Indian power sector: Key imperatives for transformation

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Table of contents

Messages from ASSOCHAM

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Energy is central to our needs across the globe, and the balance among haves and have-nots, availability of clean economical energy for all, energy efficiency and innovation demand urgent attention. There is also a need to ensure the long-term sustainability, security, affordability and inclusiveness of energy systems. The energy transition involves public–private collaboration, intra-state and inter-state partnership. Needless to say, achieving these goals requires supporting policies, technological innovation, large volumes of investment and a platform that encourages multi-stakeholder collaboration. Leaders across the world understand that the challenges faced by the energy system cannot be addressed by a single entity. Rather, a common understanding is required among all stakeholders on the long-term vision for energy transition and the near-term priorities.

For a sector influenced by several global factors and other issues, it is interesting to note that energy systems across countries are unique to local circumstances, economic structure and socioeconomic priorities, and thus, multiple pathways are required to pursue an effective energy system that is local as well as global in its impact.

Over the past few years, considering the cycle of economic development and growth, energy security and access, and environmental sustainability, governments of developed or developing nations are committing themselves to greater cooperation.

India is a large nation with its own unique challenges and a varied sense of responsibility among its corporates and citizens when it comes to energy production, consumption, saving, greening of the environment, etc. A holistic approach that engages all partners and has clearly defined short, mid-and long-term priorities and goals is essential.

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Director, East and North East
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Amidst ongoing cooperation among industry, states, governments and international players, it is essential to work towards a roadmap for sustainable energy solutions that are able to meet the growing demands of the world's population.

This certainly calls for future collaboration between energy stakeholders, especially for a growing country like India, as India's energy requirements are enormous. At the same time, demand is growing but our resources are limited, both in physical and financial terms. It is therefore imperative that these resources be exploited optimally and that efforts be made to flexibilise thermal power plants, renewable energy, demand-side energy efficiency and green energy corridors.

For growing economies, it's important to look at the issue of energy transition in the context of the global development challenges and climate change. Thus, policymakers need to bring in the element of power innovation for prosperity and introduce catalysts for entrepreneurial ecosystems for climate innovation in developing countries.

Collaboration among the stakeholders in the domain of operations, research, financing, integration of various forms of energy, and upskilling of resources is essential. The sector has immense potential, poses unique challenges and thus calls for unique solutions that engage governments and the industry.

01 Introduction

The Indian power sector has been a key driver for the country's socioeconomic growth since independence.

With a customer base of more than 200 million[1] and service outreach spanning of nearly 3.28 million sq. km,[2] the Indian power system is one of the largest and most complex power systems in the world. Currently, the system operates as a 'one nation-one frequency-one market' after the creation of the national grid post the integration of the five regional grids.

In recent years, substantial growth in installed generation capacity and transmission and distribution infrastructure, coupled with various government initiatives, has led to a reduction in energy and peak shortages (2% peak deficit in 2017–18 as against a 10% deficit in 2010–11) and surplus generation capacity.

The key features of the system are presented below:[3]

364 GW
Installed capacity

184 GW
Peak demand

1267 BU
Energy demand

2%
Peak shortage

0.8%
Energy shortage

~24%
Aggregate technical and commercial (AT&C) losses

1,122 kWh
Per capita power consumption

340,000 circuit (ckt) km
Transmission network

A focus on clean and sustainable power generation sources has been driving power sector transformation over the last few years.

In 2015–16, the Government of India released a roadmap to achieve 175 GW of renewable energy (RE) capacity by 2022, which is one of the key actions to meet its commitments towards COP21 obligations. This roadmap also underlines its pledge to grow as a low carbon emitter. A snapshot of the RE target is provided below:[4]

Solar power		Wind power		Bio power		Small hydro		Total
100 GW	+	60 GW	+	10 GW	+	5 MW	=	175 GW

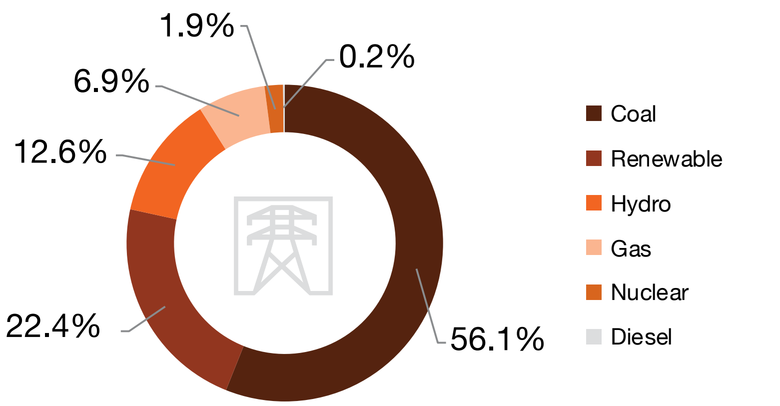
GoI commitment: Towards a greener and cleaner future
India's intended nationally determined contribution (INDC) commitments aim to reduce emissions intensity of GDP by 33–35% by 2030 from the 2005 level and to achieve 40% of installed capacity from non-fossil fuel by 2030.

1 http://indianpowersector.com
2 http://censusindia.gov.in
3 www.cea.nic.in
4 https://www4.unfccc.int

As a result, over the last decade, while the installed power generation capacity has experienced significant growth (at a CAGR of 9.3%), capacity addition through RE sources has exhibited a remarkable CAGR of 19% since FY 2006–07. The contribution of RE sources to the installed capacity has increased from 6% in 2006–07 to 22% in 2018–19.[5]

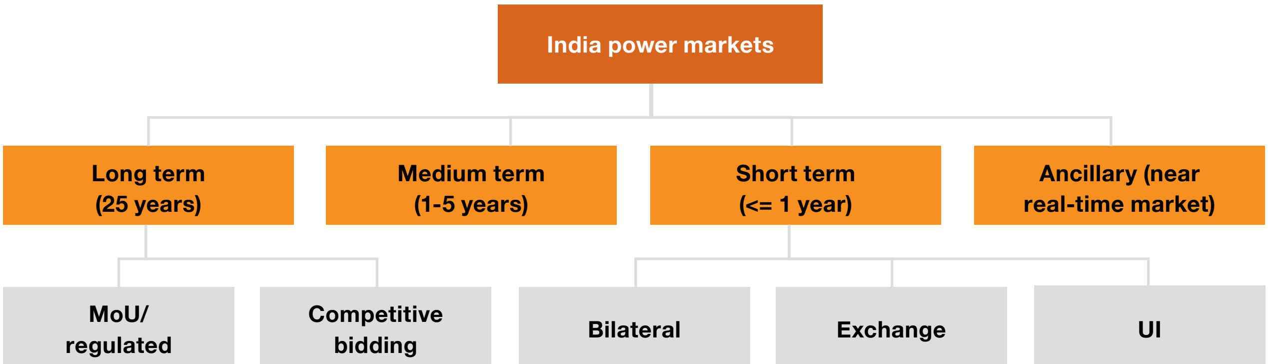
The focus on clean technologies has also led to the need for structural changes in the policy and regulatory landscape and in market design and instruments.

Installed generation (GW)



The Indian power market has also been evolving, with the share of short-term transactions increasing steadily.[6]

Bulk electric power supply in India is mainly contracted through long-term arrangements (around 25 years) and the rest in medium-term contracts (up to 5 years) and short-term contracts (up to 1 year). Power distribution utilities with an obligation to provide electricity to their consumers mainly rely on long-term/medium-term contracts for supplies, which accounts for around 89% of the total power market volumes.



Nevertheless, to meet the short-term requirements of the market participants, short-term power trading plays an important role and ensures optimum utilisation of power resources in different regions. The volume of short-term transaction electricity has increased from 9% of total energy generation in 2009–10 to 11% in 2017–18. During 2009–10 to 2017–18, the volume of short-term transactions of electricity increased at a higher rate (9%) compared with the gross electricity generation (6%).

However, it has now become essential to deepen the short-term markets by diversifying options. With greater liquidity and adequate supply on account of new capacity addition, it is essential to serve consumer needs up to desired standards of supply. Key measures include:

- introduction of forwards and future contracts on the exchange to ensure transparency in price discovery and more liquidity
- introduction of capacity markets to incentivise peaking generation
- strengthening of ancillary services and trading of transmission rights to alleviate grid frequency issues and bottlenecks due to transmission barriers and renewable integration into the grid.

