rooftops.

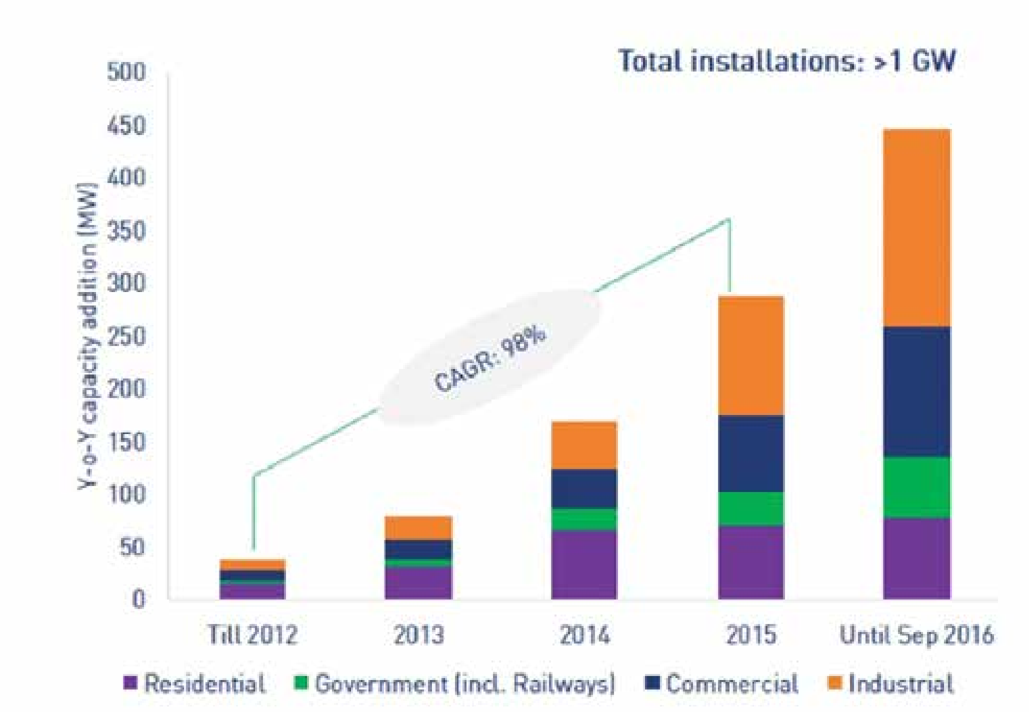
E. Impact on the renewable energy sector

In India, large-scale grid-connected renewable power has dominated the renewable sector so far. These plants are for supplying to the grid and not for captive consumption. But this situation is likely to change very fast because of the increasing cost of grid power for certain category of consumers and reducing cost of decentralised renewable energy based systems for captive consumption.

According to a recent study, the installation of solar rooftop in India is increasing at an annual growth rate of 98 per cent with majority of them being installed at industrial and commercial establishments (see *Figure 4.12: Growth in Solar Rooftop Installation*).

Figure 4.12: Growth in Solar Rooftop Installation

More than 1 GW has been installed so far



Source: Bridge to India, 2016; as presented at the conference organised by Centre for Science and Environment on replacement of DG sets with solar rooftop systems on 10 January, 2016 in New Delhi

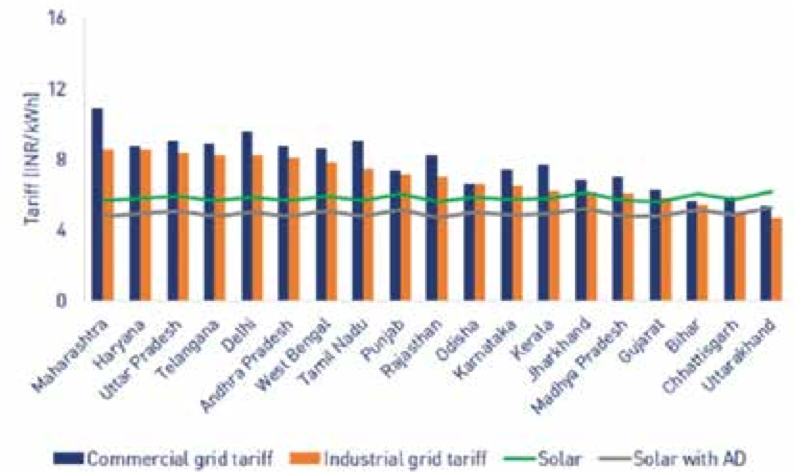
According to the same study, currently it is viable for commercial and industrial consumers in most states to shift to solar rooftop during the day time. And this viability is going to improve further in the coming years (see *Figure 4.13: Grid Tariff for Commercial and Industrial Consumers vs. Cost of Generation from Solar Rooftops)*.

What then are the implications, of this increased viability of decentralised solar and other renewable energy for captive use, on DISCOMs?

We need to consider this issue for two different kinds of projects – small decentralised renewable projects like the solar rooftop and larger decentralised projects which would use open access provision and bypass DISCOMs or use DISCOMs only for certain duration of the day.

Figure 4.13: Grid Tariff for Commercial and Industrial Consumers vs. Cost of Generation from Solar Rooftops

In most states solar rooftop projects are economically lucrative for commercial and industrial consumers



Source: Bridge to India, 2016; as presented at the conference organised by Centre for Science and Environment on replacement of DG sets with solar rooftop systems on 10 January, 2016 in New Delhi

1. Solar rooftop projects

The major impact of solar rooftop projects on DISCOMs is reduction in revenue. The first is the reduction in total amount of power purchased by the consumer due to increasing consumption from solar rooftop. As most states in India allow net metering, increased penetration of solar rooftops would lead to reduced sales for utilities, resulting in revenue loss.

As mostly high paying consumers are likely to shift to decentralised systems, utilities will lose the cross-subsidy (tariff charged over and above the cost of supply). This would put additional pressure on utilities as they would be forced to supply power to low paying consumers leading to deterioration of their balance sheet. This is not a hypothetical scenario; this has happened in the past. Because of higher grid tariff and poor quality of power, most large-scale industries in India set up captive power plants. Currently, there are at least 50 GW worth of captive power plants in the country.[63] This has reduced the cross-subsidy and increased the burden on those high paying industrial and commercial consumers that continue to buy power from DISCOMs.

As there are multiple tariff slabs based on consumption (higher the consumption, higher is the tariff), a solar rooftop consumer is likely to move to lower tariff slab thereby reducing the revenue of the DISCOM. The DISCOM is also likely get less fixed charges because of many reasons including reduction in sanctioned load by the rooftop consumer; shifting of the rooftop consumer to the lower tariff slab and reduction in sales volume.

The other loss to DISCOMs is likely due to banking of power by the rooftop consumer. The first risk is that the solar rooftop consumer would inject power during the off-peak hour when the prices are low and withdraw during the peak hour when the prices are high. In addition, solar rooftop projects with net metering are not required to pay banking charges.

Overall, as the penetration of solar rooftop projects increase, the revenue impact on DISCOMs and hence the opposition of DISCOMs to such projects is likely to increase.

63 Data on captive power plant capacity is not available for 2016. Captive power plant capacity in 2014-15 was 44,657 MW (Energy Statistics, 2016, Ministry of Statistics and Programme Implementation). They accounted for 14% of the total installed generation capacity 2014-15. If we extrapolate this number for 2016-17, at least 60,000 MW capacity can be attributed to captive power plants.

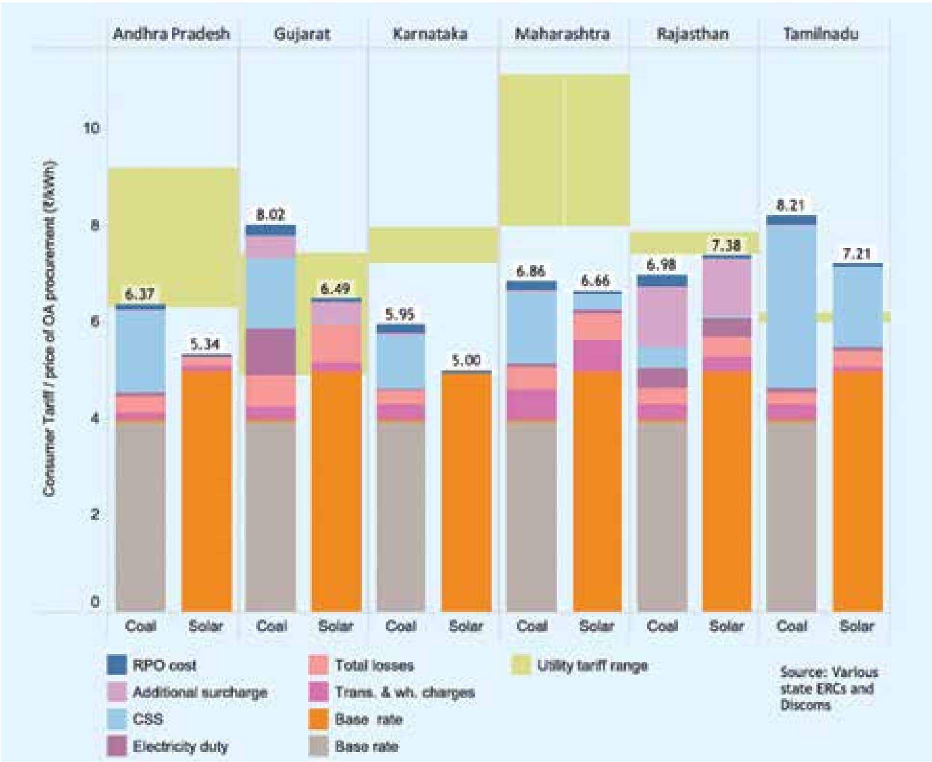
2. Large decentralised projects

The Electricity Act, 2003 allows Open Access.[64] Open access allows consumers with a connected load of 1 MW and above to buy power from the open market (see *Figure 4.14: Comparing Open Access Procurement with Utility Tariffs)*. There are several charges to be paid by open access consumers to distribution licensee, transmission licensees and other related entities. An open access consumer can also install dedicated mega-watt scale renewable energy project off site and use the grid to consume that power. This mechanism has been widely used by industries that have installed wind turbines to meet their captive demand.

The open access provision, along with reducing cost of solar energy and storage technology, is likely to be a game-changer in future. Already the estimated cost of solar power through open access in various states is cheaper than their utility tariffs for commercial and industrial consumers. In fact, the estimated cost of open access solar power is lower than the estimated cost of coal based power procured through open access.

Figure 4.14: Comparing Open Access Procurement with Utility Tariffs

In most states, cost of procuring solar power through open access is cheaper than utility tariff for commercial and industrial consumers



Source: Prayas (Energy Group), October, 2016: India's Journey towards 175 GW Renewables by 2022

It is possible that within a decade high paying consumers (including gated communities) would start moving away from DISCOMs and set up their own or have some other entity set up renewable energy projects with electricity storage facility to enable 24x7 power supply. They might use grid and local distribution network as a transmission platform and pay charges to the grid operator for transmitting that power.

Once this happens, it will put a question mark on the viability of DISCOMs. Large consumers will

64 As per Section 2 (47) of Electricity Act 2003, "Open Access means the non-discriminatory provision for the use of transmission lines or distribution system or associated facilities with such lines or system by any licensee or consumer or a person engaged in generation in accordance with the regulations specified by the Appropriate Commission".

move to large decentralised projects and small consumers towards solar rooftops and building integrated systems. The DISCOMs will be left with low paying consumers that have to be subsidised by the state.

DISCOMs would view these developments with suspicion and therefore are likely to scuttle penetration of decentralised renewable energy. To avoid this conflict, we need to find a solution in which both can thrive.

F. How can DISCOMs and decentralised renewable energy consumers co-exist?

The rich consumers in India – whether domestic, industrial or commercial – would like nothing better than a system in which they have assured supply of power and get it cheap as well. They would, therefore, prefer to move to decentralised renewable energy systems. But the poor would suffer. When the rich move out of DISCOMs, the price of electricity will escalate and the poor will not be able to afford power unless the state subsidises it.

But we also do not want a situation in which the DISCOMs continue operating as they are doing today, with poor operational and financial performance, and stall penetration of renewable energy.

The first thing to understand is that the kind of DISCOMs that we have today – big, state controlled monopolies that maintain distribution infrastructure and also supply power to the consumers – are not suitable for large penetration of decentralised renewable energy. There must be competition and consumers must have the choice to buy power from whosoever they desire. The job of the distribution company, like the transmission companies, is to maintain the distribution infrastructure and charge for its use. Any producer, trader, aggregator should be able to use the transmission and distribution infrastructure and provide power to the consumers. This is what unbundling of the distribution sector is all about. Today open access is allowed only for mega-watt scale consumers, but in future it should be allowed to individual households as well.

But in this arrangement Open Access users need to pay the infrastructure cost and rich users should cross-subsidise the poor by paying extra for this infrastructure. This is the only way in which DISCOMs and decentralised renewable energy users can co-exist. The key reforms required for this to happen are as follows:

- Allow competition at the distribution end. The distribution infrastructure can still be owned by the state monopolies (ideally these should move to private operators or to a public-private partnership model), but the sale of electricity to consumers must be opened to competition. This will lead to better collection efficiency, lower AT&C losses, lower political interference and improved operational parameters and financial health of the distribution segment. The state can still subsidise the poor by directly transferring the subsidy to the consumers or the companies.
- Decentralised renewable energy consumers need to pay for using the infrastructure and also to cross-subsidise poor consumers. For instance, for the rooftop solar consumers, the following must be done to incentivise DISCOMs to encourage solar rooftops:
  - The option of solar rooftop consumer to move to lower tariff slab should be discouraged. This hurts the DISCOMs not only from the cross-subsidy angle, but also from the reduction in fixed charges that is required to maintain the distribution infrastructure.
  - Time-of-the-day (TOD) tariff for export and import of power needs to be operationalised. This will incentivise export of power during peak time from rooftops, thereby reducing DISCOMs' burden of buying expensive power from generation utilities. This will also discourage export during off-peak and import during peak time. In addition, rooftop solar consumers should pay for the banking charges.
  - The government needs to develop an incentive scheme to encourage distribution utilities to accelerate the growth of solar rooftop in the country. MNRE can provide incentives to DISCOMs to offset any reduction in profitability that might happen due to installation of rooftop systems.

CHAPTER 5

CAN INDIA'S GRID ABSORB HIGH PROPORTION OF RENEWABLE ENERGY?

Renewable Energy (RE), especially wind and solar, is termed an intermittent source of electricity. As they are dependent on weather conditions, their generation is spatially and temporally variable. But variability is not unknown to the electricity system.

Electricity managers deal with demand side variability every day as millions of consumers do not have the same habit of using electricity and their habits are not the same every day. So, managers have to forecast demand and match that with supply on a minute-by-minute basis. So far, supply was largely from fossil fuel plants that could be controlled by operators. But large penetration of renewable energy means that managers now have to plan for supply side variability as well. This is causing a lot of concern and questions are being raised whether the Indian grid is ready for renewable energy transition. These concerns are exacerbated by the existing problems at the distribution end, like load-shedding, inaccurate demand forecasting, high AT&C losses, etc.

But it is not that the world, or for that matter India, doesn't have experience of dealing with a large proportion of renewable energy in the grid.

Countries like Denmark and Germany have dealt with this issue for more than a decade and have found solutions for it. Renewables now provide more than 30 per cent of Germany's power on an average basis. And on some peak days, solar and wind supply close to 80 per cent of peak power demand at specific times of the day. Denmark deals with even larger share of renewables, mostly wind, and wind is considered more variable than solar. In January 2014, wind supplied an average 62 per cent of the total power demand of Denmark.[65]

In India also we have experience of dealing with a significant proportion of renewable energy in the grid. Wind energy used to provide as much as 30-35 per cent of the total energy consumption in Tamil Nadu. Tamil Nadu dealt with such high wind power penetration and managed the variability through reduction of generation in the coal-based power plants. Gujarat used both the coal and hydropower plants for balancing by varying their generation between 60-100 per cent. The state has set up a renewable energy desk for weather forecasting to enable better estimation of renewable generation. The desk prepares variation in wind/solar generation for the next 7 days and this information is updated every three hours.[66]

In this chapter, we will look at the current status of the grid in India and the initiatives underway to make the grid stable and secure. We will then discuss the issues arising out of the proposed large-scale installation of RE in the grid and how India is dealing with these issues. Lastly, we will compare India with Germany to understand how far India has to go to make its grid compatible with large volumes of power from renewables.

A. The Indian Power Grid

India has a federal set-up to deal with electricity wherein each state is responsible for maintaining its load-generation balance and complying with inter-state grid code (IEGC). Each state has its own generation sources in addition to the shared generation resources called inter-state generating stations (ISGS).

The all-India grid is divided into five regional networks – north, west, east, south and northeast – and further into 28 control areas. All these are interconnected with each other through inter-state transmission links and high capacity corridors. In 2014 all five regional networks were interconnected, making India's grid one of the largest operating synchronous grids in the world. The Indian grid is also connected to Bhutan, Myanmar and Bangladesh.

65 http://www.martinot.info/renewables2050/how-is-denmark-integrating-and-balancing-renewable-energy-today
66 Large Scale Grid Integration of Renewable Energy Sources - Way Forward, Central Electricity Authority, November 2013

There has been consistent expansion in the transmission network and transformation capacity in the country to cope with the increasing demand. The increase in the transmission lines of 220kV and above voltage levels, in terms of circuit kilometres (cKm), has been roughly seven-fold in last 30 years; substation capacity increased more than 15 times in the same period. By the end of March 2017, India will have 3,64,935 cKm of transmission lines of 220kV and above voltage levels and 7,04,137 MVA/MW transformation capacity of substations and HVDC terminals of 220kV and above voltage levels. In the next five years, the transmission lines are projected to increase by about 30 per cent and transformation capacity by 40 per cent. By March 2022, India is projected to have 4,70,515 cKm of transmission lines and 9,79,637 MVA/MW of transformation capacity. The inter-regional transmission capacity at the present is about 63,650 MW which is likely to be almost double and reach 1,18,050 MW by March 2022. [67]

1. Institutional Arrangements

The transmission of electricity in India takes place at the regional, inter-state and intra-state levels. The central transmission utility – Power Grid Corporation of India Limited (PGCIL) is responsible for operation and maintenance of the regional and inter-state transmission systems (ISTS), which are connected to centrally owned generation systems, while the state transmission utilities are responsible for the intra-state transmission system (InSTS) that are connected to state owned generation systems. Distribution to end consumers is achieved through distribution lines connected to the intra-state network.