5 www.cea.nic.in
6 https://www.iexindia.com, PwC analysis

Successful implementation of several government initiatives is likely to shape the sector transformation landscape and ensure India's energy security.

The year 2022 is expected to be an inflection point in India's energy and electricity sector with policies aligned to provide citizens 24x7 power. Enablers and policy trends, both on the demand and supply side, which are in implementation mode for the transition towards this energy future are:

IEA forecasts for India's electricity requirements:

As per IEA's India's Energy Outlook, 2015, India will need 436 GW and 746 GW of installed capacity by FY20 and FY30 respectively to meet its electricity requirements.

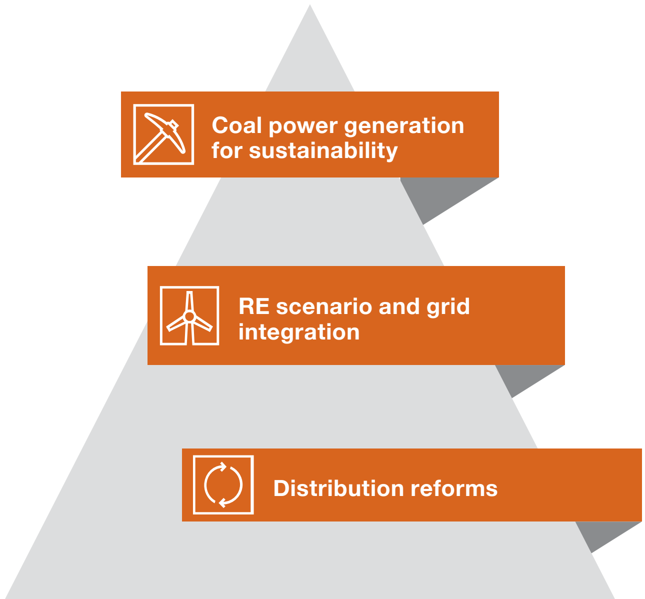
- **Power for All (PFA) initiative:** The PFA initiative along with other implementation initiatives across various states aims to ensure 24x7 electricity access to all consumers, excluding agriculture, by 2022. It would be a key driver for increasing power demand.
- **High-volume transport and electric vehicle (EV) integration:** The master plan for most Indian cities targets 60–80% of public transport ridership by 2025–30 mainly through metro rails. Additionally, the government's 'National Electric Mobility Mission Plan' aims at 100%adoption of EVs by 2030. The Indian Railways also plans to introduce 16,000 km of new lines, besides the doubling the existing lines of 6,900 km. This would be a key demand driver in the next decade.
- **Make in India:** This initiative, which aims to boost manufacturing's share of GDP from 16% to 25% percent by 2022, would also lead to substantial growth in electricity demand.
- **Reduction of aggregate technical and commercial (AT&C) losses:** Programs for reduction of AT&C losses like Ujwal DISCOM Assurance Yojana (UDAY), Integrated Power Development Scheme (IPDS) and Deendayal Upadhyaya Gram Jyoti Yojana (DDUGJY) have been implemented by the Government. The target is to reduce AT&C losses to about 13% by the year 2021–22 on an all-India basis, which would lead to reduction in electricity demand.
- **Demand-side management (DSM), energy conservation and efficiency improvement programmes:** Programmes for DSM, improvement of energy efficiency and energy conservation measures like standards and labelling, the Perform-Achieve-Trade (PAT) scheme in industries, energy-efficient lighting solutions and the Super-Efficient Equipment Programme would reduce power demand.

The current disruptions in the power sector are just the start of the transformation journey.

The following four areas are facing disruption, and it will be important for stakeholders (government, regulators, utilities, investors and development partners) to assess their strategy and implement the changes they need to make in time or, even better, ahead of time.

- customer behaviour necessitating a focus on quality energy access and technology interventions
- market evolution to support variable renewable energy resources
- structural changes to integrate different generation models and distribution channels
- wider stakeholder participation (with citizen-corporate-government connect) in policy decisions.

This paper aims to address key issues and concerns around the above areas by focusing on the three themes depicted alongside.

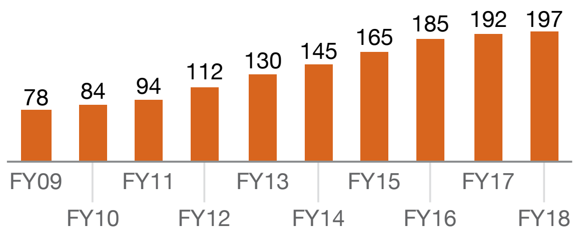


02 Coal power generation for sustainability

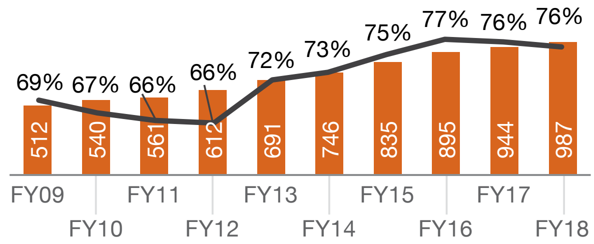
Challenges for coal power generation

India's largest source of electricity is coal. Out of the country's total installed generation capacity (349.2 GW), coal-based installed capacity accounts for 194.5 GW (~55%) as on 31 March 2019.[7] In terms of number of units of electricity generated, coal-fired plants generated close to 76% of the total electricity generated in FY18.

Installed coal-based electricity generation capacity from utilities (GW)



Gross generation of coal-based electricity from utilities (thousand GWh)

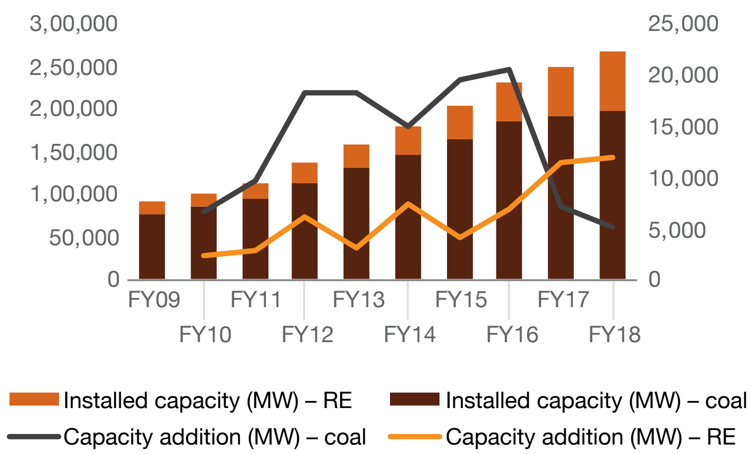


Source: CEA, Energy Statistics 2019, Ministry of Statistics and Programme Implementation

Influx of RE reducing dependence on thermal sources

The emergence of the RE sector as a significant player in the grid connected power generation capacity in recent years has been driven by an amalgamation of ambitious clean energy policies and rapidly declining prices for renewables. The National Electricity Plan (NEP) by the Central Electricity Authority (CEA) targets 275 GW of RE capacity by 2027, without requiring any new coal plants beyond those already under construction. India's coal-based power is thus facing increasing pressure due to enhanced penetration of low-cost renewables.

Renewable capacity additions displacing coal

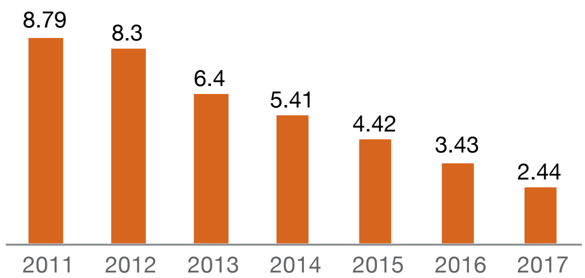


Source: CEA, Energy Statistics 2019, Ministry of Statistics and Programme Implementation

As of today, India's levellised RE costs are among the lowest in the world, and solar and wind technologies are economically competitive with coal. Between 2010 and 2017, the cost of renewables saw a massive decline, utility-scale solar cost reduced by 75% to less than USD 0.1 per kWh and onshore wind cost reduced by 16% to USD 0.04–0.05 per kWh on average. These costs are expected to further decline while prices of coal-fired generation are likely to rise in the years ahead. Additionally, in the same period, the lowest solar tariff bid declined fivefold to INR 2.44 (USD 0.035) per kWh.[8]

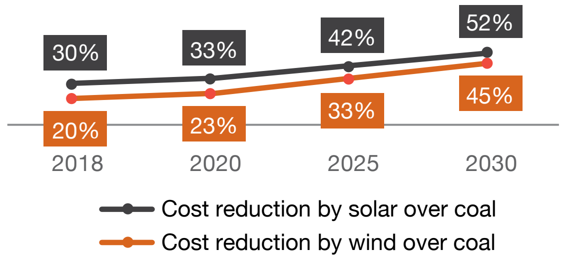
7 http://cea.nic.in/reports/monthly/executivesummary/2019/exe_summary-03.pdf
8 https://www.odi.org/sites/odi.org.uk/files/resource-documents/12407.pdf

Solar tariff (INR kWh)



Source: http://solarquarter.com/index.php/4273-solar-power-industry-in-india-trends-and-analysis

Cost reduction of renewable over coal



Source: Energetica India

Environmental concerns

According to India's Centre for Science and Environment (CSE) reports, coal is responsible for 80% of India's mercury pollution, 60% of airborne PM, 45% of SO_2 emissions, and 30% of NO levels.

One of the biggest challenges involved in the use of coal as a resource is environmental contamination.

- Coal combustion at thermal power plants emits mainly carbon dioxide (CO_2), sulphur oxides (SOx), nitrogen oxides (NOx), CFCs, other trace gases and airborne inorganic particulates such as fly ash and suspended particulate matter (SPM).
- The water runoff from coal washeries carries pollutants that contaminate groundwater, rivers and lakes, thus affecting aquatic flora and fauna.

Indian coal-fired power plants pose a major risk to the environment as well as to human health in comparison to the plans in other countries as Indian coal is of poorer quality and has a low calorific value (~15 MJ/kg) and very high ash content (25 to 45%). In addition, a majority of coal-fired plants are based on inefficient and outdated subcritical technology, which tends to utilise more coal per MWh of electricity generated. The result is more emissions damaging the environment and deterioration of public health, animal life as well as plants.

Environmental and health risks posed by coal-based power plants

Air pollution	Water pollution	Noise pollution	Land degradation
Coal-fired power plants emit several pollutants into the air, including SOx, CO, NOx, suspended particulate matter, lead and non-methane hydrocarbons.	Water is used for washing coal, circulating in the boiler furnace to produce steam and cool equipment. Dust from coal-cleaned water contaminates groundwater. Hot water, if let out into water bodies without cooling, causes a rise in temperature and affects aquatic flora and fauna.	Power plants emit high levels of noise due to usage of equipment like boilers, turbines and crushers.	Disposal of larger quantities of fly ash from coal-based plants affects natural soil properties. Soil becomes more alkaline due to the alkaline nature of fly ash.

India's pollution norms need strengthening compared to those of other major economies, including China. Despite this, its power plants fail to comply with even the relaxed levels of performance, lacking the basic technologies to control pollution. Most of the coal-fired power plants in India are yet to retrofit their facilities with pollution control technologies. Before 2015, India had no standards for either SO2 or NOx. It was in December 2015 that the Ministry of Environment introduced, emission norms for thermal power stations, including emission and effluent discharge.

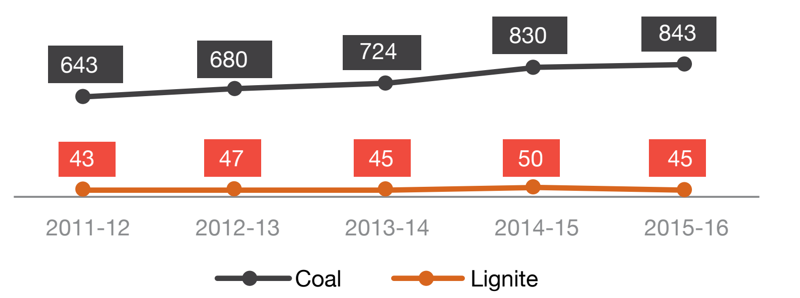
Fuel supply availability

According to the Energy and Resources Institute (TERI) report 'Transitions in the Indian electricity sector 2017-2030', electricity demand in India is likely to increase from 1,115 billion units (BU) in 2015–16 to 1,692 BU in 2022, to 2,509 BU in 2027, and to 3,175 BU in 2030.

In this context, it is important that with the improving power supply position and reliability of supply, consistent fuel supply must be ensured.[9]

- In 2015–16, the total availability of raw coal in India stood at 843 MT and raw lignite at around 46 MT.[10]
- During 2006–07 to 2015–16, the availability of coal has increased at a CAGR of about 5.7%.
- During 2006–07 to 2015–16, coal production has increased from 482 MT to 843 MT, increasing availability. The availability has also been supplemented by imports.
- During 2006–07 to 2015–16, the availability of lignite has increased at a CAGR of 3.7%.

Historical trends of coal and lignite availability in MT

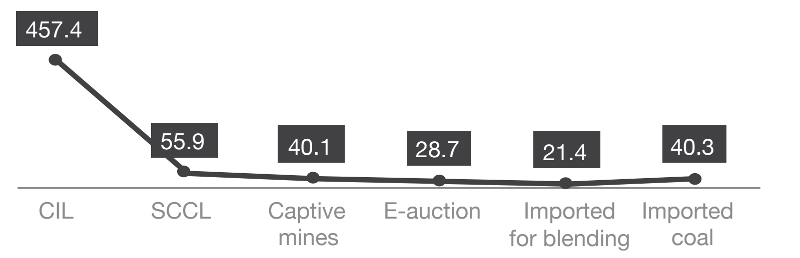


Source: Ministry of Power, Energy Statistics Report, 2017

Coal stock position for thermal power plants is monitored by the CEA on a daily basis for regular/smooth supply. As on 31 March 2019, the total coal stock position reported by power utilities was 31 MT and during 2018–19, total coal receipts were 644 MT.

Coal is imported to bridge the gap between requirement and availability from domestic sources.

Total coal supply during 2018–19 (MT)[11]



Source: Ministry of Power, Annual Report, 2018-19

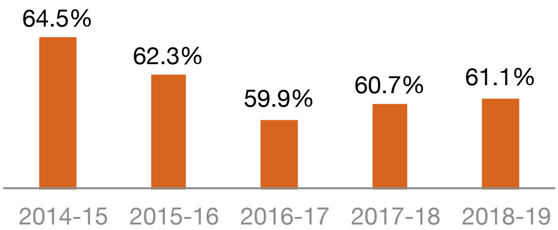
Low demand leading to stressed asset scenario

After the enactment of Electricity Act, 2003, there has been exponential addition to the generation capacity, leading to huge coal-based generation capacity addition during the 11th and 12th plan. India has marched ahead in the power sector, taking huge strides in generation, transmission and distribution. The per capita electricity consumption in India increased from 592 kWh during 2003–04 to 1,149 kWh during 2017–18.[12] Consequently, the gap between electricity demand and supply has reduced drastically in recent years.

Presently, there is enough generation capacity to meet the country's electricity demand. The peak electricity demand and supply gap is currently only 0.6%. However, huge capacity addition in recent years has raised concerns related to under-utilisation of coal-based capacities, leading to stressed assets in the sector. The plant load factor (PLF) of coal-based plants has reduced to 61.1% in 2018–19 from 78.6% during 2007–08.