The Power System Operation Corporation of India (POSOCO) established by PGCIL is responsible for ensuring optimal grid operation. The National Load Dispatch Centre (NLDC) and Regional Load Dispatch Centres (RLDC) have been founded under the aegis of POSOCO to manage the stability and security of the grid. NLDC and RLDCs are responsible for monitoring transmission and ensuring optimum scheduling and dispatch of electricity at the regional and inter-state level, respectively. Meanwhile, at the state level, State Load Dispatch Centres (SLDCs) have been set up for ensuring optimum operation of the intra-state transmission networks. Although independent, the SLDCs work in close coordination with their respective RLDCs to ensure efficient operations and implementation of regional/national directives.

At the national level, the Central Electricity Regulatory Commission (CERC) is responsible for drafting and implementing operation and commercial regulations, which apply to the interstate transmission systems. The most prominent among the rules and regulations drafted by CERC are the Indian Electricity Grid Code (IEGC) and deviation settlement mechanism (DSM). The rules and regulations drafted by the CERC are used as guidelines based on which SERCs formulate rules and regulations at the state level.

The responsibility of developing standards for operation of transmission systems, power plants and safety requirements for operation and maintenance of electrical transmission systems and plants lies with the Central Electricity Authority (CEA). At the regional level, Regional Power Committees (RPC) have been set up by CEA. These monitor operations of transmission and generation systems, draft future transmission plans for the intra- and inter-state levels, conduct stability studies and are responsible for commercial accounting of electricity at the regional level.

2. Operations

The day-ahead scheduling process, in which demand and supply of electricity is forecasted a day before, forms the backbone of grid operation in India. SLDC coordinates the day-ahead scheduling for beneficiaries and generators connected to InSTS, and RLDC coordinates this process for beneficiaries and ISGS connected to ISTS. To participate in the day-ahead scheduling process, beneficiaries and generators use forecasting methods to predict their demand and generation for the next day, respectively. These details are sent to the respective scheduling entity, SLDC or RLDC.

3. Performance[68]

The major indicator of the health of an electrical grid is its variation in frequency – the more stable the

67 Draft National Electricity Plan(Vol-II) Transmission, 2016, Central Electricity Authority

68 Grid Integration of Renewables in India: An Analysis of Forecasting, Scheduling and Deviation Settlement Regulations for Renewables, Prayas Energy Group, August 2016

frequency, the more stable the grid. The fluctuation in frequency is largely associated with mismatches between demand and supply. India's electrical grid has long been plagued by high levels of frequency variation. In the last few years, however, the situation has improved significantly with the demand-supply deficit going down and new institutional and infrastructural mechanisms being put in place to improve load forecasting. The most prominent among them is the deviation settlement mechanism.

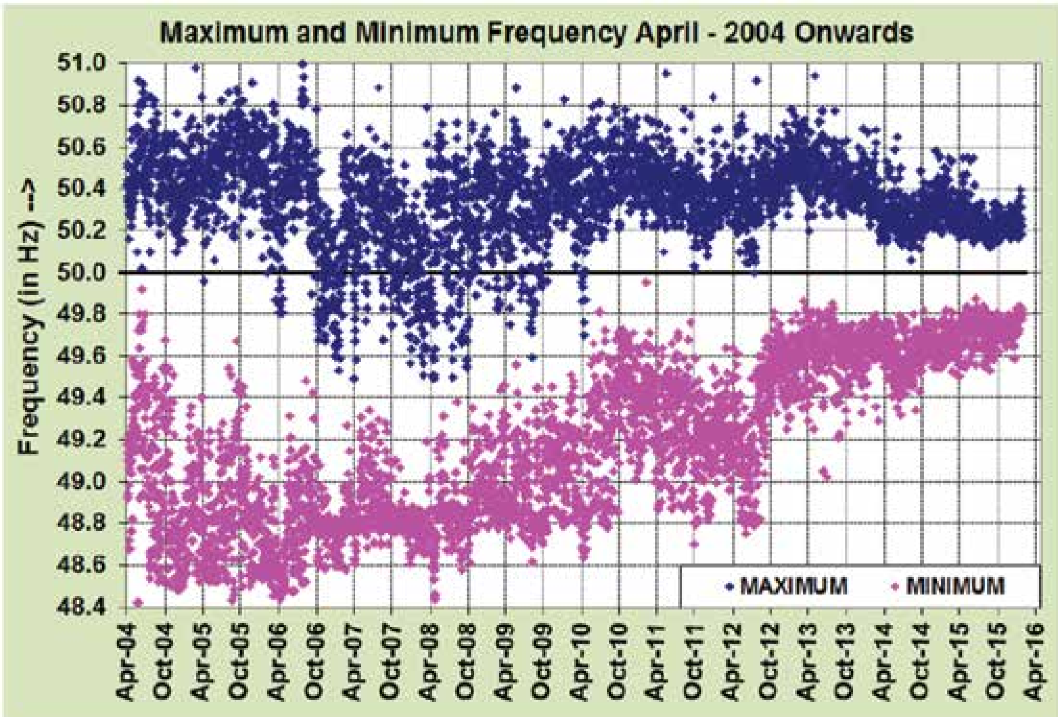
Before 2000, generators were paid based on the amount of energy generation. This tariff mechanism did not provide any incentive for increasing generation during peak demand (limited to a small period) or reducing it during off-peak hours, thereby encouraging grid indiscipline. This was reflected in the poor frequency profile during these years. To overcome this limitation, an Availability Based Tariff (ABT) mechanism was introduced in 2000. This trifurcated the existing single part payment for energy into:

- Capacity or fixed charge to be paid based on availability. This encouraged generators to remain ready for power generation at most times.
- Energy or variable charge to be paid on the basis of scheduled energy and
- Unscheduled Interchange (UI) as a penalty mechanism for deviation from generation/drawl schedule.

Instituting ABT significantly improved the grid frequency profile and grid discipline. The operating frequency band has improved from roughly 48.75 Hz to 50.5 Hz in 2004, to the present operating frequency band of 49.7 Hz to 50.3 Hz in 2015 (see *Figure 5.1: Frequency Profile of All-India Grid*).

Figure 5.1: Frequency Profile of All-India Grid

There has been significant improvement in frequency profile in the last 10 years



Source: Report of the Technical Committee on Large-Scale Integration of Renewable Energy, Need for Balancing, Deviation Settlement Mechanism and associated issues, Ministry of Power, 2016

Under the current deviation settlement mechanism, a demand-supply mismatch incurs a penalty for the distribution company in case of over-injection of electricity into the grid and in case of under-injection for the generating entity. For the ISTS and connected suppliers, this mechanism is run based on ABT, which incentivises payment based on the demand (i.e., higher payment for peak demand periods), which is known to incentivise grid stability by ensuring minimisation of demand-supply mismatch. Although ABT is now supposed to be implemented at the intra-state level, only Delhi, Gujarat, Madhya

Pradesh, Maharashtra, West Bengal and Chhattisgarh have fully implemented this mechanism. Broader implementation of this mechanism will help stabilise intra-state grid operations further.

Additionally, CERC is in the process of instituting rules for infrastructural interventions to ensure that in the event of a mismatch, frequency fluctuations are minimised. These interventions include:

- Better demand forecasting: Poor demand forecasting by DISCOMs has emerged as the single most important factor for poor grid performance. The Ministry of Power directed all the distribution utilities to implement load forecasting by 1 June, 2016.[69]
- Reserve electricity capacity: This capacity would be operated to meet the unforeseen demand-supply gap. One of the mechanisms to maintain grid frequency that CERC is targeting to implement by 2017 is Automatic Generation Control (AGC). To restore the frequency accurately to 50 Hz, secondary frequency control reserves are needed. These reserves require AGC implemented at the generator level and operated by the LDC.

Other interventions include regulating the flexibility of power plants and installing more electricity storage capacity. These two issues will be discussed in detail in subsequent sections.

B. Renewable energy grid

There are two important issues to consider before we discuss the requirements of a grid that can operate with large quantum of renewable electricity.

First is the variable nature of renewable power. Renewable energy sources like solar and wind are characterised by variable generation of electricity, due to their dependence on seasonal and diurnal variations. Additionally, unanticipated weather events may also affect the generation of electricity from solar and wind power plants. This means that it has to be supplemented with conventional energy sources in order to meet electricity demand at any given time. This combination, of variable and stable sources of electricity, needs to be carefully calibrated in order to avoid demand-supply mismatch and to allow for efficient functioning of the grid.

Second is the "must-run" status of renewable generators. In India, grid operators are mandated to use merit order dispatch principle to decide which electricity generator will have the priority on the grid. Under this principle, the generator with the least marginal cost of generation will have its power dispatched first. As renewable sources have near zero marginal costs (they do not have fuel cost like conventional generators), RE generators are accorded must-run status to the extent of transmission availability and safe system operation. This implies that grid operators have to effectively plan to meet the 'net-load' (difference between load and RE generation) through conventional generators. Conventional generators would therefore need to be 'flexible'; they will only have to operate as and when they are required to help meet the 'net-load' (see *Figure 5.2: Expected All India Load Curve with Introduction 20 GW Solar Power)*. At present, most conventional generators operate 24x7. But as the quantum of renewables increases, conventional generators will be required to be more and more 'flexible'.

69 ibid

Figure 5.2: Expected All-India Load Curve with Introduction 20 GW Solar Power

Conventional power plants will have to be flexible to meet the 'net load'

Source: Report of the Technical Committee on Large-Scale Integration of Renewable Energy, Need for Balancing, Deviation Settlement Mechanism and associated issues, Ministry of Power, 2016

Note: Point to note in the above graph is that variability is integral part of the grid. Even without solar power, the grid operator has to deal with variability in demand and supply on minute-by-minute basis. With solar and wind power, the variability would increase.

The variable nature of renewable power along with must-run operational status means that we have to design grid and conventional power plants to meet the requirements of the renewable power and not the other way round. In other words, we are looking at a renewable energy grid.

A renewable energy grid would require changes in design and operating principle and practices of the grid; in addition, newer technologies will have to be introduced for stability and security of the grid. The key interventions can be clubbed into following categories:

Strong conventional grid: The most basic requirement is a well-functioning and a stable grid. A grid that is operating at optimal frequency, is able to supply required power to all, has a well performing demand forecasting mechanism, incentivises availability and flexibility and has a large power balancing area.

Forecasting and management of solar and wind generation: Accurate forecasting and day-ahead scheduling is crucial for ensuring stability of the grid. This requires large number of monitoring stations, better forecasting methodologies and tools, a tariff mechanism that incentivises better forecasting and equipping regional, state and Central level load dispatch centres with institutional arrangements for handling and using this information.

Supply balancing: The variable nature of renewable energy necessitates supply balancing from conventional sources. This demands availability of reserve capacity to meet the net-load, increased flexibility of the conventional capacity, reinforcement of ancillary services (reserve capacity to be operationalised in times of shortfall) and power storage infrastructure. Supply balancing also demands a market mechanism that incentivises availability and flexibility of conventional capacity.

Technological interventions: Interventions like the augmentation of the transmission corridors from renewable rich states, use of power electronic devices for reactive power control, use of synchrophasor technology to stabilise the voltage of the power being supplied to the grid, technical standards for RE generation incorporating features such as Low Voltage Ride Through (LVRT), High Voltage Ride Through (HVRT), frequency thresholds for disconnection from the grid, active and reactive power regulation by RE generators, etc., are required.

Smart Grid: Demand side management, demand response and two-way communication between the consumer and supplier are key to large-scale renewable power penetration.

We will discuss each of these interventions and also assess their status in India.

1. Strong conventional grid
The transmission grid in India has expanded and improved performance considerably over the years. Today the Indian grid is operating at a much narrower frequency gap than a decade ago. It is an all-India grid now with all five regional grids interconnected. There is a lot that remains to be done, but in general the Indian grid is in a much better shape today to cope with large-scale renewable energy.

The strong aspects of the Indian grid are:
- A functional institutional management structure to deal with transmission at all scales – national, regional and state-level – and a clear division between the regulatory agency (ERCs), technical agency (CEA) and grid operator.
- A clear mechanism of demand and supply forecasting and day-ahead schedule. A lot of more still needs to be done, though, to improve the demand forecasting by DISCOMs.
- A tariff mechanism that allows for higher availability of conventional power stations, and incentivises generation plants to reduce the gap between demand and supply (time-of-the-day tariff and intra-day trading in power). Though ABT has still not been adopted by many states, it is likely to happen soon.
- Use of reserves and technologies like AGC to maintain the voltage and frequency of the grid.
- As the entire country is one synchronous grid, power balancing can happen more easily and cheaply. In fact, the large grid allows India to install renewable power in different parts of the country for better balancing.

Basically, India has all the key components required for a future grid that will be able to accommodate large-scale renewable power.

2. Forecasting and management of solar and wind generation
Forecasting and management of renewable power generation requires an adequate number of monitoring stations, a tariff mechanism that incentivises better forecasting and an institutional mechanism that generates and uses data for better operations of the grid.

Renewable energy monitoring and management
As far as monitoring stations are concerned, India already has a large part of the forecasting infrastructure in place as part of the India Meteorological Department's weather forecasting operations. This infrastructure, however, will need to be supplemented by data interpretation services/technologies that can convert meteorological data into one that can be used for forecasting renewable energy generation.[70] Also, over past couple of years renewable energy generators have started to set up monitoring stations as they now have to take part in the day-ahead schedule.

In order to manage, monitor and forecast renewable energy generation, the Indian government has decided to establish Renewable Energy Management Centres (REMCs) at SLDCs, RLDCs and the NLDC. The objectives of the REMCs at the various levels are:
- At SLDC: Optimal scheduling and balancing of power
- At RLDC: Optimal coordination of regional grid
- At NLDC: Maintaining safety and security of the grid

The proposed REMCs at every level will perform the following functions:
- Real time monitoring of all the renewable generation at the pooling station level
- Intra-day and day-ahead forecasting of renewable generation

70 Report on "Forecasting, Concept of Renewable Energy Management Centres and Load Balancing" GIZ, 2014

- Coordination with corresponding load dispatch centre (LDC) for scheduling and dispatch of renewable generation in its area of responsibility
- Coordination between corresponding LDC and renewable developers
- Monitoring the operation of reserves as and when required

In order to carry out the above functions, REMCs will have five major tools (see *Table 5.1: REMC Tools*).

Table 5.1: REMC Tools

REMCs will use advanced tools to facilitate penetration of renewables in the grid

REMC Component	Function
REMC Scada Monitoring Tool	Real time monitoring of renewable generation by collection of data from Remote Terminal Units (RTUs). Refresh rate of 2-4 seconds. SEM data can be used in case RTU is not available.
Forecasting Tool	Collection of i) forecast data from Forecast Service Providers and exchange of weather data with them, ii) site level actual RE generation data from REMC SCADA tool, and iii) weather forecasts, analysis and validation of accuracy of the forecast provided by individual RE developers, iv) provide forecast to RE developers not owning forecasting tool, v) provide point of injection level intra-day and day ahead data to REMC scheduling tool.
RE Scheduling Tool	Preparation of schedule from forecast received from RE forecasting tool. Coordinate with RE developers to integrate their individually submitted schedule.
REMC Wide Area Measurement System	Data collection of critical substation via existing WAMS system in control center.
RE Control Reserve Monitoring Tool	Real time analysis of reserves in own control area and in neighboring area, Scenario analysis of renewable generation for balancing the RE generation.

Source: Draft National Electricity Plan (Vol-I) Generation and (Vol-II) Transmission, 2016, Central Electricity Authority

Overall, India is poised to have in place adequate monitoring and management systems for better forecasting and scheduling of renewable energy.

Tariff mechanism

Till 2010, the integration of wind and solar power were not considered important from the grid stability point of view and hence RE was exempt from forecasting, scheduling and supporting grid management in terms of ancillary services. However, IEGC 2010 made it mandatory for the solar and wind generators to predict, with reasonable accuracy, the generation and provide day-ahead schedule to SLDCs/RLDCs for dispatch. This regulation is applicable to wind generators having a capacity greater than 10 MW and solar generators having a capacity greater than 5 MW being connected to the intra-state or inter-state transmission network at a voltage of 33 kV or above.

IEGC specifies that the wind energy forecasting on day-ahead basis achieve 70 per cent accuracy. The absolute error (deviation from schedule) is defined as a percentage of the scheduled generation (Scheduled Generation-Actual Generation/Scheduled Generation), and penal deviation charges are based on the CERC Unscheduled Interchange (UI) regulations.

If the variation in actual generation is beyond +/- 30 per cent of the schedule, wind generator has to bear the UI charges. For variation of actual generation within +/- 30 per cent of the schedule, the host state is to bear the UI charges. The latter is to be shared among all states in the ratio of their peak demands in the previous month based on the data published by CEA, in the form of a regulatory charge known as the Renewable Regulatory Charge, operated through the Renewable Regulatory Fund (RRF). Solar energy is exempted from UI charges.

Introducing the RRF mechanism, however, was difficult. Some of the roadblocks that came up were the lack of Special Energy Meter (SEM) installations, lack of facilities for managing the forecasting data at SLDC, an unclear commercial settlement process for open access and captive consumers, demarcation between old and new wind generators for RRF applicability, unclear responsibilities of forecasting, scheduling and commercial settlement between the wind developer and generators, unclear definition of the Power Purchase Agreement (PPA) in case of multiple generators, having different PPA rates connected to the same interconnection point, partial eligibility of wind farms due to a mix of old and new wind generators, disclosure of PPAs to RLDCs, etc.[71]

Wind generators were not happy about the financial penalty due to error in forecasting. So they filed a case against the implementation of the RRF mechanism, resulting in a stay on the commercial settlement part of the regulation, but continued forecasting and scheduling wind generation.

The failure in implementing the RRF mechanism prompted CERC to come out with the Framework on Forecasting, Scheduling and Imbalance Handling for Wind and Solar Generators Connected to ISTS in August, 2015.

CERC framework for forecasting and scheduling
The goal of the framework is to outline institutional and operational guidelines for forecasting and scheduling of supply and demand for solar and wind power plants. Although most of the solar capacity currently installed is connected to the InSTS, the new solar parks will likely be connected to the ISTS.