9 https://www.teriin.org/files/transition-report/files/downloads/Transitions-in-Indian-Electricity-Sector_Report.pdf
10 http://www.mospi.nic.in/sites/default/files/publication_reports/Energy_Statistics_2017r.pdf.pdf
11 www.cea.nic.in
12 www.cea.nic.in

PLF in India (coal- and lignite-based generation)



Source: Ministry of Power

Sector-wise PLF in India (%)

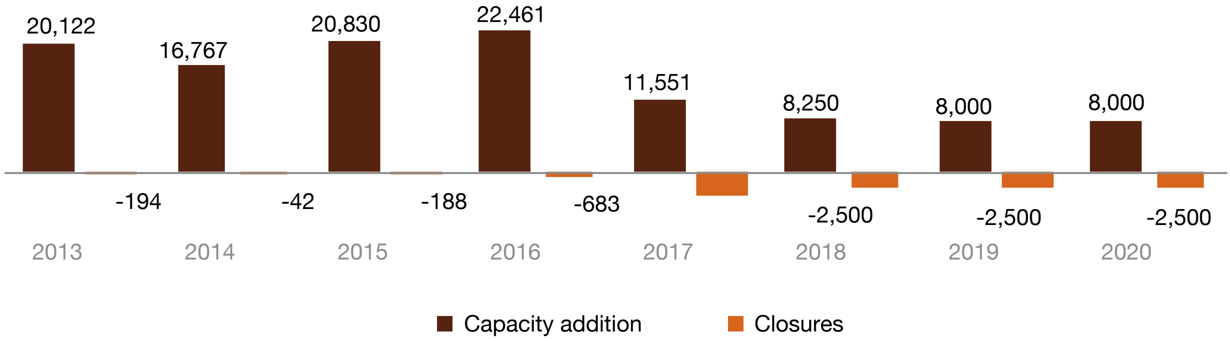
Year	Central	State	Private
2014-15	73.95	59.83	60.58
2015-16	72.52	55.41	60.49
2016-17	71.98	54.35	55.73
2017-18	72.35	56.83	55.32
2018-19	72.64	57.81	55.24

Source: Ministry of Power[13]

The Ministry of Power constituted an inter-ministerial group for analysing stressed projects in the power sector of India and made certain policy recommendations. These efforts are addressing the underutilisation scenario of power facilities. The average capacity addition in thermal plants in FY13–16 was 19.8 GW, which fell to 6.1 GW in FY17–20. The average closure stood at -277 MW in FY13–16 compared to 2.8 GW in FY17–20. Five key reasons for stalled thermal power projects across India are:

- on-availability of regular fuel supply arrangements
- lack of power purchase arrangements
- inability of the promoter to infuse equity and service excessive debts
- regulatory and contractual issues
- over-build thermal capacity resulting in lower PLFs.

Thermal gross capacity addition and closure trends and estimates (MW)



Source: IEEFA: India's electricity sector transformation

13 https://powermin.nic.in/en/content/power-sector-glance-all-india

Way ahead for sustainable coal power generation

Retirement of older coal assets

A significant percentage of coal-fired power plants in India have outlived their utility and are non-compliant with the country's environmental standards. Such older plants are based on outdated technologies and have high coal consumption, thus contributing significantly to environmental pollution. One of the major initiatives taken by the Government of India is retiring such old and inefficient thermal plants and replacing them with new and more efficient units.

Retirement of coal-based units

Years	Coal capacity retired (GW)
2017–2022	22.72
2022–2027	25.57

As per CEA guidelines, thermal power plants exceeding 25 years of commercial operations are either to be shut down or renovated. Alternatively, to continue operations, plants can switch to more efficient super-critical technologies. A capacity of 2.4 GW and 5.1 GW has already been retired during the 11th and 12th plan period respectively. Further, as per NEP 2018:

- A capacity of 22.7 GW of coal-based capacity has been considered for retirement during 2017–22. This includes 5.9 GW capacity with more than 25 years of age and 16.8 GW capacity that doesn't have enough space for installation of flue-gas desulphurisation (FGD) systems to arrest SOx emissions as per the latest environmental norms by the Government of India.
- Additionally, a capacity of 25.3 GW is planned for retirement from 2022–2027, which will be completing more than 25 years of operation by 2027.[14]
- These identified units are to be phased out in a timebound manner along with matching capacity additions to avoid any demand/supply mismatch due to their retirement.

The action of retiring old and inefficient power plants and replacing them with supercritical units will not just conserve natural resources like land, water and coal, but also reduce the carbon footprint.

Additional coal-based capacity required during 2017–22 and 2022–27

Year	Capacity required	Remarks
2017–22	6.5 GW	Less coal-based capacity addition would be required, since 47.9 MW is under different stages of construction and likely to be commissioned during 2017–22.
2022–27	46.4 GW	This is in addition to 47.9 GW of coal-based capacity which is likely to be commissioned by 2022.

Source: National Electricity Plan, 2018

Stricter environmental norms for reducing emissions

Considering the damage to air quality caused by thermal power plants, Ministry of Environment, Forest and Climate Change (MoEF&CC) prescribed stringent environmental norms in December 2015. These standards aim to significantly cut emissions of PM, SO2, NOx and mercury. Prior to this, India had set standards only for PM reduction. Additionally, new norms for specific water consumption by thermal power plants were introduced.

14 http://www.cea.nic.in/reports/committee/nep/nep_jan_2018.pdf

New environmental norms for thermal power stations (mg/Nm³)

Emission parameter	PM	SO2	NOx	Mercury
Old standards	150–350	None	None	None
New standards				
Units installed till December 2003	100	<500 MW – 600 >=500 MW – 200	600	>=500 MW – 0.03
Units installed after December 2003 and up to December 2016	50	<500 MW – 600 >=500 MW – 200	300	0.03
Units installed after Jan 2017	30	100	100	0.03

Source: CEA, New Environmental Norms for Thermal Power Stations in India

In December 2015, MoEF&CC has set standards as per the Central Pollution Control Board (CPCB) recommendations and after consultation with stakeholders. The norms have been made more stringent for new plants and are the most stringent for upcoming plants. Moreover, the timelines for plants to meet the new standards were tighter.

- Existing plants – 2 years
- Plants commissioned after 1 January 2017 – from the start of their operations

MoEF&CC water norms for thermal power plants

- All plants with once-through cooling (OTC) shall install a cooling tower (CT) and achieve specific water consumption of 3.5 m³/MWh within 2 years of notification.
- All existing CT-based plants shall reduce specific water consumption up to a maximum of 3.5 m³/MWh within a period of 2 years of notification.
- New plants to be installed after 1 January 2017 shall have to meet specific water consumption of 2.5 m³/MWh and achieve zero water discharge.

Source: CEA, New Environmental Norms for Thermal Power Stations in India

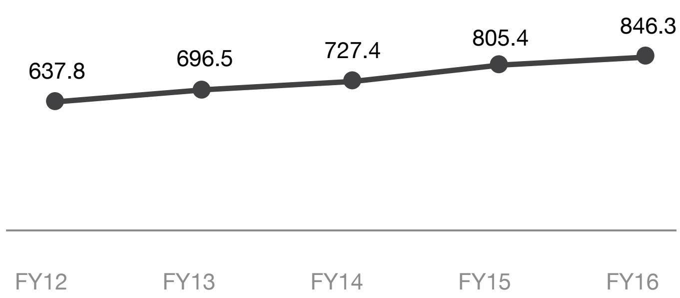
This is a critical step taken by GoI to reduce the impact of the coal-based power sector on the environment. In order to adhere to the above emission standards, significant investments are required from power producers to install pollution control technologies. Power plants that find it too expensive to comply will either be used sparingly or completely phased out. The expected environmental benefits of compliance are: reduction in PM, SO2, NO and mercury by 40%, 48%, 48% and 60% respectively, thus improving the quality of air. Consumption of water by coal-based plants will also be reduced by 40%.[15]

Carbon capture and storage (CCS) technologies

India occupies the fourth position globally in terms of CO_2 emissions from energy production. It contributes 7% of global emissions. In 2017, the country's emissions increased by around 4.6% and these are expected to double by 2030. CO_2 is one of the main greenhouse gases (GHG) responsible for global warming and climate change.

CCS or carbon sequestration technology has the potential to massively reduce the CO_2 footprint as compared to any other existing technology. Therefore, it is considered to be a significant climate protection technology for coal-rich countries like India. It is also one of the flexibility mechanisms defined under the Clean Development Mechanism (CDM) in the Kyoto Protocol.

Total CO_2 emissions (in million tonnes) of power sector in India



Source: Ravinder Kumar et al., Status of carbon capture and storage in India's coal fired power plants: A critical review

15 https://cleanairasia.org/wp-content/uploads/2016/09/06_Sanjeev-Paliwal_CPCB.pdf

Three major steps involved in CCS are:

Capture	Transportation	Storage
Pre-combustion While separating CO_2 before combustion, fuel is converted into a mixture of hydrogen and CO_2, which can be separated conveniently.	**Oxy-fuel combustion** Oxy-fuel combustion uses pure oxygen instead of air. The exhaust gas consisting of water vapour and CO_2 is separated by cooling the flue gas such that water vapour condenses into liquid.	**Post-combustion** Using amines for capturing CO_2 is the most widespread practice of the post-combustion process. Post-combustion can be fitted to different types of emitters (power plants and industrial plants).

Current CCS activities in India[16] include:

- member of Carbon Sequestration Leadership Forum (CSLF) and International Energy Association (IEA) Greenhouse Gas (GHG) R&D Programme
- participating in the Future Gen Programme
- introduced Clean Energy Tax on domestic and imported coal in 2010; tax revenue goes to the National Clean Energy Fund (NCEF)
- in 2012, the National Action Plan on Climate Change (NAPCC) expanded to include clean coal and clean carbon technology to minimise CO_2 emissions

Geological CO_2 storage potential in India

Deep saline reservoirs (on- and offshore) estimates: 360 $GtCO_2$

Depleted oil and gas well estimates: 7 $GtCO_2$

Un-mineable coal seams: 5 $GtCO_2$

Volcanic rock: 200 GtCO2

- 12th FYP of India emphasised the need to invest in R&D on ultra-supercritical units
- 72 coal power plants (16.5 GW) undergoing life extension, modernisation and renovation
- Institute of Reservoir Studies is carrying out CO_2 capture and enhanced oil recovery (EOR) field studies in Gujarat
- National Geological Research Institute (NGRI) is performing feasibility tests for storing CO_2 in basalt form.

Steps taken by India towards deploying this technology by acknowledging the importance of coal in its economic growth alongside the need to reduce CO_2 emissions would play a major role in meeting its energy needs while delivering near-zero emissions. CCS technology would not only enable further use of fossil fuels in a sustainable manner, but also help in reaching the goals specified in Paris climate targets.

Focus on supercritical technology

The government is shifting towards supercritical technology (SCT) based units, to enhance efficiency of power generation and reduce coal consumption and GHG emissions from coal-fired power plants. Units based on SCT have higher efficiency than conventional subcritical technology, thereby ensuring lower CO_2 emissions.

Supercritical units are designed with higher steam parameters of 247 kg/cm2, 565/593° C. On account of the improved thermodynamics of expanding higher pressure and temperature steam through turbines, they attain 2–3% (up to 42%) higher efficiencies than traditional subcritical power plants.

Key benefits of supercritical power plants

- Reduced fuel cost due to improved plant efficiency
- Plant costs less than subcritical technology costs and other coal technologies
- Significant improvement of environment by reduction in CO_2 emissions
- Much reduced NOx, SOx and particulate emissions
- Can be fully integrated with appropriate CO_2 capture technology

In recent times, a majority of coal-based capacity additions are based on SCT. During the 12th plan period, coal-based capacity additions through SCT accounted for 42% (35.2 GW) of the total capacity addition from coal units (84.8 GW). This capacity addition had an impact on CO_2 emissions. Nearly 20.69 MT of CO_2 has been avoided due to adoption of SCT in thermal generation.[17]

16 https://sustainabledevelopment.un.org/content/documents/3293dadhich_presentation.pdf
17 http://www.cea.nic.in/reports/committee/nep/nep_jan_2018.pdf

Coal-fired power plants based on ultra-SCT that operates at an advanced steam temperature of 1,100° F (600° C) or above are also being introduced in the country. These plants have a higher capacity (up to 45%) than supercritical plants. A Few upcoming plants, namely the Khargone Thermal Power Plant (TPP) of NTPC, Jawaharpur Supercritical TPP (STPP) and ObraC STPP of Uttar Pradesh Rajya Vidyut Utpadan Nigam Limited (UPRVUNL) already have ultra-supercritical steam parameters.

Additionally, R&D on advanced ultra-supercritical (A-USC) power plants with steam parameters of pressure ≥300 kg/cm2 and temperature ≥700° C is ongoing in India under the National Mission for Development of Clean Coal Technologies. With such enhanced steam conditions, the efficiency of the plants is expected to be in the range of 45–47%. India's first advanced ultra-supercritical (AUSC) thermal power plant with a capacity of 800 MW at Sipat station of the NTPC in Chhattisgarh is expected to be commissioned by 2019–2020. This is a collaborative project involving the Indira Gandhi Centre for Atomic Research (IGCAR), NTPC, Bharat Heavy Electricals Limited (BHEL) and Central Power Research Institute (CPRI).

GoI has taken an initiative to set up Ultra Mega Power Projects (UMPPs), each having a capacity of 4 GW or above in 2005–06. the projects have been awarded to developers through tariff-based competitive bidding. These projects utilise SCT to ensure high efficiency and lower CO_2 emissions. Out of 16 UMPPs identified in various parts of country, 4 projects were awarded:[18]

- Sasan UMPP, Madhya Pradesh
- Mundra UMPP, Gujarat
- Krishnapatnam UMPP, Andhra Pradesh
- Tilaiya UMPP, Jharkhand.

SCT-based capacity addition during the 12th plan

Unit size (MW)	No. of units				Total capacity (MW)	% of total coal-based capacity
	Central	State	Private	Total		
800	2	4	4	10	8,000	9.4
700	0	1	2	3	2,100	2.5
685	0	0	2	2	1,370	1.6
660	5	3	28	36	23,760	28.0
Sub-total (supercritical)	7	8	36	51	35,230	41.5
Less than 660 (subcritical)	23	33	74	130	49,620	58.5

Source: National Electricity Plan, 2018

Thus, more and more power projects are being brought into the supercritical fold in the country. Implementation of this technology helps India to achieve its goals and balance the increasing demand for electricity, as well as improve coal utilisation efficiency and reduce emissions from coal-fired power plants. Increased efficiency from these installed supercritical units reduces in fuel consumption, which eventually translates into a lower fuel cost per kWh of the units.

18 https://powermin.nic.in/sites/default/files/uploads/MOP_Annual_Report_Eng_2018-19.pdf

Commercial coal mining

In order to drive competition and adopt the best possible technology in mining, GoI has taken a progressive and strategic approach towards privatising coal mining in India. Recently, the government introduced the Coal Mines (Special Provision) Act, 2015, which allows private companies to mine coal for commercial use. Under this new reform, allocation of coal blocks will be based on price per tonne of coal offered to the state government, with no restrictions on the sale of the commodity. Prior to the reform, the door was open to private players only for captive mining for their captive use and they were not allowed to sell in the open market.

Advantages of commercial mining

- Brings efficiency into the coal sector by moving from an era of monopoly to competition
- Increases the energy security of the country
- Ensures assured coal supply, accountable allocation of coal, and affordable coal as well as power prices for consumers
- Allows the use of the best possible technology in the sector, drives investments, and creates direct and indirect employment in coal-bearing areas
- Speeds up the opening of new mines and creates direct and indirect jobs

SWOT analysis of commercial mining in India

Strength	Weakness	Opportunity	Threat
• Growing power demand • Large availability of manpower • Government support for commercial mining • Good domestic supplier base	• Environmental clearance • Constraints in land acquisition • Poor quality of coal • Huge initial capital investment	• Contribution to GDP • Introduction of new technology • Reduction of power tariff • Electrification of the entire country • Introduction of electric vehicles	• Poor R&R packages • Poor amenities to workers • Neglecting safety issues • Heavy environmental degradation

The decision will boost competitiveness and mining efficiency of private players through the use of the best possible technologies. The sector will now attract higher investments, and this will have a positive economic impact on coal bearing areas in terms of infrastructure development, employment creation and business opportunities.[19]