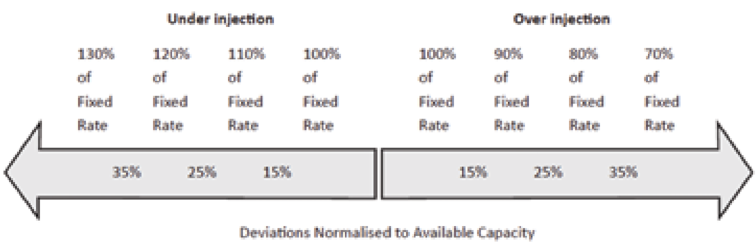
- **Data procurement:** According to the guidelines outlined by CERC, the forecasting data can either be provided by generators themselves or they can rely on information provided by the RLDCs; in either case, they will be responsible for any deviation penalties that are payable under the guidelines.

  Additionally, in situations where multiple generating entities are connected to the ISTS by way of a pooling station, the CERC guidelines have a provision for setting up of a qualified coordinating agency (QCA) – which could comprise the principal generator. This agency would be responsible for dealing with all the forecasting and scheduling guidelines and settling any deviation penalties on behalf of the generating entities.

- **Settlement of penalties***:* The renewable generators at the regional level will be paid according to scheduled generation. Settlement penalties are payable based on the absolute error between scheduled and actual generation. The absolute error (deviation from schedule) is defined as a percentage of the Available Capacity (Schedule Generation-Actual Generation/Available Capacity). Here, in case of over-injection into the grid, the generator is compensated, while in case of under-injection the generator is liable for the penalty (see *Figure 5.3: Deviation Normalised to Available Capacity under CERC Framework*). The payments will be made as per the average power purchase price (APPC) determined by CERC and will follow the deviation bands mentioned below:

Figure 5.3: Deviation Normalised to Available Capacity under CERC Framework

Penalties will be paid as percentage of fixed rate



Source: CERC

State level forecasting and scheduling
Based on the CERC guidelines for renewable generators connected to ISTS, the forum of regulators (FoR) has come up with a draft of model regulations for forecasting and scheduling at the state level. These regulations are especially important since a large majority of the solar and wind power installations are

71 Grid Integration of Renewables in India: An Analysis of Forecasting, Scheduling and Deviation Settlement Regulations for Renewables, Prayas Energy Group, August, 2016

connected to InSTS. Eight states have now come with drafts frameworks for forecasting and scheduling; these include Rajasthan, Andhra Pradesh, Jharkhand, Karnataka, Odisha, Madhya Pradesh, Chhattisgarh and Tamil Nadu.

- **Data procurement*:*** Unlike the CERC framework, this framework recommends a hybrid approach for data procurement for scheduling. The SLDC will perform broader level grid security focused forecasting, while QCAs will deal with plant level data and deviation settlement.

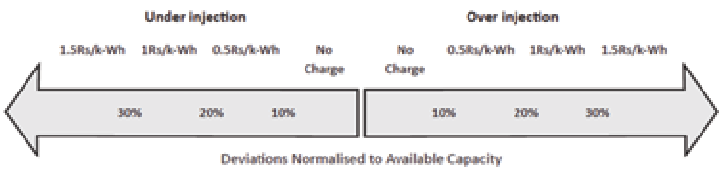
  Just like the CERC framework, the QCA is to be selected from the set of generators connected to a single pooling station. The QCA can have the responsibility to forecast for all the generating entities or the individual plants can forecast on their own and the QCA can then coordinate with the individual entities to prepare day-ahead forecasts.

- **Settlement of penalties***:* Generators connected to the state grid and selling power within the state (intra-state transactions) will be paid according to the actual generation, and those selling power outside the state (inter-state transactions) will be paid according to scheduled generation. This difference is primarily due to the lack of an ABT compliant energy accounting framework in most states. However, as the intra-state ABT is implemented across most states, the payment to the renewable energy generators for intrastate transactions should also be based on scheduled generation.

Settlement mechanism is almost identical to the one suggested in the CERC framework, with two major differences. One is that the model framework for state generators has absolute penalties (in Rs/KWh) for over- and under-injection. The other difference is that generators are responsible for both over- and under-injection penalties, unlike the CERC framework (see *Figure 5.4: Deviation Normalised to Available Capacity under State Framework*).

Figure 5.4: Deviation Normalised to Available Capacity under State Framework

Absolute penalties will be charged for deviation



Source: Forum of Regulators

The allowable absolute error is 10 per cent in the state framework as opposed to 15 per cent under the CERC framework; however, these guidelines are subject to changes when adopted by individual states.

Overall, a tariff mechanism to encourage better forecasting and scheduling is taking shape. There are concerns in the existing mechanism but these will be sorted over a period of time. For instance, an analysis of the CERC and FoR guidelines by Prayas Energy Group, has identified certain issues to be resolved to make these guidelines more favourable for large-scale penetration of renewable energy[72]. These include:

- The commercial settlement mechanism with regard to the state grid puts more financial burden on the host state DISCOMs. This might push host states/DISCOMs to oppose further increase in the deployment of variable RE.
- Since penalties (beyond permissible deviation limits) for under-injection are higher than that for over-injection, both for state and regional generators, it may bias the generators to under-schedule. This possibility should be considered when deviation bands are revised in the future.

72 Grid Integration of Renewables in India: An Analysis of Forecasting, Scheduling and Deviation Settlement Regulations for Renewables, Prayas Energy Group, August, 2016

- Deviation penalties for inter-state transactions and for regional entities are based on fixed rates (linked to tariff under their PPAs), while those for intra-state transactions are based on absolute value (absolute value in Rs/kWh). Such absolute values need careful attention and regular revision in line with the wind and solar market prices.
- If there remains a wide variation in defining absolute error, deviation bands and deviation errors among states, there is a fear that newer investments may not come up as expected in states with higher risk of penalties. Hence, the FoR should try to evolve consensus amongst states to have the same deviation framework.

3. Supply balancing
As RE generation has to be balanced with conventional energy, flexibility of conventional generators, availability of ancillary services for supply-balancing and grid stability, and large-scale electricity storage becomes very important. In addition, a market mechanism will have to be devised wherein conventional generators can be paid for remaining available and for being more flexible.

Flexibility
A flexible conventional-generator fleet is required to meet the net-load. The flexibility of a conventional generator is defined by three parameters:

- Technical minimum: The minimum capacity at which a conventional thermal and hydro power plant can function without major disruption. Most thermal power plants in India have reported their technical minimum as 70 per cent of rated capacity. However, this is much higher than the 50 per cent prescribed in the technical standards for construction of electric power plants formulated by CEA. CERC has also mandated a technical minimum of 55 per cent for all central and inter-state power plants. So, slowly regulations are being developed to make conventional generators reach lower levels of technical minimum.
- Ramp rate: It is the rate at which a power plant can increase its generation. A high ramp rate is important for greater penetration of renewable energy as conventional generators can then quickly fill the supply-demand gap. In general, coal plants have very high ramp rates and are generally in the range of one per cent of Maximum Continuous Rating (MCR) per minute. So far, no guidelines or regulations have been put in place for RE ramp rate, but CERC has plans to introduce regulations over the next few years.
- Minimum up and minimum down time: This is the minimum time that a power plant takes to reduce/increase generation or come back online after it has gone down to zero per cent generation.

Although all these parameters are currently not part of regulations, they are gradually becoming more and more prevalent. A fast track enforcement of regulations is crucial for maintaining grid stability as India's installed capacity, especially penetration of renewable energy in the electricity mix, grows. Additionally, REMCs must be made operational as soon as possible in order to coordinate and improve supply balancing activities.

Reserves
Reliable operation of large electricity grids like that of India necessitates reserves in generation. Reserves have to be identified in advance, kept available and deployed immediately in real time at the instance of the System Operator. The generator may be given necessary incentives for maintaining and deploying these reserves. Reserves can be spinning or non-spinning, but their deployment time is crucial; 0-10 minutes is the typical norm for deployment of spinning reserves. Generation reserves are more relevant in the context of large penetration of wind and solar energy.

The total quantum of reserves and its segregation into primary, secondary and tertiary reserves is extremely important in the context of balancing. The National Electricity Policy of 2005 mentions five per cent spinning reserve, but so far no ERC has notified any regulation on reserves. However, CERC in 2015 issued a *suo motu* order on the roadmap to operationalise reserves in the country. A regulated framework has been provided for identification and utilisation of spinning reserves and implemented with effect from 1 April, 2016 till 31 March, 2017. Also, it is envisaged that a market based framework is required for efficient provision of secondary reserves from all generators across the country for implementation by 1 April, 2017.

In India, primary reserve, which is available with all conventional generator, is made mandatory by IEGC. For secondary reserve, which has to be operated with the help of an automated generation control (AGC) system operated by the LDC, CERC has set an April 2017 deadline for all regional generators. To use the tertiary reserves present at inter-state level, CERC notified the Central Electricity Regulatory Commission (Ancillary Services Operations) Regulations, 2015 in August 2015. All un-requisitioned surplus generation from regional entities, whose tariff is determined by CERC, can be used as part of reserve regulation ancillary services (RRAS). The forecasting for the amount of reserve needed would be performed on a day-head basis and would take into account data from RLDC and SLDC and communicate the same to the generating entities.

Storage

The need for storage will become more and more important as the share of renewable energy in the power generation mix increases. A reliable storage capacity can increase flexibility in generation and demand. India has started looking at storage technology seriously. It has set up pilot projects to test some storage technologies and is seriously looking to install more pumped storage hydro plants (PSHP) projects.

The most cost efficient option that is currently available is pumped storage hydro plants (PSHP). India has potential of 96.5 GW of PSHP, of which about 4.8 GW has been installed so far. Additionally, 1,080 MW capacity is under construction and another 2,600 MW capacity is envisaged to be developed in the near future.[73] PSHP is the cheapest storage technology and its use, in conjunction with renewable power, is likely to increase the cost of solar/wind power by Rs 3-4 per KWh.

The prices of battery technology are going down consistently. Considering the projections on costs, batteries might become viable for larger scale use in the coming years. According to a report published by KPMG, the cost of lithium-ion battery is likely to fall from Rs 12.6/ kWh currently to Rs 3.5/ kWh by 2025, bringing it on par with PSHP (see *Figure 5.5: Falling Cost of Lithium Ion Battery in India*).

Figure 5.5: Falling Cost of Lithium-Ion Battery in India

Cost is projected to fall by 70-80% in next 10 years

Source: Tesla Motors, U.S. Department of Energy's EV everywhere Grand Challenge, KPMG in India's analysis, October 2015

Currently a pilot project on grid connected battery energy storage system (BESS) is under implementation at Puducherry. Three different technologies – advanced lead acid, lithium-ion and NaNiCl2/alkaline/flow – are being installed under this project. Advanced lead acid and lithium-ion batteries for 500kW for 30-minute storage (250kWh) and sodium nickel chloride/alkaline/flow batteries for 250kW for four-hour

73 Draft National Electricity Plan (Vol-II) Transmission, 2016, Central Electricity Authority

storage (1 MWh) are being installed. All three systems will be tested mainly for frequency regulation and energy time shift applications to facilitate integration of renewables in future. These BESSs will be connected to the network through a 22/0.433 kV transformer at Puducherry substation of Power Grid Corporation.

India is also testing other storage technologies. At Talheti, Rajasthan a 1 MW thermal energy storage system is under operation. Two more small-scale molten salt storage based projects are under construction in Rajasthan and Gujarat. A 1,400 kWh Giga-Capacitor based energy storage system is under construction in Hyderabad.[74]

Market design

As more and more renewable generators come online, the requirement of conventional generators will be to supply power only during deficit. This means that there has to be a market design that allows conventional generators to remain on standby and supply electricity on short notice. India already has an ABT framework wherein generators are paid to remain 'available'. From remaining available to remaining on standby is a short-journey that India can take with conventional generators when the time comes.

India already has the market in place to sell electricity on a real time basis. To manage the intra-day generation-demand balance, utilities can trade short-term power through the power exchanges. Earlier such intra-day trading in the power exchange was limited to only a few hours in the day. However, intra-day trading can be done for 24 hours with requested electricity delivered in three hours. Similarly, there is discussion for allowing reserve capacity to be sold on intra-day basis. For instance, a market mechanism for ancillary services is expected to be implemented in 2017-18. The new framework will allow the RRAS providers to bid at power exchanges for providing the RRAS services. Over a period of time, as large-scale storage becomes necessary, a market for electricity storage is also likely to emerge.

Overall, a clear framework seems to be emerging for a dynamic market in which conventional power plants can remain on standby and sell power on short notice.

4. Technological interventions

Large-scale installation of renewables will require certain augmentation and modification in the grid and introduction of newer technology including in the renewable energy generators themselves

Augmentation in transmission

Adequate transmission infrastructure is essential to evacuate renewable power to load centres. A few years ago, wind generators with capacity of hundreds of mega-watts were kept idle in Tamil Nadu because of a lack of transmission lines.[75] Recognising the existing inadequacies in evacuating power from renewable rich states, and the plans for large-scale development of RE capacity during 2012-2017 period, Power Grid carried out studies to identify transmission infrastructure requirements for RE. This resulted in the development of the 'Green Corridor' project. Green Corridors are high voltage transmission lines to evacuate power from renewable energy rich states to the national grid.

Two green corridor transmission networks are being constructed. In the first (Green Corridor I), inter-state transmission network is being constructed to evacuate power from renewable energy rich Tamil Nadu, Karnataka, Andhra Pradesh, Gujarat, Maharashtra, Rajasthan, Himachal Pradesh and Jammu & Kashmir. This will support transmission of 33 GW of solar and wind power.

The second (Green Corridor II), is meant to provide support for solar parks that have been planned all over the country. Green corridor II will provide transmission infrastructure for 20 GW of capacity. The total investment in the project equals about Rs 43,000 crore, out of which Rs 8,000 crore will come from the German government in the form of soft loans. The project in totality will provide transmission infrastructure for approximately 55 GW of renewable energy capacity.

---

74 ibid

75 http://timesofindia.indiatimes.com/city/chennai/Tamil-Nadu-loses-800MW-of-wind-power-to-poor-transmission/articleshow/20217522.cms?referral=PM

Green corridors, together with the projected expansion in the transmission grid during the 2017-22 period, are likely to meet the transmission requirement of 175 GW of renewable energy that India plans to install by 2022.

Grid technology

- **WAMS:** As more and more renewable energy is added to the grid, the need for its real-time monitoring gains importance. In this regard, Wide Area Measurement System (WAMS) is emerging as an important technology. WAMS enables synchronous measurement of real-time parameters across the widely spread grid with quick data transfer to control centres, which would be effective in reliable, secure and economical grid operation. It will facilitate integration of large quantum of intermittent and variable renewable generation into the grid.

  Application of synchrophasor technology, using Phasor Measurement Unit (PMU) integrated with Phasor Data Concentrators (PDC) with fibre optic communication backbone, has emerged as the key technology for WAMS.

  In India Power Grid is implementing WAMS at the national level under a project titled Unified Real Time Dynamic State Measurement Project (URTDSM). Under this PMUs are being installed on substations of 400kV and above in the state and Central grids, generating stations of 220kV level and above, HVDC terminals and important regional and national connection points. PDCs are being installed at various levels to create a hierarchy of data collection from sub-station to the regional level. The first phase of this project is underway in which 1,186 PMUs are being installed. The second phase will be implemented based on the feedback from the first phase. Beyond 2014-15, provision of PMUs for all new substations and generating stations is to be ensured.

- **Reactive Power Planning:** Reactive Power Planning, particularly the use of Power Electronic Devices (PEDs) like Static Var Compensators (SVCs), STATCOMs also become important from the viewpoint of having a flexible power system. Currently, SVCs and STATCOMs are under implementation in the ISTS network of India. Projects worth Rs 3,662 crore are under implementation, which include cost of SVCs in the northern region, expected to get commissioned shortly. The remaining will be implemented progressively during 2017-2022.

  These devices have been primarily planned to provide dynamic stability to the Grid under contingency conditions and to provide a fast and robust system response to severe disturbances in the grid where voltage recovery is critical.

Renewable generator technology

- **Low Voltage Ride Through:** In conventional power grids, inverter-based distributed generation plants must be quickly disconnected when the grid voltage or frequency exceeds the allowable operating range. In grids with a high share of distributed renewable units, the simultaneous loss of a large number of generation plants and capacity due to short-term voltage or frequency fluctuations (which may, for example, result from a fault in the transmission network) can threaten the grid's overall stability. To avoid this, wind generators need a technical capability of Low Voltage Ride Through (LVRT). This essentially allows wind generators to continue being online for momentary voltage dips up to a certain time.

  LVRT technology is now mandatory for wind generators in India. As per CERC direction, wind turbines of capacity more than 500 kW (except of stall type) have to install LVRT by 2018. Recognising the expected large capacity addition of solar power, CEA is in the process of amending the Central Electricity Authority (Technical Standards for Connectivity to the Grid), 2007 regulations for mandating LVRT for solar generators (except rooftop solar). CERC has recommended all new solar generators to plan for incorporating LVRT at their generating stations.[76]

76 Grid Integration of Renewables in India: An Analysis of Forecasting, Scheduling and Deviation Settlement Regulations for Renewables, Prayas Energy Group, August, 2016

As can be seen from the above, India is in the process of implementing necessary technology interventions to allow more penetration of solar and wind power. Investments are being made for transmission augmentation and for introducing new grid management technologies. In addition, renewable energy generators are being directed to install technologies that will ensure the stability of the grid.

C. Smart Grid

A smart grid refers to an electricity grid which incorporates several digital technology features like automatic supply cut-off when demand declines, managing fluctuations of supply especially that coming from renewable energy sources, smart meters, etc.

The first official definition came in 2007 when the American Energy Independence and Security Act laid down 10 characteristics of a smart grid[77]:

- Increased use of digital information and controls technology to improve reliability, security, and efficiency of the electric grid;
- Dynamic optimisation of grid operations and resources, with full cyber-security;
- Deployment and integration of distributed resources and generation, including renewable sources;
- Development and incorporation of demand response, demand-side resources, and energy-efficiency resources;
- Deployment of 'smart' technologies (real-time, automated, interactive technologies that optimise the physical operation of appliances and consumer devices) for metering, communications concerning grid operations and status and distribution automation;
- Integration of 'smart' appliances and consumer devices;
- Deployment and integration of advanced electricity storage and peak-shaving technologies, including plug-in electric and hybrid electric vehicles, and thermal-storage air conditioning;
- Provision to consumers of timely information and control options;
- Development of standards for communication and interoperability of appliances and equipment connected to the grid, including the infrastructure serving the grid;
- Identification and lowering of unreasonable or unnecessary barriers to adoption of smart grid technologies, practices and services.