19 Source: Manish Yadav, et al. Commercial Coal Mining in India Opened for Private Sector: A Boon or Inutile

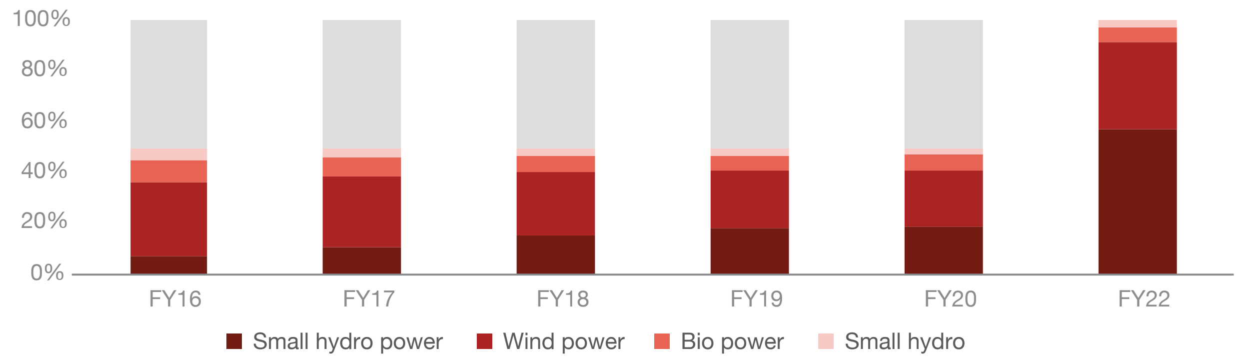
03 RE scenario and grid integration challenges

As discussed earlier, the last few years have witnessed large-scale renewable capacity additions with commissioning of 8,619 MW of renewable capacity in FY 2018–19 alone. As of November 2019, the total installed renewable capacity in India is approximately 83 GW or 23 % of India's total installed capacity of around 357 GW. This is expected to increase to 450 GW by FY 2030, which will be approximately 54% of the total installed capacity.

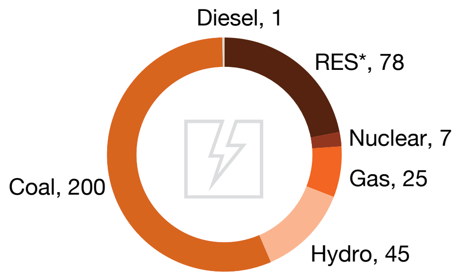
This large-scale renewable capacity addition is likely to have huge implications on the reliability and stability of the Indian power system.

The contribution of renewable capacity in India's generation mix is expected to grow from 22% in 2019 to 54% by 2030.

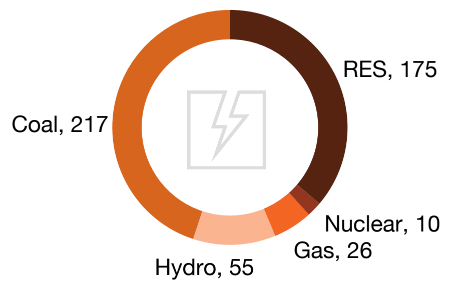
VRE status in India – installed capacity



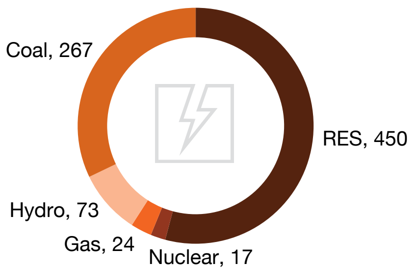
Installed capacity (2018): 356 GW



Forecasted installed capacity (2022): 483 GW

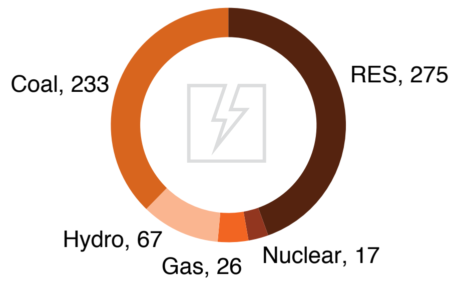


Anternative scenario – installed capacity (2030): 831 GW



Assuming 50% RE target achieved and coal generation picks up

Forecasted installed capacity (2027): 617 GW



Assuming retirement of 22.7 GW + 25.5 GW*

RES: Renewable energy sources

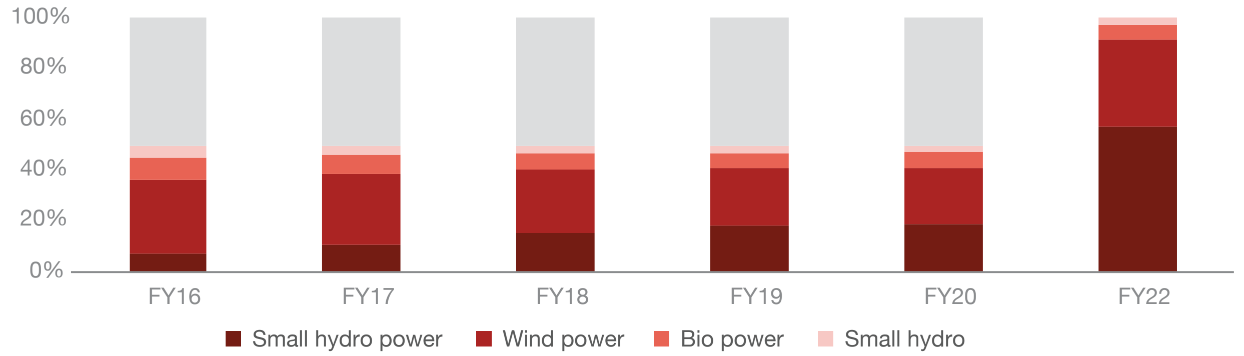
Source: CEA report on 'Flexible operation of thermal power plant for integration of RE generation',2019

Variable RE availability

Out of the total RE, solar and wind are intermittent variable renewable energy (VRE) and constitute around 40 % of the total RE installed capacity. This is expected to increase to 91% considering the FY22 renewable target. Since, renewable generating sources are non-rotating, they cannot contribute to the inertial frequency control.

Daily variation in solar energy output is more or less predictable but change in weather (cloud, rain) may limit generation for short periods of time. Wind energy is less predictable and subject to daily and seasonal weather patterns. This can pose serious challenges if the output corresponds to a lower load.

Source-wise renewable distributtion

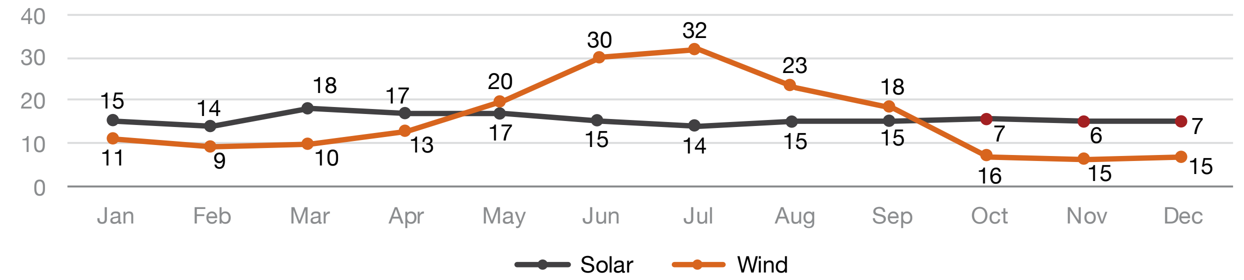


Source: CEA report on installed capacity

The monthly trend of VRE generation is shown below:

Electricity generation (TWh)

Highest wind power generation – 33 TWh in July **Highest solar power generation – 18 TWh in July**



The highest solar output is observed in the dry summer months and wind power generation is the highest during the monsoon months. The highest average monthly RE generation occurs in June and July (each 31%) and the lowest in November (15%), when wind generation is at its lowest level.

Challenges of VRE integration into the grid

Large-scale renewable capacity addition, which is known for variable and intermittent generation, is likely to have significant implications on grid stability and security. Apart from incurring system costs for integration of renewables in the grid (in terms of upgrade to the transmission and distribution networks), additional firm balancing capacity would be essential worldwide for ensuring grid reliability and stability.