The primary reason for having a smart grid is to achieve large-scale integration of renewable energy on the energy system and yet keep the grid stable and secure.

The other important factor that requires smart(er) grids is that a consumer may no longer be a consumer alone. For example, an individual with a rooftop solar system may be able to generate enough electricity for his own needs and still have balance electricity he may wish to 'sell' to the grid. Thus, a grid which will cater to this dual nature of the same user becomes imperative. If smart grids become the norm, so will smart meters; these will need to deal with the same intermittent supply of energy as well use and the dual nature of users by being able to share and disseminate information accordingly. In addition to the technology of smart grids and meters, what this needs is infrastructure which will support the transmission.

The International Energy Agency (IEA) puts down different technology components of smart grids as follows[78]:

- **Wide-area monitoring and control**: This includes real-time monitoring of information about generation like supply, fuel mix, frequency, voltage, etc., over large geographical areas. Analytics arising out of this information will help system operators to be able to respond to outages, sudden spike in demand, problem with any generation source, etc. Thus the first important technology that is needed is one that will enable this 24-hour monitoring and analyses of generation/supply information. Similar information on demand is also needed to be able to help integration of renewable energy better.

---

77 https://www.govtrack.us/congress/bills/110/hr6/text as viewed on August 3, 2016

78 Anon, 2011, *Technology Roadmap – Smart Grids*, International Energy Agency, France

- **Information and communications technology integration**: This technology is needed across the entire pathway of power provision starting from generation to distribution and use. While some of the technology to be used is available already (mobiles, radio networks, internet, etc.), others are being piloted. It also needs an advanced computing and system control enabling two-way flow/exchange of information. This is probably the most mature technology component of all those mentioned and needs to be adequately deployed for the purpose.
- **Renewable and distributed generation integration**: The most important technology needed to be able to manage integration is an energy storage system which can decouple energy generation and distribution.
- **Transmission enhancement applications**: Applications like the Flexible AC Transmission Systems (FACTS) are used to enhance control of transmission and maximise transfer capability. High Voltage DC (HVDC) technologies are used to connect offshore energy generation sources (wind and solar) to a large power area, etc.
- **Distribution grid management**: Distribution automation using sensors and providing real-time information is a pre-requisite.
- **Advanced metering infrastructure**: This will include smart meters which will be able to exchange two-way information on parameters like price, energy consumption, remote control of connections, etc. Smart billing infrastructure could also be incorporated.

At the same time, some of the challenges of the smart grid technology are – nascent technology, cyber security, high cost associated with setting up the associated network and installation of meters and the control system, etc.

The smart grid technology is estimated to be US$ 220 billion market by 2020 and US$D 500 billion by 2030[79]. Some countries are already piloting smart grids or starting the process towards moving to smart grids.

1. International experience

Spain[80]: In 2006, Red Electrica started the operation of the Control Centre of Renewable Energies (Cecre). When set up, facilities with power capacity greater than 10 MW were to register with a Generation Control Centre (GCC). In June 2015, the power capacity for registration was reduced to 5 MW, which has now gone down to 1 MW[81]. GCC feeds information like production of active and reactive power, voltage and connection status, to Cecre every 12 seconds on a real-time basis. All data are then analysed to check how much renewable energy can be integrated into the electricity system without affecting the supply. The system is designed in a way that if it falters, renewable energy generation can be reduced within 15 minutes. This real-time monitoring of renewable energy generation allows for maximum integration into the grid. They are using tools like SIPREOLICO for predicting wind generation – hourly forecast 48 hours in advance and aggregated hourly forecast for up to 10 days in advance[82]. In 2008, the government mandated replacement of existing meters with smart ones, at no additional cost to consumers. Since 2013, this has ensured that more than 40 per cent of the annual electricity demand is met by renewable generation[83].

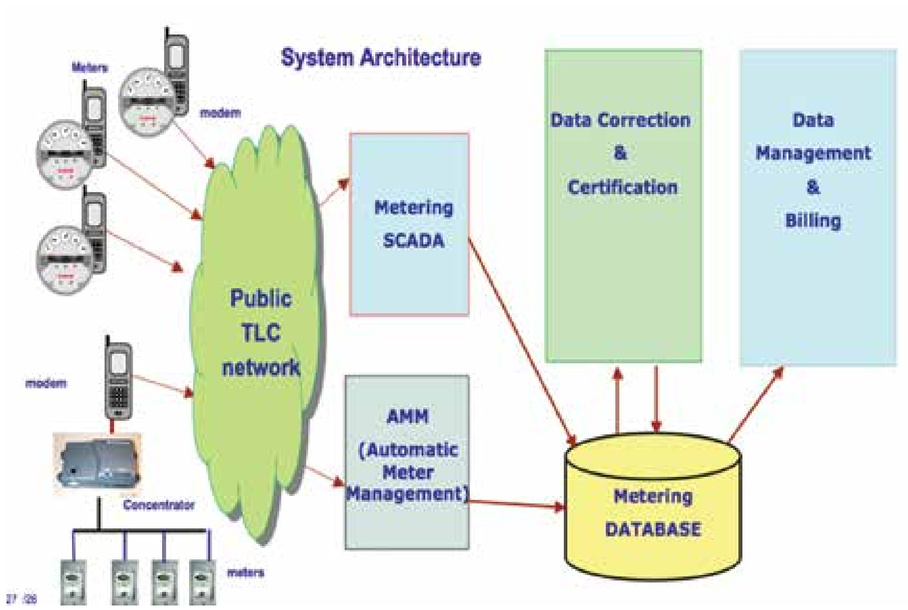
Red Electrica de Espana explains that this has not been possible without its set of challenges[84]. To begin with, demand coverage poses a huge hurdle. Since it is impossible to store energy in large quantities, it forces generation to adapt to demand at all times, which is difficult given that renewable energy depends on availability of primary energy source. This need to supervise and control renewable energy generation combined with the sheer number of RE facilities in Spain makes the job even tougher (there are 3,400 RE facilities). This along with variability in production, error margins in production forecasts, technological glitches causing disturbances, limited interconnection capacity, etc., have meant that

79 Anon, 2014, *Smart Grid Vision and Route-map*, Smart Grid Forum, Department of Energy & Climate Change, UK
80 http://www.ree.es/en/activities/operation-of-the-electricity-system/control-centre-renewable-energies as viewed on 4 August, 2016
81 Interview with Miguel de la Torre Rodriguez of Cecre
82 Anon, 2013, *Large-Scale Grid Integration of Renewable Energy Sources – Way Forward*, Central Electricity Authority, Delhi
83 Anon, 2016, *Safe Integration of Renewable Energies*, Red Electrica De Espana & Cecre
84 Interview with Miguel de la Torre Rodriguez of Cecre

integration into smart grid has not been easy.

***Italy*[85]:** The Telegestore Project, launched in 2001 by ENEL Distribuzione SpA, installed 33 million smart meters (see *Figure 5.6: ENEL Metering System*) and 1,00,000 automated distribution substations with an investment of 2.1 billion Euros. This investment, which includes R&D costs, production and installation of meters and concentrators and IT system development, has led to savings of 500 million euros a year. The national grid, direct generation sources and other sources are metered into the ENEL distribution system; from here the power is metered out to other distributors and users. Building on this project, the national regulator has awarded 8 projects to demonstrate integrated systems at scale.

Figure 5.6: ENEL Metering System



Source: Sergio Rogai, 2006, *ENEL Telegestore Project*, Economic Commission for Europe, Committee on Sustainable Energy, Geneva

***USA*[86]**: Different regional grids in the country have different mechanisms. In California, a Participating Intermittent Resources Programme (PIRP) has been developed which allows individual wind stations to self-schedule integration according to shared forecasting. Various power suppliers have come up with 'standby' products which start operating in case of sudden loss of a power plant or transmission line.

***United Kingdom*[87]**: The UK through the Low Carbon Network Fund (US$ 650 million), under the Office of Gas and Electricity Markets (Ofgem), is supporting innovative solutions that will design and pilot smart grids. Under the Government' Smart Metering Implementation Programme, UK also aims to install 53 million smart meters by 2020[88].

It must be noted that all these pilots have either come up as a result of a policy or a commitment which has in turn needed various policy changes.

2. Smart Grids in India

India is looking at the smart grid not only from the perspective of integrating renewable energy, but also from the perspective of solving some of the problems at the distribution level. The distribution segment is plagued by high transmission and distribution losses, power theft, frequent load-shedding, low voltage etc. Smart grid technologies allow India to address some of these problems.

Realising the growing importance of smart grid technologies in the Indian power sector, the Ministry

85 Anon, 2011, *Technology Roadmap – Smart Grids*, International Energy Agency, France
86 Anon, 2013, *Large Scale Grid Integration of Renewable Energy Sources – Way Forward*, Central Electricity Authority, Delhi
87 https://www.ofgem.gov.uk/electricity/distribution-networks/network-innovation as viewed on August 5, 2016
88 Anon, 2014, *Smart Grid Vision and Routemap*, Smart Grid Forum, Department of Energy & Climate Change, UK

of Power (MoP) took early steps in 2010 and constituted the India Smart Grid Task Force (ISGTF) and the India Smart Grid Forum (ISGF). ISGTF is an inter-ministerial group created under MoP to provide policy direction to the smart grid initiatives in the country. ISGF is a non-profit voluntary consortium of public and private stakeholders formed with the prime objective of accelerating development of smart grid technologies in the Indian power sector. There are also several additional initiatives that various entities have been undertaking for smart grid support such as CEA, Bureau of Indian Standards (BIS), Central Power Research Institute (CPRI), Bureau of Energy Efficiency (BEE), etc. For instance, BIS was involved in developing standards for smart meters.

The Government of India approved the establishment of a National Smart Grid Mission (NSGM) in March, 2015. The total outlay for NSGM activities for the 12th Plan (2012-17) is Rs 980 crore with a budgetary support of Rs 338 crore. The scope of NSGM is:

- Deployment of Smart Meters and Advanced Metering Infrastructure (AMI)
- Substation Renovation and Modernisation with deployment of Gas Insulated Sub-stations (GIS)
- Development of Distributed Generation in the form of Rooftop PVs.
- Real-time monitoring and control of Distribution Transformers (DT).
- Provision of Harmonic Filters and other power quality improvement measures.
- Creation of Electric Vehicle (EV) Charging Infrastructure for supporting proliferation of EVs.
- Development of medium-sized micro-grids.

To evaluate the real benefits and to identify suitable technologies/models of the smart grid, MoP has sanctioned 11 pilot projects across the country with different functionalities of the smart grid (see *Table 5.2: Smart Grid Pilot Projects in India*). At present all these pilot projects are at various stage of implementation. The main objectives of these pilots are indigenisation of technology, development of scalable and replicable models, formulation of suitable standards and regulations based on these pilot project experiences.

Table 5.2: Smart Grid Pilot Projects in India

Eleven smart grid projects are being implemented

Sl. No.	Smart Grid Pilot	Date of Award	Sanctioned Cost □ Crore	Households Covered
1	CESC, Mysore SGIA - Enzen	Mar'14	32.59	21824
2	HPSEB, Himachal Pradesh SGIA – Alstom	Feb'15	19.45	1554
3	UHBVN, Haryana SGIA - NEDO Japan	Apr'14	NA	11000
4	APDCL, Assam SGIA - Phoenix IT	Mar'15	29.94	15083
5	PSPCL, Punjab SGIA - Kalkitech	Mar'15	10.11	2737
6	WBSEDCL, West Bengal SGIA - Chemtrols	Jun'15	7.03	5265
7	TSECL, Tripura SGIA - Wipro	Sep'15	63.43	45029
8	TSSPDCL, Telangana SGIA - ECIL	Oct'15	41.82	10397
9	PED, Puducherry SGIA - Dongfang	May'16	46.11	33499
10	AVVNL, Ajmer	Sep'15	NA	1000
11	UGVCL, Gujarat	NA	82.70	Yet to be awarded

Source: Presentation on Indian Smart Grid Journey, National Smart Grid Mission, Ministry of Power, 17 August, 2016
Note: *SGIA- Smart grid implementing agency

Puducherry Smart Grid Project

Puducherry Smart Grid project is one of the pilots which is being developed jointly by Power Grid Corporation of India Ltd (Power Grid) and Puducherry Electricity Department (PED).

Puducherry has a population of about 1 million. The distribution network in this Union Territory is divided into 10 divisions. The smart grid project is being implemented in Division I.

Division I of Puducherry has 100 per cent electrification. It has 87,035 consumers, predominantly domestic (about 79 per cent). The entire area is supplied by one 110/22/11 kV sub-station, which feeds to seven 22kV overhead feeders, five 11kV underground cable feeders and 325 distribution transformers handling a total load of 127.8 MVA.

The project has been implemented in two phases. In the first phase, a pilot was conducted to test smart grid technologies. Under an open collaboration, 21 companies installed and tested their smart meters (1,658 smart meters installed). All the functions of a smart grid were demonstrated in an area covering around 1,400 consumers in 22kV town feeder with nine Distribution Transformers (DTs). This interim pilot tested various communication technologies of smart meters and a state-of-the-art smart grid control centre was installed.

In the second phase, full pilot has been awarded to Dongfang Electric (India) Pvt. Ltd., a wholly-owned subsidiary of Dongfang Electric Corporation, China Ltd., to implement the pilot in Division-I.

The pilot project in Division-I covers all the features of smart grid like Advanced Metering Infrastructure, Peak Load Management, Outage Management System, Power Quality Management, Renewable Energy Integration and energy storage.

- Advanced Metering Infrastructure (AMI): A smart meter is about bi-directional communication. AMI facilitates full measurement and capture of data from smart meters at consumer premises by the utility through communication modes such as wireless and wired.
- Peak Load Management: Peak load management solution helps to make the electric grid much more efficient and balanced by assisting consumers to reduce their overall electric demand, and/or shifts the time period when they use their electricity avoiding high peaks and associated high tariffs.
- Power Quality Management (PQM): PQM solutions are needed to address events like voltage flicker (Sags/Swells), unbalanced phase voltages and harmonic distorted/contaminated supply, etc.
- Outage Management System (OMS): OMS like Fault Passage Indicator (a device to detect and signal fault), Feeder Remote Terminal Unit (to monitor all Fault Passage Indicators), Sectionalisers (to automatically isolate faulted section of the network and allow the remaining network to remain functional) etc. is being installed to allow the Puducherry Electricity department to manage outages quickly.
- Supervisory Control and Data Acquisition/Distribution Management System: The Supervisory Control and Data Acquisition system (SCADA) will provide real time monitoring and control functions of distribution network from a central location.
- Renewable Energy Integration: Integration of Distributed Power Generation and Renewable energy resources into the existing Grid. In Puducherry currently three solar rooftop projects with net metering are being tested.
- Energy storage systems: Large-scale energy storage devices will act as energy reservoir, injecting electricity in maintaining grid parameters during contingencies, such as fluctuation in voltage and frequency due to demand supply gap. In Puducherry, three different technologies – advanced lead acid, lithium-ion and NaNiCl2/alkaline/flow – are being installed. Advanced lead acid and lithium-ion batteries are being installed for 500 kW for 30-minute storage (250kWh) and sodium nickel chloride/alkaline/flow batteries for 250 kW for four-hour storage (1 MWh). All three systems will be tested mainly for frequency regulation and energy time shift applications to facilitate integration of renewables in future.

- Street Lighting: All street lights have been converted to LEDs. They have been automated with pre-set ON/OFF based on ambience and traffic movement density.
- Electric Vehicle: In Puducherry two electric vehicles (EVs) are being charged with solar rooftop systems to understand the integration of EVs and solar rooftop systems.

Once it is fully implemented, the utility will have time-sliced data on consumption (and generation in case of rooftop PV) of each consumer and transformer serving it. The consumers can see her/his generation and consumption of power online. Data on all energy parameters – voltage, current, power, outages, etc. – will be available on a real time basis. This will facilitate automatic billing and online payment.

All these features will be accomplished by following key components:

Smart meters: Smart meter with AMI is the basic component in a smart grid that allows two-way communication between the consumer and the utility. A smart meter allows consumers and the utility to know energy consumption on a real-time basis. For a consumer, the information on power use along with pricing could influence his consumption pattern. Smart meter is essential for the implementation of time-of-day tariff.

For a utility, the information is vital for correct metering, reduction in theft and load management. Tamper alerts like meter bypass, terminal cover open and other faults can be easily identified with AMI. Many invisible faults inside the consumer wiring system that lead to abnormal energy readings like load through earth fault (caused mainly due to damaged wiring system that cannot be identified manually) can also be identified and indicated in the smart meter as tamper. So, smart grids can rectify poor billing and theft, two major problems in many states in India.

In Puducherry, the pilot project demonstrated how load management can be done using the information from the smart meters. If a consumer exceeded the sanctioned load, the connection was disconnected immediately. The utility also used the load profile to work with the consumer to decide voluntary load reduction.

Data Collector Units (DCU): DCUs collect real time consumption data from the smart meters and transmit to the central data base server system. One DCU is installed to take care of 50-100 consumers.

Energy consumption data is stored in the DCU in a time slot of 30 minutes and is used to implement time-of-day tariff and incorporate the real-time prices from the power market. DCU is an important component to tackle the illegal tapping of electricity. To avoid pilferage, threshold consumption level is added in the DCU. The average electricity usage for the last several months, which can be obtained from the consumption history, is used to detect electricity theft through comparison between the usage and the threshold.

In the pilot, it was found that one DCU can cater to not more than 50 meters in many cases, especially when the communication is based on radio frequency (RF).

Communication Network: Communication networks could be RF communication, power line carrier communication (PLC) and general packet radio service (GPRS) networks. This is used to transmit the bi-directional data.

Database and Management System: Customer information is stored in a central database. The data from the DCUs is collected through a meter data acquisition system (MDAS) based on which the meter data management system (MDMS) provides the necessary data in the prescribed formats to both the utility and the consumer. A typical MDMS (see *Figure 5.7: Load Monitoring from MDMS in Puducherry*) provides the billing details to consumers as per scheduled billing cycles and to the utility details of tampers, if any, besides the occurrences of any power faults/failures in the system for corrective actions.

Figure 5.7: Load Monitoring from MDMS in Puducherry

Snapshot of load monitoring in Puducherry

Source: I.S. Jha, Subir Sen, Kashish Bhambhani and Rajesh Kumar - Grid integration of renewable energy sources, *Journal of Scientific and Technical Advancements*, Volume 1, Issue 3, pp. 1-5, 2015

As can be seen from the case study of Puducherry, India is investing in smart grids primarily to improve and strengthen the functioning of the distribution segment. It is just that this strengthening would also allow large-scale introduction of renewable energy at the distribution end in the form of distributed renewable energy systems.

Under the Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY), Integrated Power Development Scheme (IPDS), Domestic Efficient Lighting Programme (DELP) and UDAY, different components of smart grid are being installed.[89]

- Feeder and Distribution Transformer (DT) metering is being done across the country. So far, feeder metering has been completed at all rural and urban feeders and about 45% of the DT for rural area and 48% for the urban areas have been completed.
- Smart meter has been made mandatory for consumers consuming more than 200 kWh/ month. This has to be completed by 31 December, 2019. So far less than 5% have been installed, but it is likely to pick up in the coming years.
- Other initiatives like consumer indexing and upgradation of transformers, etc. are being implemented.

What is required now is to bring all these initiatives into a coherent framework and add other components of smart grids, like the data and communication infrastructure, to move the entire country towards smart grid technology. This investment will allow India to install more renewable power and keep the grid stable and secure.

D. How far is India from Germany in integrating and balancing renewable energy in the grid?

Germany is considered a leader in renewable power today. In 2016, renewables (excluding hydropower) provided close to 30 per cent of Germany's power (see *Figure 5.8: Net power generation in Germany in 2016*). About 14 per cent of electricity was produced from wind and seven per cent from solar. Together, solar and wind contributed 21 per cent of the total power generation.[90] India is likely to have a similar

89 https://www.uday.gov.in/home.php

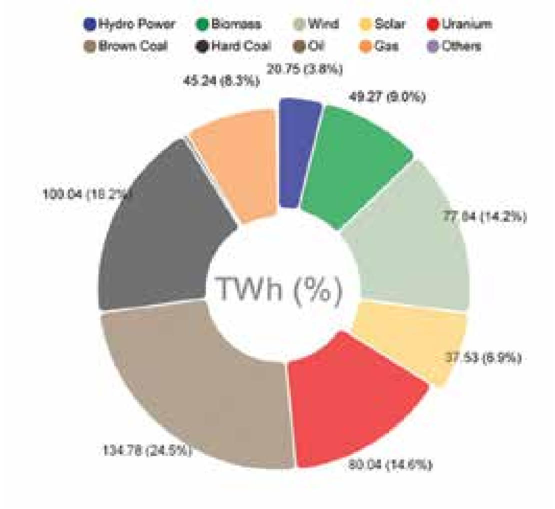
90 Presentation of Prof. Dr Bruno Burger on "Power generation in Germany – assessment of 2016", Faunhofer Institute for Solar Energy Systems ISE, 2017

level of power generation from solar and wind by 2026-27.[91] So, in terms of the use of solar and wind power, India is about a decade behind Germany. Germany has set a target of meeting 35 per cent of its electricity from renewable sources by 2020 and 50 per cent by 2030.

Because of the merit order dispatch, renewables are always used first, sometimes leaving very little power demand to be met from conventional sources. So how is Germany dealing with such high levels of intermittent solar and wind power in its grid? Also, how far behind India is compared to Germany in terms of grid technology and associated management systems in integrating and balancing large quantum of renewable power?

Figure 5.8: Net Power Generation in Germany in 2016

Solar and wind contributed more 20% of the total generation



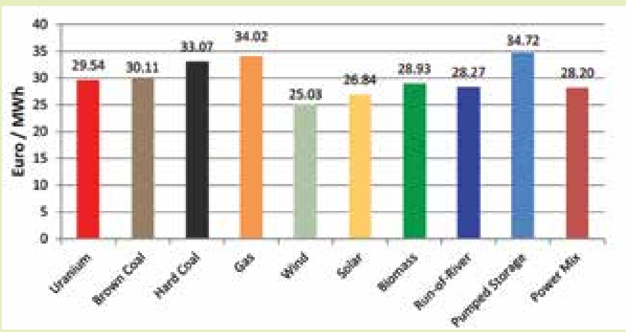
Source: Faunhofer Institute for Solar Energy Systems ISE, 2017

Box 5.1
Cost of Solar and Wind Power in Germany

In 2016, solar and wind power were the cheapest sources of electricity in Germany. The day-ahead market value of wind power was the lowest followed by solar power. In comparison, coal and gas power were the most expensive in 2016. Solar power prices are also falling in India and in a recent bid (Rewa solar park @ Rs. 3.30/kWh), the cost of solar fell below the cost of new coal power plants. It is estimated that by 2020, the cheapest source of power in India would be from solar rooftops.

Day-ahead market values, weighted by volume, of different sources of power: 2016

Wind and solar were the cheapest sources of power in 2016



Source: Faunhofer Institute for Solar Energy Systems ISE, 2017

91 Draft National Electricity Plan (Vol-I) Generation, 2016, Central Electricity Authority

1. Germany vs. India

Germany has so far managed to integrate and balance its current share of renewable energy with very modest changes to its power system. The reason for this is the existing strength of its power grid and the flexible operation of its coal and nuclear plant (and to a lesser extent gas and pumped hydro). In addition, Germany has managed quite well because of:

- Better design of the balancing (ancillary) power markets, to make them more effective, faster, and open;
- Better system control software and day-ahead weather forecasting;
- Modest technical improvements to local-level distribution systems;
- Exports of power to neighbouring countries; and
- Solving the "50.2 hertz" inverter problem.[92]

Let us look at these issues one by one and compare Germany with India on these issues.

Design: Germany's power grid is among the most secure in the world. There are hardly any outages and the frequency and voltage are stable. The average German has not experienced 20 minutes of per customer annual power losses for years compared to 240-odd minutes in the US.[93] In India, outages are frequent and normal and a large number of people do not even get six hours of electricity every day. This strength of the existing grid in Germany has meant that few upgrades have been necessary to accommodate renewables.

Germany, however, had to strengthen transmission lines to accommodate higher renewables and manage regional imbalances in supply and demand. It had to increase transmission capacity to transport wind power from the country's northern part, where generation is high but demand is low, to the southern part where demand is high. An additional three north-south transmission lines are being planned as part of this process. In general, "network planning with future renewables in mind" has represented a paradigm change in Germany. Interestingly, India has also started a similar exercise and the recent transmission planning done by the CEA has specifically focused on transmission planning for incorporating higher renewable power.[94]

The learning from Germany is clear: a strong and stable grid is a prerequisite for larger integration of renewable energy. India has recognised this and is working towards strengthening the grid and the distribution network.

Currently, distribution systems suffer with poor power quality, large outages, power theft and high transmission and distribution losses. DISCOMs are running with massive losses and are not even able to recover the cost of supply.

To strengthen the distribution network, Feeder and Distribution Transformer (DT) metering is being done across the country. Smart meter has been made mandatory for consumers consuming more than 200 kWh/ month. Apart from this, transformers and meters are being upgraded. However, the real issue at the distribution segment is the financial viability of DISCOMs. UDAY has been launched to tackle this, but the scheme's success is still uncertain.

At the transmission level, India is constructing "Green Corridors" to evacuate power from renewable energy rich states to other load centres. The advantage that India has over Germany is that it already is a large synchronous grid wherein every part of the country (including some neighbouring countries) is interconnected. Once Green Corridors are constructed, India can evacuate its planned renewable energy generation easily. Currently, SVCs and STATCOMs are also under implementation in the Inter State Transmission network of India. As more and more renewables get connected to grid, such voltage regulating technologies will also have to be installed at Intra State networks.

92 http://www.martinot.info/renewables2050/how-is-germany-integrating-and-balancing-renewable-energy-today
93 https://cleantechnica.com/2015/10/09/german-outages-12-minutes-per-customeryear/
94 Draft National Electricity Plan (Vol-II) Transmission, 2016, Central Electricity Authority

Coal and Nuclear in Balancing: Like India, there is a surplus of coal power capacity in Germany, and this excess coal power capacity is being used very effectively to provide sufficient balancing power to offset the variability of renewables. Most of the coal power plants in Germany have been originally designed or later modified for flexible output – the ability to "ramp" on an hourly basis to much less than full output, and "cycle" on and off on a daily basis. The lignite power plants in Germany are less flexible, but many of these have been modified in recent years to allow ramping down to 40 per cent of their maximum output, compared to only 60 per cent previously. This is an important learning for India as most coal power generators in India are reluctant to make their plants 'flexible'.

Coal power plants can sell their power into the "ancillary" (also called "balancing") electricity markets in Germany. These markets are designed to provide minute-by-minute and hour-by-hour balancing of the difference between supply and demand. Coal power plants are not selling as much of their power into the normal day-ahead wholesale markets, because wind and solar receive priority dispatch in those markets. So coal plants sell into the balancing markets as an alternative source of revenue, which creates more robust balancing markets. In participating to a greater extent in the balancing markets, coal power operators have also developed better software to ramp their plants faster, and developed operational practices that reduce the stress on equipment from ramping and cycling.

It is not only coal plants that sell power in the balancing markets, but also nuclear, gas, and pumped hydro plants. Nuclear plants in Germany have also been designed to be flexible on a routine basis, to allow ramping their output up and down. The German experience of operating nuclear on a flexible basis is contrary to conventional thinking that nuclear cannot be flexible. Gas turbine plants can be even more flexible, but in Germany gas plants have not been able to compete with coal because of higher prices. Thus for economic rather than technical reasons, most of the balancing today is done with coal and nuclear, and less with gas and pumped hydro.

India has large coal power capacity and relatively smaller hydropower capacity. Gas is largely imported and hence expensive and nuclear power is marginal. For large-scale integration of renewables, coal and hydropower will have to provide the balancing and hence will have to be made more flexible.

India currently does not have many regulations to make coal plants flexible. CERC has mandated a technical minimum of 55 per cent for all central and inter-state power plants. However, this has not been implemented and there are no regulations on ramp rate and minimum up and down time. A fast track implementation of regulations is crucial for making coal plants flexible.

Balancing by Markets: The balancing and intra-day electricity markets have been modified in ways that provide greater flexibility for renewables. Both of these markets provide additional power on short time frames (minutes and hours) to handle the imbalances between supply and demand that might occur as renewable output varies. For example, in 2011, Germany allowed the intra-day market to be used for trading to handle the imbalances created by wind forecast errors. To achieve this, the intra-day market auction period was reduced from 1-hour auctioning to faster 15-minute auctioning to handle faster system "ramping" dynamics.

In India, the market for balancing will have to be developed. Currently, intra-day trading is allowed but for a three hours' ahead market. As more and more renewables get into the grid, the auction period will have to be reduced, even to 15-minutes ahead market.

Software: Power system operators (ISOs) in Germany have greatly improved their power control and dispatch software and analytical tools. One of the impacts of high shares of renewables is that the German network has had to contend with much higher system ramp rates than in the past, for example up to 1,800 MW per hour, due to swings in renewable power output. ISOs have been able to successfully modify their software to accommodate higher ramp rates. In addition, day-ahead weather forecasting was greatly improved, allowing for better integration and balancing of renewables in several countries.

India has a lot of work to do to improve forecasting and develop better management systems. Accurate demand forecasting has emerged as an important issue for improving the grid stability. A study done by the national grid operator in states with high renewable energy generation (Gujarat and Tamil Nadu), concluded: “The results for correlation of schedule deviations with change in demand vs. change in conventional generation vs. change in wind generation were studied. It was observed that there was little correlation of observed deviations on state boundary with change in wind generation, instead, much higher correlation was observed with demand change”.[95] The Ministry of Power directed all the distribution utilities to implement load forecasting for their utility by 1 June, 2016. There is no status report on the implementation of this direction, but it is clear that the government is working to improve demand forecasting.

Similarly, forecasting of renewable energy is becoming more important. All solar and wind generators in India that are connected to the inter-state networks are required to forecast with at least 70 per cent accuracy and take part in day-ahead scheduling. They are penalised if the forecasting is inaccurate by a margin of more than +/-30 per cent. However, this margin has to be reduced further and forecasting will have to be refined. In addition, this regulation has to be implemented for the intra-state renewable generators as well.

Needless to say, grid operators will have to improve power control and dispatch software and analytical tools to deal with more renewable energy. India is setting up Renewable Energy Management Centres at different levels to do exactly this. In addition, India is implementing a Wide Area Measurement System (WAMS) at the national level using synchrophasor technology to enable synchronous measurement of real-time grid parameters across the widely spread grid.

Technical Improvements at Local Level: In Germany, modest technical improvements have been made to local-level distribution systems. At the distribution level, power utilities in Germany have had to cope with two-way (“reverse”) flows of power from rooftop solar generators. This happens when solar generation from rooftops increases in a local node higher than power demand in that node. In general, power systems were never designed for reverse flow at the distribution level. Some distribution utilities have had to do grid upgrades, including substations, transformers, and power lines. But many distribution grids have not yet required upgrades. Some distribution utilities have installed special tap-changing transformers to manage reverse flows. For many distribution utilities, reverse flows are one of the main manifestations of high shares of solar, and the main challenge at the distribution level to date.

Some distribution utilities have done pilot projects of smart-grid technologies. This includes new monitoring and data acquisition systems. In particular, some distribution utilities are starting to monitor voltages on the distribution grid, to better manage reverse flows.

In the future, a variety of additional measures will be required on distribution grids to handle storage, demand response, smart inverters, two-way flows, “virtual power plants” combining generation with flexible load, integration with heat supply and heat storage, and other developments yet to be encountered on distribution grids. For example, some German distribution utilities are starting to forecast local renewables output to better manage the local grid. Others are considering how to integrate local balancing and peak-shaving with local combined-heat-and-power plants and heat storage. Some utilities are experimenting with smart inverters installed on distributed solar power systems as a new way to regulate distribution system voltage and reactive power. And some utilities are thinking about long-term planning and modelling for their local networks, a practice not seen historically.

In India, major improvements will be required at the distribution systems to integrate more renewable energy. The advantage is that these improvements will have to be carried out in any case to improve the performance of the distribution systems and DISCOMs. The introduction of smart grid technology, like smart meters, would go a long way in strengthening the distribution system and improving the operational and financial position of DISCOMs. It would also allow for introduction of larger volumes of solar power in the local grid. India has set a target of installing 40 GW of solar rooftop capacity by 2022. Installation of smart meters has been made mandatory and many other communication technologies are being piloted to allow for bi-directional communication. It will take time, but in next couple of years one can expect large-scale adoption of smart grid technology in India.

95 Grid Integration of Renewables in India: An Analysis of Forecasting, Scheduling and Deviation Settlement Regulations for Renewables, Prayas Energy Group, August, 2016

Peak Pricing: When wind and solar reach very high levels of generation on peak days, this causes electricity market prices to decline in Germany, even go to zero or negative. This price mechanism has the effect of reducing output from other sources like coal and gas, and also causing those other sources to export their power to neighbouring countries instead of trying to sell into the German market. (This also has the effect of reducing power prices in those neighbouring countries.) However, the mechanism of importing and exporting power with neighbouring countries plays a very modest role in balancing renewables in Germany. This is because imports are prohibited from participating in Germany's balancing markets, and the bidding time frames for exports and imports (i.e., multiple days in advance, not day-ahead or intra-day) are too long to provide balancing functionality.

India has an advantage over Germany in the sense that it already has a 'wider balancing area'. The entire country is interconnected with high voltage transmission network and construction of green corridors to evacuate 55 GW of renewable energy is in progress. So, transporting power from high renewable areas to high demand areas is not a problem.

The 50.2 HZ Inverter Problem: Finally, one of the most comprehensive changes has been in response to the "50.2 hz inverter problem." An inverter is the equipment that feeds solar power into the grid, converting the power from DC to AC. The inverter can sense the state of the grid and decide to "cut off" the solar output to the grid if conditions indicate an abnormal state (like an over- frequency of 50.2 hertz). Initially, all inverters on distributed solar PV systems around the country were designed with the same "cut off" frequency. However, with the growing share of power from solar, this meant that if the grid frequency went above 50.2 hz, all the solar could go off-line at once, which became a huge threat to system stability. So inverter firmware was redesigned and inverters modified to vary the cut-off frequency. This problem arose in the first place because no one in earlier years could imagine that solar would become such a large share of total generation in Germany.

The German experience teaches us to come out with regulations and technical specifications that do not lead to expensive retrofits. Realising this, India has come out with clear technical specifications for solar and wind power. For instance, regulation exists on frequency thresholds for disconnection from the grid and on active and reactive power. Technology like LVRT has been made mandatory for wind generators and is soon to be made mandatory for solar generators. So, India is in line with Germany in terms of technology specification for renewable generators.

2. Issues to be resolved for the Future

There are many issues that have not yet impacted Germany's ability to integrate and balance renewables today, but are likely become significant issues in the future. These include:

Capacity market: In Germany, some coal and gas plants are required by the regulatory authority to continue operating, even if they generate very little power. These plants have been determined necessary for covering regional bottlenecks or seasonal variations. These plants receive "capacity payments" to cover their costs of operating at zero output. Today, a full "capacity market" does not exist in Germany, although many have been debating the merits of one. Still, what is clear is that as Germany starts producing close to 50 per cent of its total electricity from solar and wind, only a balancing market would not be sufficient to keep the conventional fleet in operation. Some kind of capacity market would have to be developed.

India already has something similar to a capacity payment, though not a full capacity market. Under Availability Based Tariff (ABT), plants are paid to remain available and are also paid for amount of power supplied to the grid. For remaining available, plants are paid a fixed cost that takes care of the labour cost, interest on capital, return on equity, depreciation, etc. So, even if a plant does not operate it would still get the money to cover all its costs, except the fuel cost. The leap from ABT to capacity market is small and would not be difficult for India to move to. The major problem is that the power cost is likely to increase and many people would find it difficult to afford such expensive power. India cannot afford to have a large fleet of conventional generators sitting idle.