Considering the total installed wind capacity of Southern India, a wind generation drop from 2,000 MW to 200 MW, in a duration of 1–1.5 hours, usually translates to fall of around 1.5 Hz in system frequency.

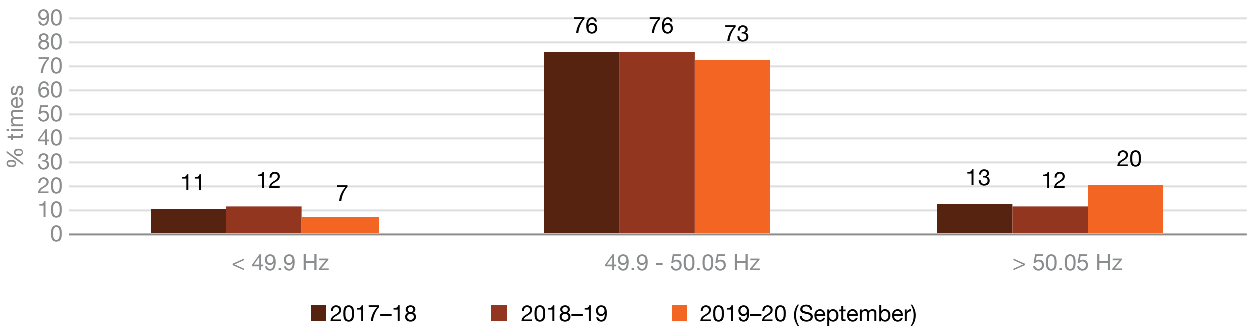
With high RE penetration, system inertia will decrease due to the reduced rotating mass of conventional machines (primarily coal-fired thermal generators). It is also important to note that older machines, which will retire, have a much higher inertia (4 MW-seconds/MVA) as compared to the newer units (2.5-3.0 MW-seconds/MVA). This means the system will have less time to react to power deficit contingency and restore the frequency to reference level. This would have an impact on the frequency fall immediately following a large contingency (inertial response) and before primary response effect comes into play. Hence, the generation that serves the net load, in aggregate, needs to be more flexible in order to smoothen the load curve and balance the variability in the system due to high RE integration.

The key challenges may be summarised as follows:

- **Variability and intermittency of RE generation:** Renewable sources such as solar and wind exhibit variability and intermittency in generation due to seasonality and changes in weather conditions.
- **Variations in net load:** During periods of high RE penetration, net load (= load – RE power) would exhibit steeper ramps and lower minimum generation levels. Hence, generation that serves the net load, in aggregate, needs to be more flexible in order to smoothen the load curve.
- **Financial viability of thermal generation for RE balancing:** High penetration of RE into the grid would lead to marked decrease in PLFs of thermal generation units. Also, the thermal plants would experience an increased number of starts and time spent at minimum generation. This would impose high operation and maintenance costs.

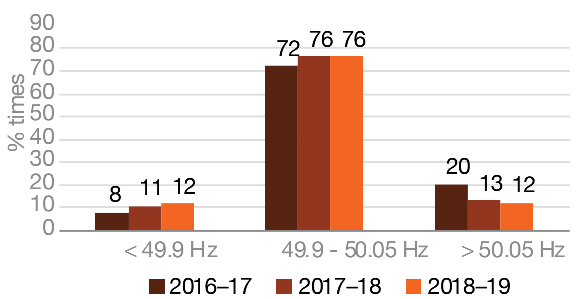
Frequency profile of India grid

The present frequency profile shows frequency to be outside the Indian Electricity Grid Code (IEGC) mandated frequency band (49.9–50.05) for an average of 23% times. Any overdrawal/underdrawal of power in frequency outside the IEGC band results in the distribution/generating utility being penalised as per the Deviation Settlement Mechanism Regulation. Huge variation in frequency may also be triggered (primary, secondary or tertiary response) by the different sources available in the system in similar order.

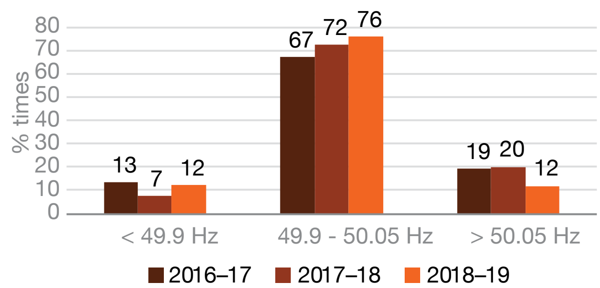


Region-wise adherence (frequency response) to the IEGC mandated frequency band

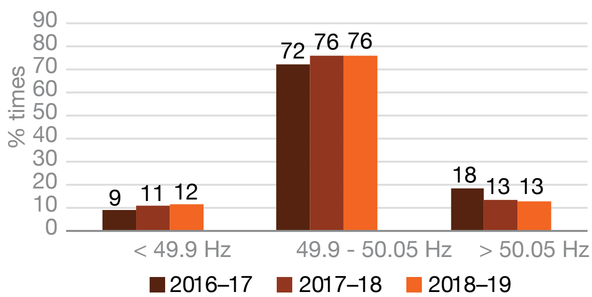
Eastern region



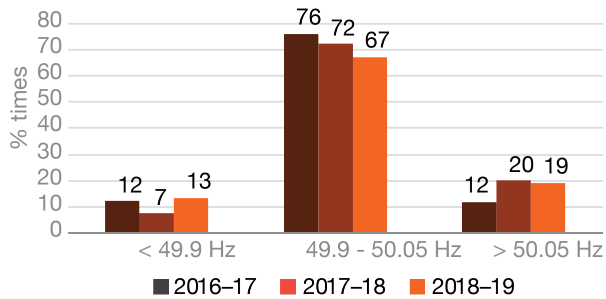
Western region



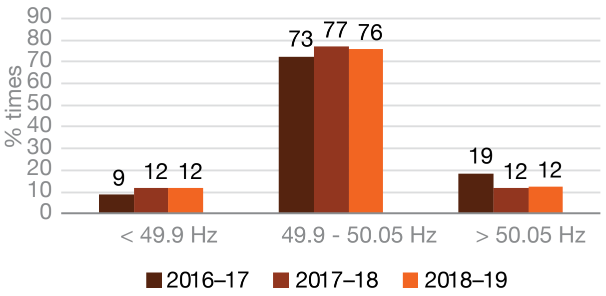
Northeastern region



Northern region



Southern region



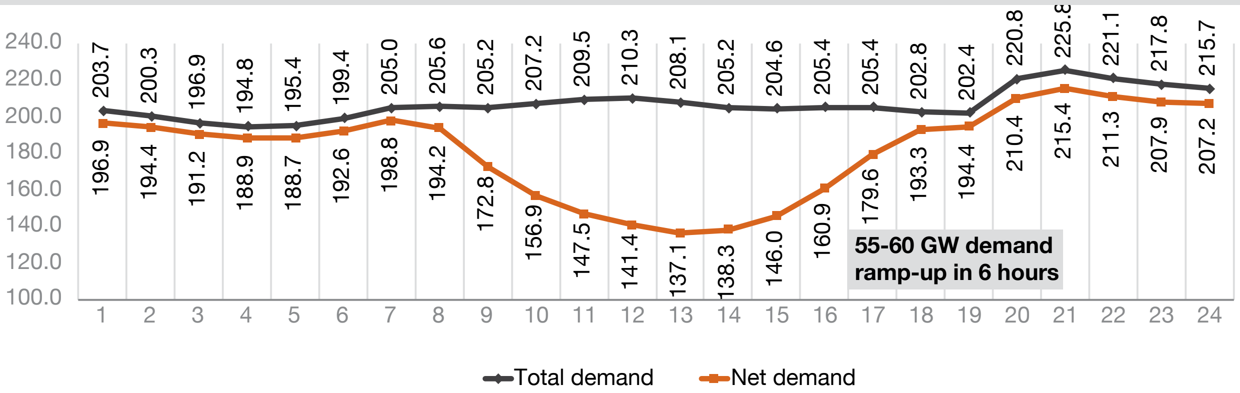
Source: CEA report on 'Flexible operation of thermal power plant for integration of RE generation',2019

The northern region has the highest percentage of frequency deviation. A frequency of 33% times is observed to be outside the IEGC frequency band of 49.9–50.05 Hz, whereas the average frequency deviation for the rest of the region lies between 23–24% times.