Demand response: Demand response means changes in the consumption pattern of a consumer in response to the changes in the electricity price. So far in Germany, demand response is very small relative to its potential for providing flexibility and balancing. Some large power generators are selling this flexible demand into the balancing markets. Some generators are integrating demand response with their coal plants to give them economic flexibility for selling into the balancing market. Some system operators (ISOs) have also been contracting directly with large demand response providers on a pilot basis. However, the German regulator has so far not explicitly included demand response in its planning, or set rules specifically for demand response.

India has still not implemented time-of-day tariff (TOD) at the consumer's end. But with widespread use of smart meters, TOD implementation would become feasible. India, however, has started implementing a large energy efficiency programme for appliances that is already reducing power demand and peak load. The Domestic Efficient Lighting Programme is a programme to replace household and street light incandescent bulbs with LED bulbs. As of February, 2017 more than 200 million LED bulbs have been distributed which will lead to 27 billion kWh saving in energy consumption and 5,400 MW reduction in peak load.[96]

Backing down of renewable power output: Backing down occurs when a renewable generator is stopped from pumping power into the grid to balance the grid. In 2014, about 1.16 per cent (about 1581 GWh) of renewable power in Germany was lost due to backing down; in 2014, this was about 0.4 per cent.[97] Strict curtailment rules have been instituted for ISOs, which have to curtail wind power output if transmission bottlenecks appear. In addition, there is a provision for compensating the renewable power generator for backing down. Reports suggest that in 2015 Germany paid $548 million to curtail wind power.[98] Curtailment may become a bigger issue in the future, depending on progress with transmission upgrades and planning.

Though all-India figure is not available for renewables backing down, wind power curtailment has become a major issue in Tamil Nadu and Rajasthan. By some estimates, as much as 50 per cent of wind generation in Tamil Nadu was not allowed to be pumped into the grid, which cost wind generators close to Rs 1,650 crore.[99] Reports from Rajasthan indicate that wind generators lost Rs 100-150 crore in April-May, 2016 alone.[100]

At present, there is no provision for compensation for backing down in India. A court case in this matter has also ruled in favour of wind developers, stating that the Tamil Nadu Generation and Distribution Corporation (TANGEDCO) could not impose backing at will. The National Solar Energy Federation of India (NSEF) petitioned Tamil Nadu Electricity Regulatory Commission (TNERC) to ensure must run status for solar plants, following which TNERC asked TANGEDCO to technically justify the backing down of solar power plants.[101]

These sporadic court rulings and regulatory commission's directions would not suffice. India needs to come out with a clear regulation on when to back down renewable generators and what compensation to pay them. Today conventional generators get paid through ABT when they are asked to back down. A similar ABT mechanism for renewables coupled with forecasting and scheduling requirements is the only way forward. In addition, inter-state trading in renewable power would also reduce backing down. Recently, the ministry of new and renewable energy (MNRE) and Power Trading Corporation of India (PTC) announced a joint venture to develop a trading platform wherein states can buy, sell and trade renewable power.[102] This initiative can greatly reduce the need for backing down of renewables.

96 http://www.ujala.gov.in/; as seen on 11 February, 2017

97 https://energytransition.org/2015/11/renewable-power-curtailment-in-germany/

98 http://dailycaller.com/2016/04/29/germany-paid-wind-turbines-548-million-to-sit-idle/

99 Grid Integration of Renewables in India: An Analysis of Forecasting, Scheduling and Deviation Settlement Regulations for Renewables, Prayas Energy Group, August 2016

100 http://economictimes.indiatimes.com/industry/energy/power/wind-energy-developers-in-rajasthan-face-losses-as-discoms-curtail-intake/articleshow/52787510.cms

101 Grid Integration of Renewables in India: An Analysis of Forecasting, Scheduling and Deviation Settlement Regulations for Renewables, Prayas Energy Group, August 2016

102 http://www.business-standard.com/article/economy-policy/renewable-energy-to-soon-get-a-separate-trading-platform-116062700265_1.html

Storage: Energy storage has played almost no role in Germany's integrating and balancing renewables so far. Also, many in Germany do not expect storage to play a role in the coming decade; or at least until the share of renewables goes above 40 per cent.[103] But, already there are projects for grid-level storage like the one in the northern German city of Schwerin which installed 5 MW battery storage plant, the biggest project of its kind in Europe.[104] In 2013, Germany announced a 25 million-euro storage subsidy programme which would provide financial support to all solar generation systems (photovoltaic) containing battery energy storage (660 euros/KW)[105]. This subsidy was recently extended till 2018.[106] The German market for electrical storage devices is expected to double between 2012 and 2025 with an associated investment of about 30 billion euros over the next 20 years[107].

In India too discussions of storage have started and few pilot projects are being run to test different storage technologies. The German exercise indicates that till 20 per cent share of solar and wind power is achieved, storage is not an important issue for the grid – balancing can be done with the conventional fleet. However, balancing the grid with storage would become an important issue in the future especially with respect to cost. If the cost of storage technology comes down significantly then balancing with the storage or balancing with conventional fleet would be an economic decision. Looking at the rapid reduction in the cost of battery technology, this is a real issue to address in the future.

Meanwhile, it is clear that solar rooftop systems along with battery storage for self-consumption would become very common in the coming years in India. Currently, there is a subsidy for rooftop solar, but not with storage. However, considering the potential of solar rooftops with storage in local grid balancing as well as in replacing the Diesel Generating (DG) set as backup power, India needs to come out with a policy to promote storage.

3. Conclusion

There are both similarities and differences between Germany and India. The two countries have a large coal based fleet, an ambitious renewable energy plan and a well-established institutional structure. The differences are on the operational side. Germany has a strong grid and is ahead of India in terms of forecasting and managing renewable energy integration. It also has a well-developed market for balancing. These are the features that India needs to learn from Germany. India should also learn about 'flexible coal' and how it can be used for balancing solar and wind generation.

The advantage that India has is what we call 'co-benefit'. India is going to make large investments in expansion of the grid and strengthening of the distribution network. These investments would also allow India to integrate large-scale renewable energy into the grid. India is already planning for the grid "with future renewables in mind". Similarly, strengthening of the distribution system by using smart grid technology will allow large-scale distribution of solar generation and its integration into the local grid.

On the market side, ABT is a major strength and it should also be implemented for renewable generators. India, however, will have to develop a market for balancing. Overall, there are initiatives underway in almost all fronts – generation, transmission, distribution, market, regulation. What is required is to bring all these initiatives together under a coherent plan for a renewable energy future for India.

---

103 http://www.martinot.info/renewables2050/how-is-germany-integrating-and-balancing-renewable-energy-today

104 https://www.chinadialogue.net/article/show/single/en/9344-Power-storage-a-fix-for-the-German-energy-transition-

105 Rainer Bussar et al, 2013, *Battery Energy Storage for Smart Grid Applications*, Eurobat, Germany

106 https://www.pv-magazine.com/2016/02/22/germanys-solarstorage-subsidy-extended-to-2018_100023314/

107 http://www.siemens.com/innovation/en/home/pictures-of-the-future/energy-and-efficiency/smart-grids-and-energy-storage-bottled-sunlight.html as viewed on 6 August, 2016

CHAPTER 6

THE BIG PICTURE

The primary enquiry of this report is whether or not India can meet its Intended Nationally Determined Contribution (INDC) commitments. Along the way, however, we realised that a fundamental shift is taking place in India's energy sector, which needs to be examined. This chapter is about that fundamental shift.

Over the past five years, things have changed dramatically in India with respect to solar energy. Prices have fallen precipitously and the ambition of India to install solar energy has multiplied by a factor of five. During this period, the wind power sector also stabilised and energy storage technology (household level and utility scale) matured, though it is still expensive. A combination of renewable technologies with energy storage has dramatic implications for the energy sector in the country. We discuss these implications in this chapter.

A. Meeting commitments and targets

In its Intentionally National Determined Contribution (INDC) commitments India has pledged to achieve about "40 per cent cumulative electric power installed capacity from non-fossil fuel based energy resources by 2030 with the help of transfer of technology and low cost international finance including from Green Climate Fund (GCF)". The non-fossil fuel based energy resources include hydropower, nuclear, biomass, solar, wind and any other renewable resources like geo-thermal and wave energy.

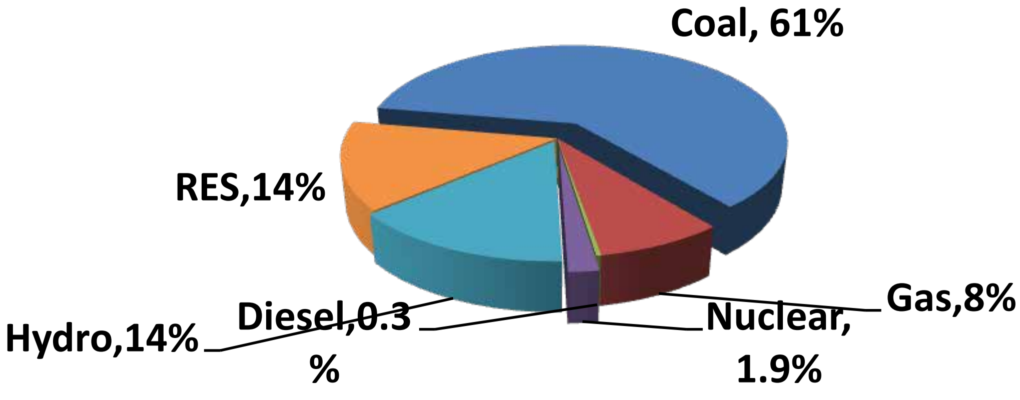
Can India meet this commitment? Can India meet this commitment from its own resources, or will it need technology transfer and international funding support? If it needs international funding support, what kind support would be most effective? Let us try and answer these questions one by one.

1. Can India meet 40% non-fossil fuel target?

As of November, 2016 about 30 per cent of the installed capacity of the electricity sector in India was already based on non-fossil fuel resources (see *Figure 6.1: Installed Power Capacity in India, November, 2016*).

Figure 6.1: Installed Power Capacity in India in November, 2016

70% of the installed capacity is based on fossil fuels; 30% on non-fossils



Source: http://www.cea.nic.in/reports/monthly/installedcapacity/2016/installed_capacity-11.pdf

All studies done in the last few years show that India's intent to achieve 40 per cent of total electric power installed capacity from non-fossil-fuel based energy sources by 2030 can be achieved relatively easily. Let us examine some of these studies.

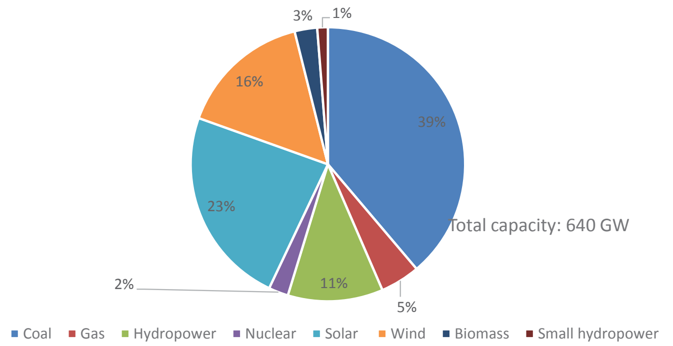
Draft National Electricity Plan

The Central Electricity Authority (CEA) prepares a National Electricity Plan every five years to plan for the growth in generation and transmission of electricity. The Draft National Electricity Plan for generation and transmission was released in December, 2016. These are two separate documents prepared by two separate committees.

- The Draft National Electricity Plan (Volume I) – Generation: This report details the requirements for 2021-22, and also projects the electricity demand, generation and transmission requirements till 2026-27. According to the study, in 2026-27, the non-fossil fuel sources would account for 56.5 per cent of the installed electricity capacity compared to 43.5 per cent from fossil fuel sources (see *Figure 6.2: Projected Installed Capacity of the Power Sector by 2026-27*). The installed capacity of coal power is projected to be 39 per cent of the total installed capacity compared to 43 per cent by renewable energy sources. India is projected to have more solar and wind power plants (250,000 MW) than coal and lignite based power plants (248,513 MW).

Figure 6.2: Projected Installed Capacity of the Power Sector by 2026-27

India is projected to have more solar and wind capacity than coal by 2026-27

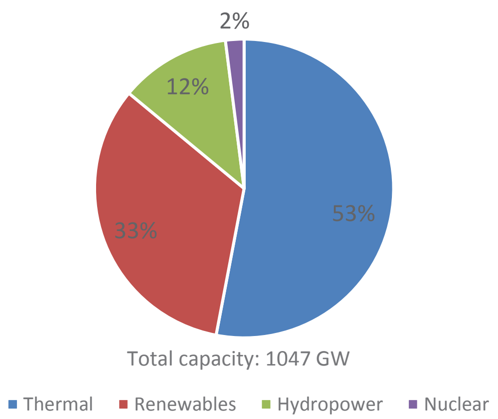


Source: Draft National Electricity Plan (Volume I) – Generation, Central Electricity Authority, 2016

- The Draft National Electricity Plan (Volume II) – Transmission: This details the transmission requirements for 2021-22, and also projects electricity demand, generation and transmission requirements till 2036-37. According to the report, in 2031-32, the total installed capacity of non-fossil fuel resources will be 47 per cent of the total capacity (see *Figure 6.3: Projected Installed Capacity of the Power Sector by 2031-32*). Thermal capacity, which will be largely based on coal, will account for 53 per cent of the capacity.

Figure 6.3: Projected Installed Capacity of the Power Sector by 2031-32

Non-fossil fuel capacity is projected to be 47% by 2031-32



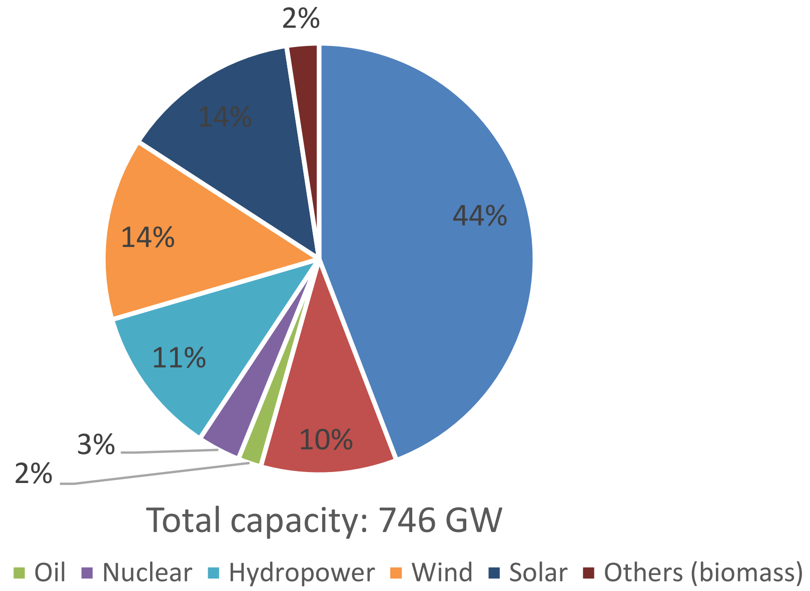
Source: Draft National Electricity Plan (Volume II) – Transmission, Central Electricity Authority, 2016

Overall, according the Draft National Electricity Plan, India will have more than 40 per cent of electricity installed capacity from non-fossils.

International Energy Agency
India Energy Outlook, published by the International Energy Agency in 2015, projects 43 per cent of installed capacity from non-fossil fuel resources by 2030 (see *Figure 6.4: Projected Installed Capacity by 2030*). Wind and solar power is projected to account for 27per cent of the total installed capacity by 2030.

Figure 6.4: Projected Installed Capacity by 2030

IEA projects 43% installed capacity from non-fossils by 2030



Source: India Energy Outlook, World Energy Outlook Special Report, International Energy Agency, 2015

Niti Aayog
The India Energy Security Scenarios 2047, a tool developed by Niti Aayog, estimates the electricity demand and supply for India under different scenarios[108]. It gives energy pathways up to 2047, comprising likely energy demand and supply scenarios.

- **Level 1** - the 'Least Effort' scenario: This assumes that little or no effort is being made in terms of interventions on the demand and the supply side, and represents a pessimistic outlook.
- **Level 2** - the 'Determined Effort' scenario: This describes the level of effort, which is deemed most achievable by the implementation of current policies and programmes of the government. It may be seen as the 'current policy' with autonomous improvements.
- **Level 3** - the 'Aggressive Effort' scenario: This describes the level of effort needing significant change, which is hard but deliverable.
- **Level 4** - the 'Heroic Effort' scenario: This considers extremely aggressive and ambitious changes that push towards the physical and technical limits of what can be achieved.

For a realistic view, we have considered Level 2 and Level 3 scenarios to projected installed capacity in 2030 (see *Table 6.1: Projected Installed Capacity in 2030*). In both these scenarios, more than 40 per cent of the installed capacity is projected from non-fossil fuel resources by 2030.

108 http://www.indiaenergy.gov.in/ as viewed on July 16, 2016

Table 6.1: Projected Installed Capacity in 2030

44-46% of the installed capacity is projected to be from non-fossils

Installed capacity (in GW)	Level 2 Scenario	Level 3 Scenario
Coal	310	360
Gas	40	52
Nuclear	16	20
Hydropower	65	74
Solar PV	46	65
Solar CSP	11	17
Onshore Wind	100	120
Offshore Wind	4	10
Small Hydro	12	16
Distributed Solar PV	11	23
Biomass	7	12
Waste to Electricity	1	1
Total installed capacity	623	770

Source: http://www.indiaenergy.gov.in/ as viewed on 16 February, 2017

Based on the above studies, it can be assumed that India will meet its INDC commitment of 40 per cent installed electricity capacity from non-fossil fuel resources by 2030.

2. Can India meet its INDC commitments on its own?

India has put forth in its INDC an initial estimate of US $206 billion for adaptation to climate change, during 2015-2030[109]. Mitigation costs are higher with Niti Aayog estimating a requirement of US $834 billion till 2030[110]. But there is no breakup of this cost. Overall, Government of India estimates that climate actions will require financing of the order of US $2.5 trillion between now and 2030[111]. India has puts down two main requirements for meeting its INDCs – finance and technology transfer.

On technology transfer, India has advocated global collaboration in research and development, particularly in clean technologies and enabling their transfer, free of Intellectual Property Rights (IPR) costs, to developing countries. India has asked for IPR costs to be borne from the GCF through a separate window. It has given a list of technology in its INDC document. The list is varied and includes technologies related to clean coal, nuclear and renewable energy, among others.[112]

On funding requirement, India has broadly stated the need for developed countries to provide "adequate finance" to developing countries meet their INDCs and to even boost their efforts. Other than IPR costs, India has not put forth any concrete proposal on funding.

As elaborated in Chapter 1, India will need about US $200 billion over the next five years to meet the 175 GW target. The availability of finance is not likely to be an issue; the high cost of finance is the main problem. There are concrete proposals to reduce the cost of finance including setting up a payment security mechanism and a foreign exchange hedging facility. India could put proposals for getting funds from GCF to set up these facilities. Other than these, India can meet its INDC commitments of 40 per cent electricity installed capacity from non-fossil fuels on its own.

But this target is not an issue any more. As we will see in the next section, India is on the verge of a major shift in its energy sector. The issue is how can the international community facilitate this shift.

109 http://www4.unfccc.int/submissions/INDC/Published%20Documents/India/1/INDIA%20INDC%20TO%20UNFCCC.pdf as viewed on 25 August, 2016

110 ibid

111 ibid

112 ibid

B. Beyond coal

In mid-January 2017, there were headlines in all the major newspapers that India does need new coal power plants till 2027. These articles were based on the Draft National Electricity Plan (Volume I) – Generation. The basis for this projection by CEA is less than the anticipated growth in demand for electricity and over-installation of coal based power plants in the last five years.

1. Projecting demand

Electric Power Survey (EPS) is conducted every five years to forecast state-/Union Territory-wise, region-wise and all-India, electricity demand on short-, medium- and long-term basis. The 19th EPS is under progress and its results are expected soon.

Over the past few years, the gap has widened between the demand projection by EPS and the actual demand (see *Table 6.2: 17th EPS Forecast vs. Actual Demand*). For instance, the 17th EPS, published in 2007, had projected energy demand of 1,258 billion units (BU) and peak load demand of 184 GW in 2015-16. However, the actual energy requirement was 1,114 BU (11.4% lower than forecast) and actual peak demand was 153 GW (16.6% lower than forecast). The same forecasting deviation occurred with the 18th EPS also.

Table 6.2: 17th EPS Forecast vs. Actual Demand

17th EPS forecast was significantly higher than actual demand

Year	Energy demand forecasted (BU)	Actual Energy requirement (BU)	Difference in energy forecast vs. actual requirement (%)	Peak energy load demand forecasted (GW)	Actual peak energy load demand (GW)	Difference in peak load forecast vs. actual peak load (%)
2013-14	1085	1002	7.6	156	136	13.0
2014-15	1168	1069	8.5	169	148	12.6
2015-16	1258	1114	11.4	184	153	16.6

Source: 17th EPS & Monthly performance reports of Central Electricity Authority

The 18th EPS, published in 2011, made medium-term projections till 2021-22 and long-term projection for 2026-27. Its projection for 2021-22 is significantly higher than the projections of the Draft National Electricity Plan – Generation, published in 2016 (see *Table 6.3: 18th EPS vs. Draft National Electricity Plan*). The 18th EPS, for instance, has projected energy demand of 1,905 BU and peak load demand of 283 GW in 2021-22. The Draft National Electricity Plan in comparison has projected the energy requirement of 1,611 BU (15.4% lower) and peak demand of 235 GW (17% lower). Similarly, the Draft National Electricity Plan projected peak demand of 317 GW and energy requirement of 2,131 BU at the end of 2026-27, around 20.7 per cent and 21.3 per cent lower than the corresponding projections by the 18th EPS report.

Table 6.3: 18th EPS vs. Draft National Electricity Plan

Demand forecast by 18th EPS and Draft National Electricity Plan varies significantly

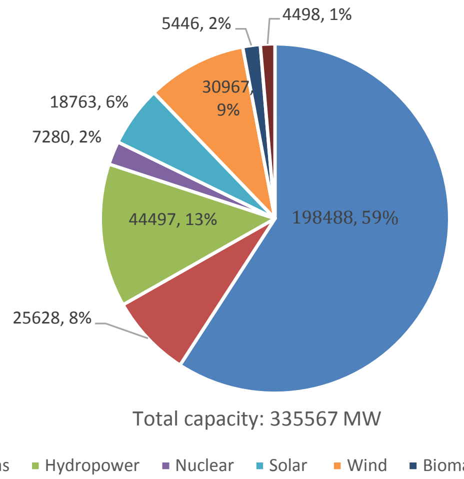
Year	Energy demand forecasted by 18th EPS (BU)	Energy demand forecasted by Draft National Electricity Plan (BU)	Difference in energy forecast between 18th EPS and Draft National Electricity Plan (%)	Peak energy load demand forecasted by 18th EPS (GW)	Peak energy load demand forecasted by Draft National Electricity Plan (GW)	Difference in Peak energy load between 18th EPS and Draft National Electricity Plan (%)
2021-22	1905	1611	15.4	283	235	17
2026-27	2710	2132	21.3	397	318	20.7

Source: 18th EPS & Draft National Electricity Plan (Volume I) – Generation, Central Electricity Authority

The implications of higher demand forecast by the 17th EPS and 18th EPS has been that during the 12th Plan (2012-17), capacity addition of 1,01,645 MW is expected to be commissioned against a target of 88,537 MW from conventional sources (comprising fossil fuels, hydropower and nuclear). It is for the first time in the history of the Indian power sector that such a large capacity addition during a single plan period will be achieved, which is likely to be about 115 per cent of the target (see *Figure 6.5: Projected Installed Capacity of the Power Sector, as of 31.3.2017*). In addition, 34,775 MW of renewable energy is also projected to be installed during 2012-17. At the end of 2016-17, therefore, India is projected to have 335 GW of installed capacity.

Figure 6.5: Projected Installed Capacity of the Power Sector, as of 31.3.2017

Installed capacity of the power sector is projected to reach 335 GW by the end of 2016-17



Source: Draft National Electricity Plan (Volume I) – Generation, Central Electricity Authority, 2016

The peak demand in 2016-17 is projected to be just 160 GW[113] against a 335 GW installed capacity. Consequently, the coal-based power sector is projected to operate at a plant load factor (PLF) of 60 per cent[114], which is likely to go down further.

2. Meeting electricity requirement for 2021-22 and beyond

According to the Draft National Electricity Plan – Generation, the projected electricity requirement and peak demand for the entire country for 2021-22 is 1,611 BU and 235 GW, respectively. For 2026-27, the projected electricity requirement is 2,132 BU and the projected peak demand is 318 GW (see *Table 6.4: All-India Electricity and Peak Load Demand Forecasted*). These projected demands do not include the reduction in demand on account of rooftop solar plants[115]. India has set a target to install 40 GW of rooftop solar plants by 2021-2022. But with rooftop solar reaching grid parity in almost all sectors, these numbers are likely to be surpassed. With installation of more rooftop solar plants, both electricity demand and peak demand are likely to reduce further than projected by the Draft National Electricity Plan.

Table 6.4: All-India Electricity and Peak Load Demand Forecasted

Peak demand in 2026-27 will be about 320 GW, double of current peak demand

Year	Electricity requirement (BU)	Peak load demand (GW)
2021-22	1,611	235
2026-27	2,132	318

Source: Draft National Electricity Plan (Volume I) – Generation, Central Electricity Authority, 2016

113 Ministry of Power, http://powermin.nic.in/content/overview, as viewed on 17 January, 2016
114 ibid
115 Draft National Electricity Plan (Volume I) – Generation, Central Electricity Authority, 2016

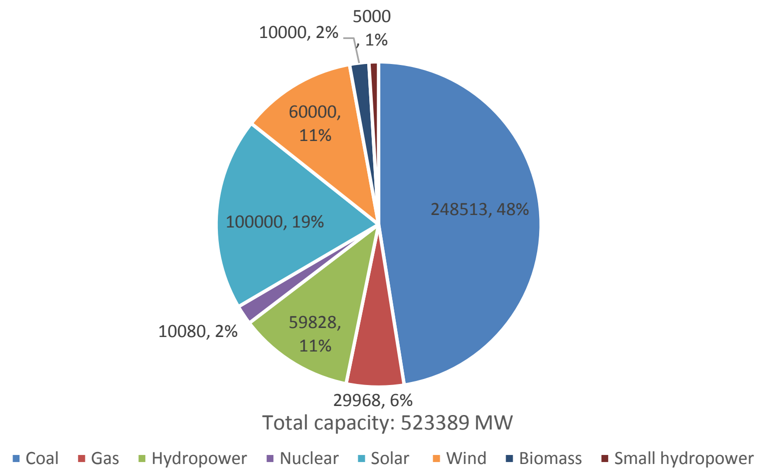
Now, let us consider the new power plants being installed or targeted to be installed in the coming years.

- During 2017-22, about 50 GW worth of new coal based power is likely to be commissioned. At present, these power plants are at various stages of construction.
- By March 2022, 2,800 MW of nuclear reactors will be commissioned and by March 2027 another 4,800 MW is likely to come on stream. So, 7,600 MW capacity nuclear reactors are at various stages of development currently.
- About 15 GW of hydropower plants are at various stages of development and are likely to come on stream by 2021-22.
- About 4 GW of gas-based power plants are at different stages of development and are likely to be commissioned by 2022.
- India has set a target to install 175 GW of renewable energy by 2021-22.

If all the above-mentioned plants are commissioned, then the projected installed capacity by March 2022 is likely to be 523 GW (see *Figure 6.6: Projected Installed Capacity of the Power Sector, as of 31.3.2022*).

Figure 6.6: Projected Installed Capacity of the Power Sector, as of 31.3.2022

Installed capacity of the power sector is projected to reach 523 GW by the end of 2021-22



Source: Draft National Electricity Plan (Volume I) – Generation, Central Electricity Authority, 2016

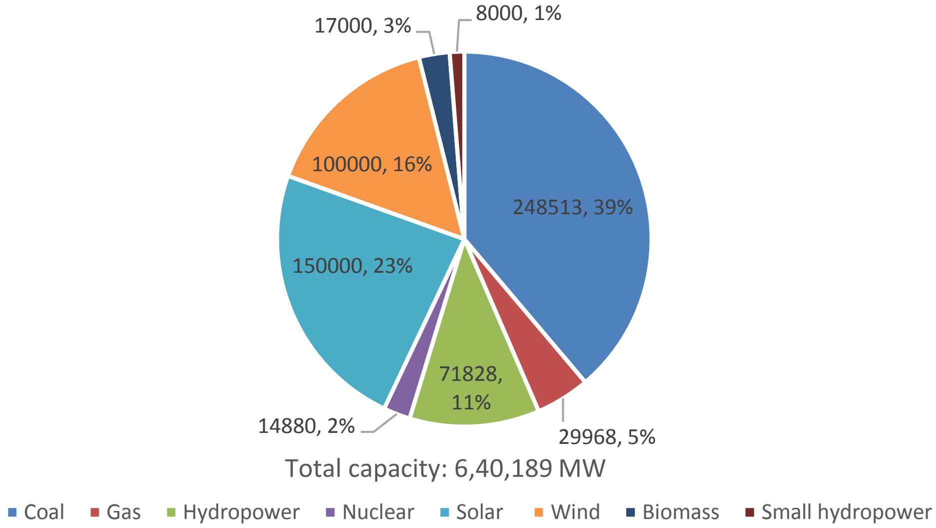
The projected capacity mentioned above are more than enough to meet the electricity requirement and peak load requirement for 2021-22. The PLF of coal-based power plants is likely to dip further to about 53 per cent in 2021-22. CEA's modelling studies show that even if only 125 GW of renewable energy is installed by 2022, the PLF of coal-based power plants will barely reach 60 per cent. In other words, India will have far more installed capacity than actual electricity demand by 2021-22. But what will happen in 2026-27? Will India meet its electricity demand in 2026-27 with whatever capacity it has in 2021-22? CEA has done a detailed modelling study on this too.

3. Meeting demand in 2026-27

According to CEA's projections, the momentum in the renewable energy sector will lead to an addition of another 100 GW renewable power capacity between 2021-22 and 2026-27. CEA also projects installation of 12 GW hydropower capacity during 2022-2027 (see *Figure 6.7: Projected Installed Capacity of the Power Sector, as of 31.3.2027*). In addition, 4.8 GW capacity nuclear plants are likely to be commissioned by 2026-27. CEA's modelling shows that if these capacities come on stream, India will not need to install any coal or gas based power plants during 2022-2027. The coal capacity existing in 2021-22 would be more than sufficient to meet energy and peak load demand in 2026-27. In fact, the PLF of coal-based power plants in 2026-27 will remain below 60 per cent.

Figure 6.7: Projected Installed Capacity of the Power Sector, as of 31.3.2027

No new coal-based power plant is required between 2022 and 2027

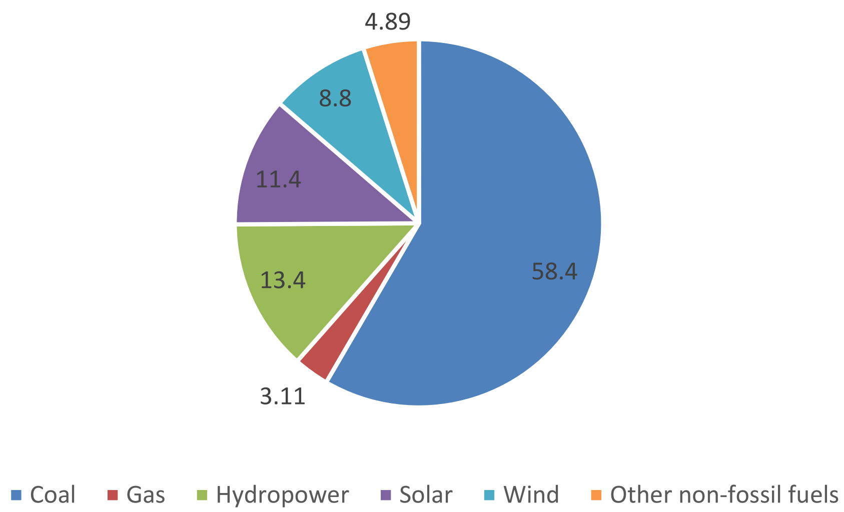


Source: Draft National Electricity Plan (Volume I) – Generation, Central Electricity Authority, 2016

In 2026-27, 58 per cent of the electricity will be generated from coal and lignite based power plants (see *Figure 6.8: Projected Electricity Generation from Various Sources in 2026-27*). The remaining will come from non-fossil fuels; about 20 per cent of the generation will come from solar and wind plants. This will be a wholly new world for the electricity sector in India.

Figure 6.8: Projected Electricity Generation from Various Sources in 2026-27

More than 40% of electricity is projected to be generated from non-fossil fuels



Source: Estimation based on data from Draft National Electricity Plan (Volume I) – Generation, Central Electricity Authority, 2016

4. The electricity sector in 2026-27

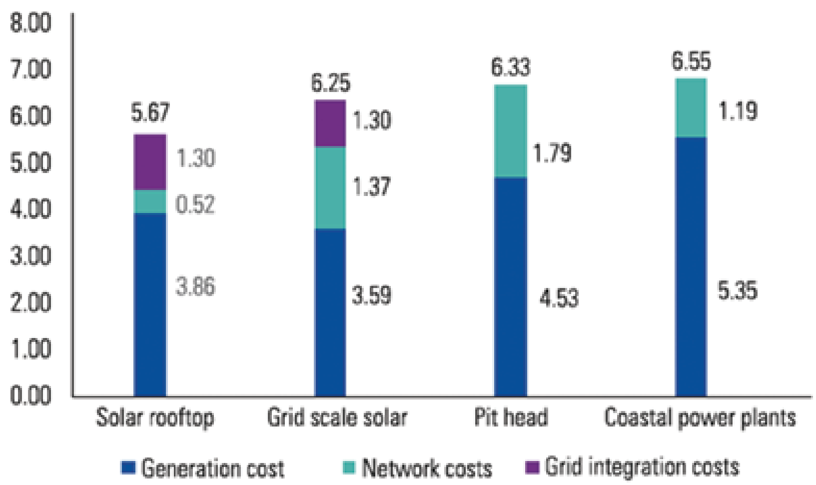
A renewable energy world

The world of 2026-27 will belong to renewable energy. India will have more solar and wind power capacity (250 GW) than coal-power capacity (248 GW) by then. During the period 2017-2027, for every 1 MW of coal capacity addition, India is projected to install at least 4 MW of solar and wind power capacity. By 2026-27, wind and solar power industries will dominate the energy sector and not coal based power.

In such a world, the cheapest source of electricity for a consumer in India will be solar and wind power (see *Figure 6.9: Levelised Cost of Power in 2025*). Solar rooftop is projected to have the lowest levelled cost of electricity.

Figure 6.9: Levelised Cost of Power in 2025

Solar rooftop is likely to be the cheapest source of power by 2025



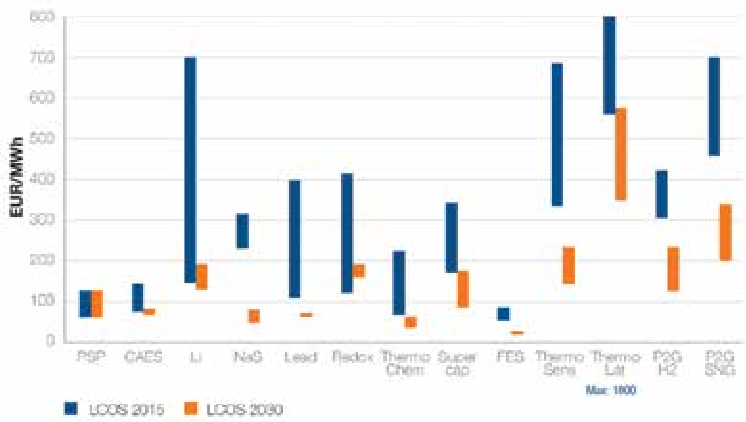
Source: The Rising Sun: Disruption on the Horizon, KPMG, November, 2015

Electricity storage becomes a viable alternative

By 2026-27, the cost of electricity storage for all applications – utility-scale, household level or distributed applications – would become cost competitive. By 2030, that battery technology becomes especially more competitive, with sodium sulphur (NaS), lead acid and lithium-ion technologies leading the way[116] (see *Figure 6.10: Levelised Cost of Electricity Storage for 2015 and 2030*).

Figure 6.10: Levelised Cost of Electricity Storage for 2015 and 2030

By 2030, the cost of electricity storage can be expected reach Rs 3-4/kWh



Source: E-storage: Shifting from cost to value, Wind and solar applications 2016 World Energy Council, 2016

Notes:

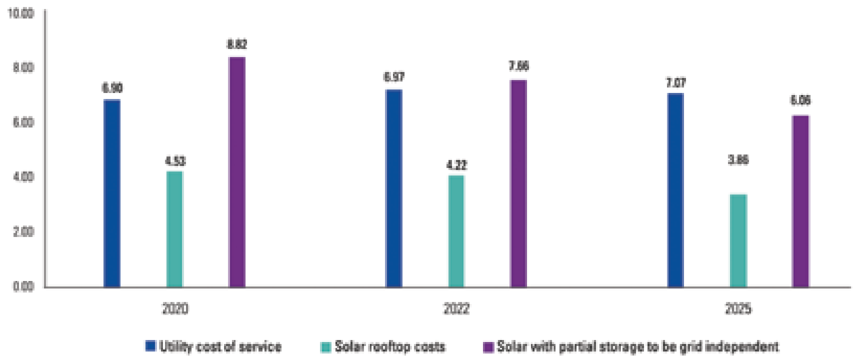
- 1 Euro = Rs. 72
- PSP: Pump hydropower storage; CAES: Compressed Air Energy Storage; Li: Lithium ion battery; NAS: Sodium Sulphur battery; Lead: Lead Acid Battery; Redox: Redox flow battery; Thermo chem: Thermo-chemical storage; Super cap: Super capacitors; FES: Flywheel Energy storage; P2G: Power to Gas

116 Source: E-storage: Shifting from cost to value, Wind and solar applications 2016 World Energy Council, 2016

By 2025 a grid-independent solar house is likely to become reality (see *Figure 6.11: Cost of Solar Rooftop with Storage vs. Utility Cost of Service*). Therefore, large numbers of rich domestic consumers plus commercial and industrial would get part or all of their requirements from captive solar and wind power.

Figure 6.11: Cost of Solar Rooftop with Storage vs. Utility Cost of Service

By 2025, grid-independent solar house will become reality



Source: The Rising Sun: Disruption on the Horizon, KPMG, November, 2015

Setting up new coal based power plant would become unviable

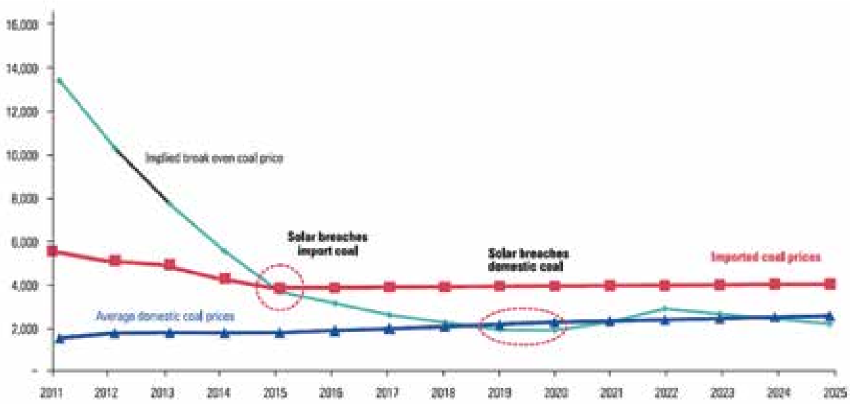
There will be two factors that will influence setting up of new coal based power plants post 2026-27. One, the reducing cost competitiveness of coal power plants vis-à-vis renewable energy projects, and two, more than sufficient installed capacity of coal-based power plants.

Decreasing competitiveness of coal based power

By 2025, the falling cost of solar power along with energy storage technologies will put immense pressure on the coal based power sector. Today, solar energy prices are chasing the price of coal power. By 2020, it will be the coal power plants that will try to compete with solar power plants (see *Figure 6.12: Implied Break-even Coal Price*). The implied break-even coal price (the price of coal that leads to same power tariff as solar power) from 2020 onwards will start chasing solar prices.

Figure 6.12: Implied Break-even Coal Price

By 2020, coal prices will start chasing the solar prices



Source: The Rising Sun: Disruption on the Horizon, KPMG, November 2015

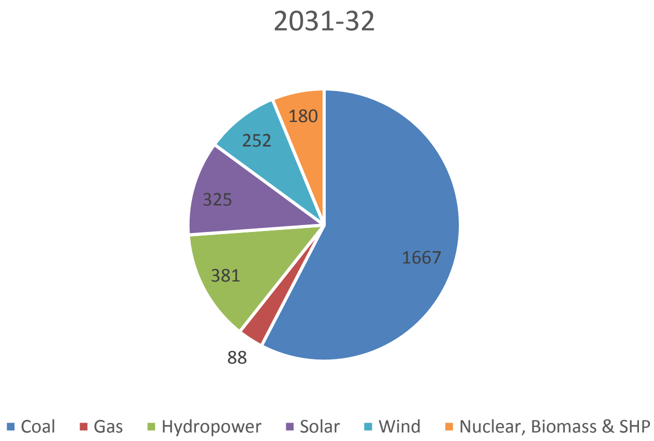
Over capacity of coal power plants

The authors of this report have tried to project the electricity requirement in India in 2031-32 and the amount of coal power capacity needed to meet this demand.

The Draft Electricity Plan – Generation, has projected a cumulative annual growth rate (CAGR) 0f 6.3 per cent in electricity demand in India between 2015-16 and 2021-22. Between 2021-22 and 2026-27, the CAGR in electricity demand is projected to be 5.8%.[117] Even if we assume 6 per cent CAGR in electricity demand and peak load demand between 2026-27 and 2031-32, then the total electricity demand in India will be about 2,853 BU. The peak load demand in 2031-32 will be 426 GW. If we assume that the proportion of electricity produced from various sources in 2026-27 remains the same in 2031-32, then the electricity generation in 2031-32 will be as given below (see *Figure 6.13: Projected Generation of Electricity from Various Sources in 2031-32*).

Figure 6.13: Projected Generation of Electricity from Various Sources in 2031-32

In 2031-32, 1,667 Billion Units of electricity need be generated from coal

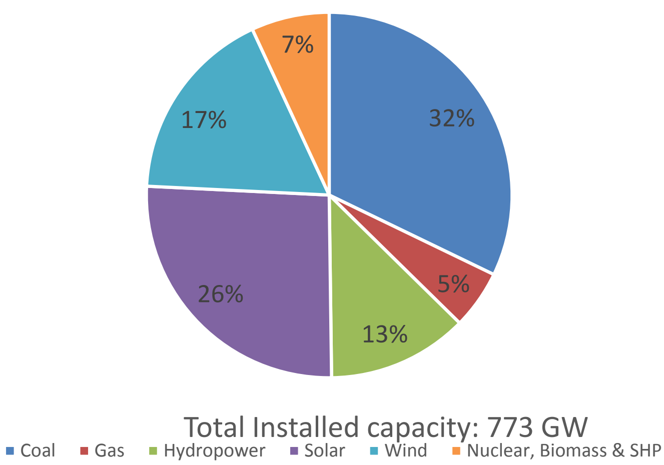


Source: Estimated by authors

As we can see, to meet the projected demand of 2031-32, 1,667 BU of electricity will have to be generated from coal based power plants; 1,667 BU power can be produced from 248 GW coal power plant capacity at a PLF of 77 per cent (see *Figure 6.15: Projected PLF of Coal-based Power Plants till 2031-32*). So the coal capacity existing in 2021-22 would still be sufficient to meet the electricity demand of 2031-32. The projected installed capacity in 2031-32 is given below (see *Figure 6.14: Projected Installed Capacity in 2031-32*).

Figure 6.14: Projected Installed Capacity in 2031-32

Installed capacity of coal will constitute only 32% of the total installed capacity of the power sector

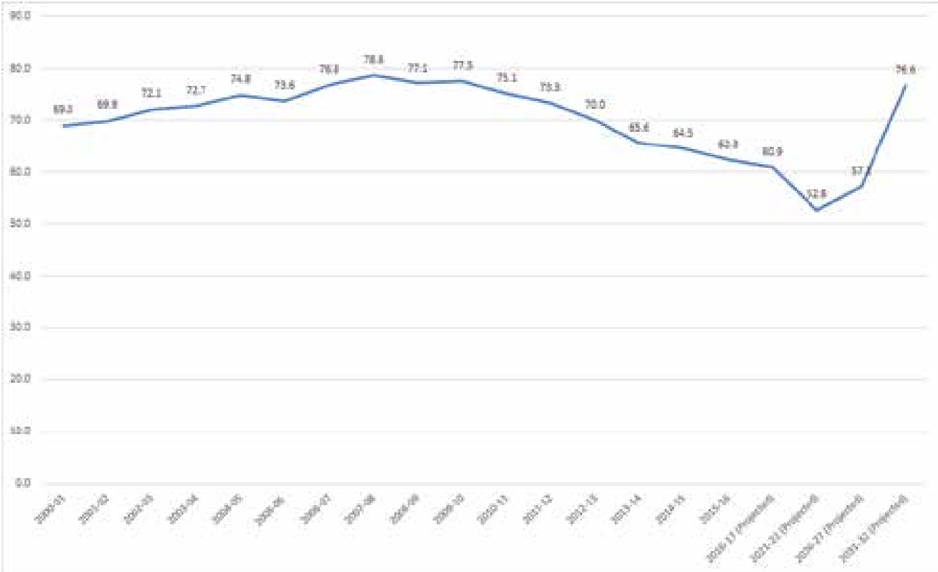


Source: Estimated by authors

117 Draft National Electricity Plan (Volume I) – Generation, Central Electricity Authority, 2016

Figure 6.15: Projected PLF of Coal-based Power Plants till 2031-32

Even in 2031-32, PLF will be less than 80%



Source: Draft National Electricity Plan (Volume I) – Generation, Central Electricity Authority, 2016. For 2031-32, estimation was done by the authors

Let us do a recap of the trajectory of power sector in India from 2016-17 to 2031-32 (see *Table 6.5: Projected Installed Capacity from Various Sources over Next 15 Years*).

- The proportion of coal in installed capacity reduces from 59 per cent in 2016-17 to 32 per cent in 2031-32
- The installed capacity of coal power sector remains the same from 2021-22 to 2031-32 at 248 GW. That is, India will not have to install new coal power plants between 2021-22 and 2031-32
- From 2020 onwards, coal prices will start chasing solar prices and not the other way round, as is the case today.
- By 2025, rooftop solar with battery storage will be cheaper than grid power making off-grid houses possible
- Between 2016-17 and 2031-32, for every 1 MW of coal power plant installation, 4.5 MW of solar and wind capacity will be installed
- Between 2016-17 and 2031-32, 85 per cent of all the new power plants installed in India will be from non-fossil fuels
- By 2032, electricity storage technology will advance significantly. The price of large energy storage systems like compressed air energy storage and smaller energy storage systems like batteries (lithium, sodium or lead) will reduce significantly. Estimates show that the cost of batteries could go down to Rs3/kWh. At this price, solar rooftop with battery storage would be the cheapest energy source for a large number of consumers.
- Cheap electricity storage technology would mean that it would become techno-economically viable to make storage act as both a base-load plant as well as a peaking plant.
- In 2032, it would be expensive to set up new coal power plant compared to a new solar and wind plant coupled with storage.
- Therefore, it is quite possible that India will not need any new coal based power plants even post 2032. In fact, India can think about phasing-out coal by 2050.

Table 6.5: Projected Installed Capacity from Various Sources over Next 15 Years

India will not have to install new coal power plant post 2021-22

Installed capacity (in MW)	2016-17	2021-22	2026-27	2031-32
Coal	198488 (59%)	248513 (47%)	248513 (39%)	248513 (32%)
Gas & Diesel	25628 (8%)	29968 (6%)	29968 (5%)	40104 (5%)
Hydropower	44497 (13%)	59828 (11%)	71828 (11%)	96122 (12%)
Nuclear	7280 (2%)	10080 (2%)	14880 (2%)	19913 (3%)
Solar	18763 (6%)	100000 (19%)	150000 (23%)	200734 (26%)
Wind	30967 (9%)	60000 (11%)	100000 (16%)	133823 (17%)
Biomass	5446 (2%)	10000 (2%)	17000 (3%)	22750 (3%)
Small hydropower	4498 (1%)	5000 (1%)	8000 (1%)	10706 (1%)
Total installed capacity	335567	523389	640189	772664

Source: Draft National Electricity Plan (Volume I) – Generation, Central Electricity Authority, 2016. For 2031-32, estimation was done by the authors

Note: Figures in parenthesis is the percentage of total installed capacity

5. Phasing out coal: Is it possible?

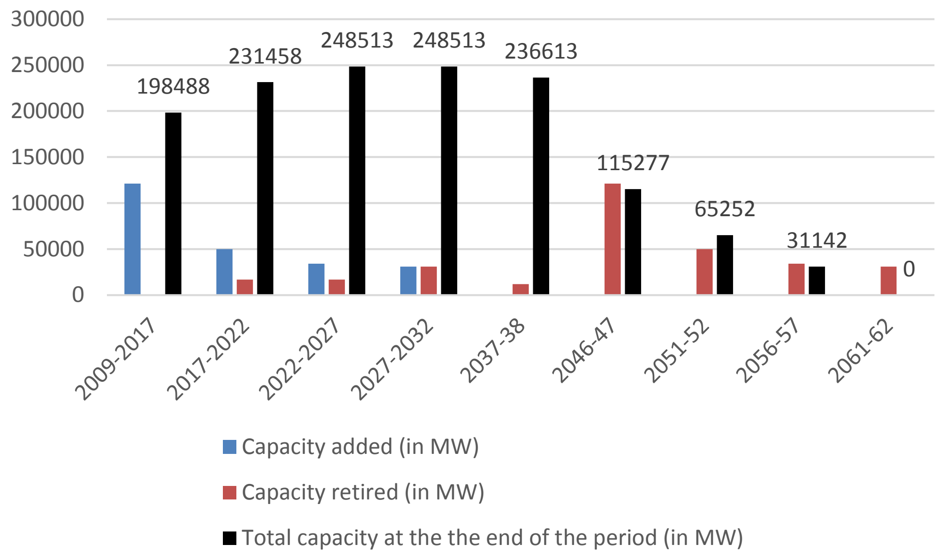
As we have seen above, India will not need to set up new coal power plant even after 2031-32 as electricity storage can act as both base-load and peak load plants. We are, therefore, looking at peaking of coal consumption for thermal power plants in India by 2031-32 (see: *Figure 6.16: Possible Phase-out Schedule of Coal-based Power Plants in India*).

If we assume coal consumption of 0.65 kg/kWh[118], then in 2031-32 India will consume about 1.1 billion tonnes of coal in the power sector. So, India's coal consumption for power can peak at 1.1 billion tonnes by 2031-32.

If we assume the life of coal-based power plants to be 30 years, then by 2061-62, India can retire its last coal power plants. However, this can be expedited if India can be compensated for retiring these plants ahead of their retirement age.

Figure 6.16: Possible Phase-out Schedule of Coal-based Power Plants in India

The last coal power plants in India can be shut by 2061-62



118 ibid

6. The new brave world

We are staring at a new brave world of renewable energy. For the first time since the climate change negotiations started in 1992, there is a marked shift that has the potential to decarbonise the energy sector. As this report has shown, the peaking of coal consumption in the power sector in India could become real in 2030s. The last coal based power plants can be shut by 2060s. Unlike the past prediction of coal consumption in excess of 2.0 billion tonnes, India's coal consumption is likely to peak at much lower level of 1.1 billion tonnes. In the 2030s, most of the installed capacity of the power sector will come from non-fossil fuels. If this shift takes place, what will happen to the grid and DISCOMs? Let us encapsulate what we have learnt in the previous chapters:

- It is clear that in the next couple of years, solar rooftops with storage and open access consumers will start eating into the market of existing DISCOMs. Most lucrative consumers will slowly start to move out of DISCOMs as renewable energy with storages becomes cheaper. DISCOMs are likely to resist this shift.
- Once the rich consumers start to move out of DISCOMs, the financial performance of the distribution companies is likely to deteriorate. In fact, even with schemes like UDAY, the operational and financial position of DISCOMs is not likely to improve significantly simply because they are just too deep in debt. In fact, most DISCOMs are bankrupt and manage to stay afloat with government support.
- The only way to deal with this, as has been done in many developed countries, is to unbundle the distribution sector. That is, the distribution operation and the supplier of electricity must be clearly separated. DISCOMs can be dissolved, with all their liabilities taken over by the state and the central governments.
- The job of the Distribution Network Operator (DNO) would be to plan, maintain and operate the distribution network. The supplier of electricity will pay the DNOs for the use of the infrastructure. In this arrangement, the consumers will have the choice to buy electricity from whosoever they wish.
- Smart grid will become common and the distribution network will become bi-directional with solar rooftops feeding the electricity to the distribution grids. Virtual power companies would emerge that will collect power generated from individual rooftops and renewable power plants and sell to other consumers. They will have no asset of their own.
- Energy storage companies will emerge who will install big utility-scale electricity storage devices and provide electricity to the grid for balancing, peaking and even base-load requirement.
- The energy efficiency market will also become big with Energy Efficiency Service Companies selling efficiency products to consumers.
- Time-of-day tariff will become the norm.
- Availability based tariff will become the norm for all generators.
- What will happen to the poor? If the rich move out, who will cross-subsidise the poor? The answer is that the rich will cross-subsidise the operations of the grid and the distribution network. As they will use these infrastructure, they should be charged higher to cross-subsidise the poor. As far as electricity is concerned, the government can provide direct subsidy to consumers to provide for their minimum electricity need.
- This is the only way India can decarbonise the electricity sector and provide energy access to all.

Heinrich Böll Stiftung
C-20, First Floor, Qutub Institutional Area, New Delhi – 110016, India
Tel: +91 11 2685 4405, 2651 6695, **E:** in-info@in.boell.org, **Website:** www.in.boell.org