Impact of RE integration on net load – high ramp-up/down due to variable nature of renewable generation source

The figure below demonstrates the total demand vs net demand in a day during the high RE condition considering 175 GW of renewable capacity. The net demand (= total demand – RE power) is seen to exhibit a steeper ramp rate and lower generation levels.

All India demand and net demand (for a typical day) – GW



In order to meet its net demand, India will need a ramp-up of 55–60 GW in 6 hours with RE penetration of 175 GW.

At present, the summer ramp-up is estimated to be 170 MW/min during evening peak hours and the winter ramp-up is estimated to be 200 MW/min in the morning.

The present capacity of thermal sources can provide 1396 MW/min ramp-up capacity. Hydro generation can provide a high ramp-up (2506 MW/min but generation will be subject to weather and monthly patterns). Region-wise ramp-up capacity of thermal and hydro are given below:

Thermal ramp-up capacity

Region	Installed capacity for ramp-up (MW)	% MW/min	Ramp-up capacity (MW/min)
Eastern region	23,790	0.4-1.4	206.6
Northeast region	420	0.1-0.12	0.273
Northern region	34,220	0.63-1.68	333.38
Southern region	33,870	0.48-1.59	289.7
Western region	70,700	0.3-1.8	565.7
		Total	**1,395.653**

Source: 'Analysis of ramping capability of coal-fired generation in India 2019', POSOCO

Hydro ramp-up capacity

Installed capacity range (MW)	Installed capacity for ramp-up (MW)	% MW/min	Ramp-up capacity (MW/min)
0–150	2,631	4–20	310
150–300	3,651	4–21	384
300–600	7,042	4–17.4	669
600–900	5,141	4–9	348
900–1,200	7,825	4–11	580
1,200–1,500	4,045	4–6	215
		Total	**2,506**

Source: POSOCO operational report on optimisation of hydro resources and facilitating RE integration in India, 2017

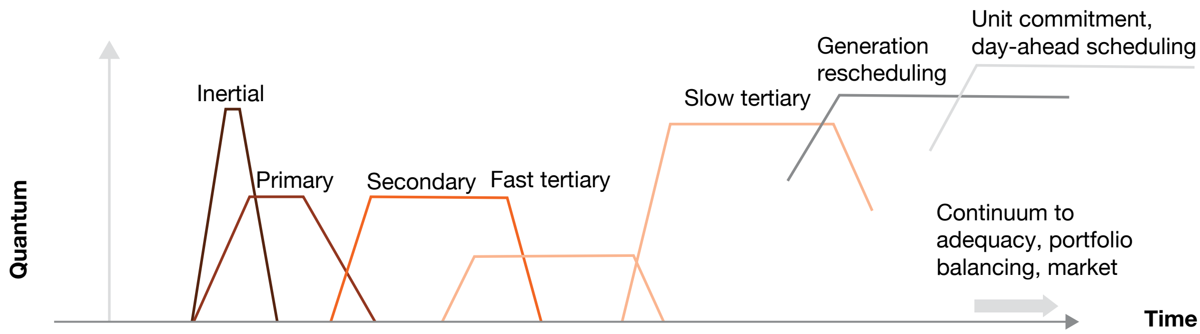
India further commits to increase its RE capacity to 450 GW. This target is over five times its current renewable capacity (82.5 GW) and more than India's total installed electricity capacity (362 GW). According to CEA's draft report on 'Optimal generation capacity mix for 2029-30', if the target of 450 GW is met, RE will account for 54% of the total generation mix. This will have a massive impact on grid stability and will require a much higher ramp-up/ramp-down requirement to meet the net load. It will also require additional flexible reserves like pumped hydro, battery, hydro and ancillary services for meeting the net load and maintaining grid security and stability. In the present load supply scenario, the Indian power sector uses only slow tertiary reserves to meet the ramp-up/ramp-down requirement.

Ancillary reserves in India

Existing structure of ancillary market in India

The existing regulatory regime governed by the Central Electricity Regulatory Commission (Ancillary Services Operations) Regulations, 2015, limits ancillary services to providing frequency support (slow tertiary response); these regulations have been operational since April 2016. The regulatory and market framework in India is still emerging to incentivise other forms of grid balancing services.

Classification of ancillary services in India



Response → Attribute ↓	Inertial	Primary	Secondary	Fast tertiary	Slow tertiary	Generation/ rescheduling market	Unit commitment
Time	First few sec	Few sec – 5 min	30 sec–15 min	5–30 min	> 15–60 min	> 60 min	Hours/day ahead
Quantum	~10,000 MW/Hz	~4,000 MW	~4,000 MW	~1,000 MW	~8,000–9,000 MW	Load generation balance	Load generation balance
Local/LDC	Local	Local	NLDC/ RLDC	NLDC	NLDC/ SLDC	RLDC/SLDC	RLDC/SLDC
Manual/ automatic	Automatic	Automatic	Automatic	Manual	Manual	Manual	Manual
Decentra-lised/ centralised	Decentra-lised	Decentra-lised	Centra-lised	Centra-lised	Decentra-lised/ centralised	Decentra-lised	Decentra-lised
Code/order	IEGC/ CEA standard	IEGC/ CEA standard	Roadmap on reserves	Ancillary regulations	Ancillary regulations	IEGC	IEGC
Paid/ mandated	Mandated	Mandated	Paid	Paid	Paid	Paid	Paid
Regulated/ market	Regulated	Regulated	Regulated	Regulated	Regulated/ market	Regulate/ market	Regulated/ market
Implemen-tation	Existing	Partly existing	Yet to start	Yet to start	Existing	Existing	Existing

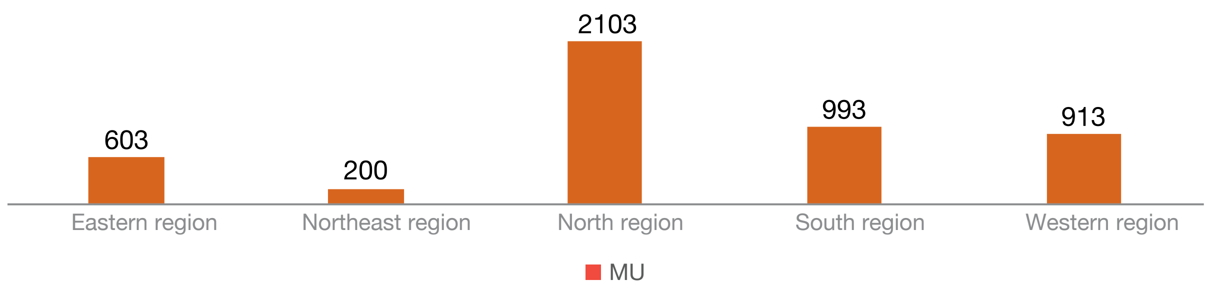
The reserve capacity currently required to integrate variable renewable sources in the grid and ensure operations within prescribed frequency bandwidth (49.9–50.05 Hz).

Type	Requirement (GW)	Remarks
Primary	4	• Maintain at the national level considering outage of the largest generating station • Source from all possible generating stations irrespective of ownership
Secondary	3.6	• Maintain in each region • Source from regional inter-state generating stations (ISGS) whose tariff is determined by the Central Electricity Regulatory Commission (CERC)
Tertiary	5.2	• Maintain in a decentralised manner in state control area for at least 50% of largest-sized generating unit as a tertiary reserve within state control area

At present, there are 75 Reserves Regulation Ancillary Services (RRAS) providers (thermal sources), as identified by the CERC, with a total installed capacity of 68.4 GW (NER – 6 GW, ER - 10.9 GW, NR – 16.2 GW, SR – 13.9 GW, WR – 26.8 GW). Energy ramped up through RRAS for India is 4,811 MU, with the western region being the highest.

The number of instructions dispatched for ramp-up/ramp-down and energy power ramped up through RRAS for each of the regions is shown below:

RRAS ramp-up energy transacted – region-wise



Summary of RRAS market operations for FY 2019

	Up-regulation	Down-regulation
Number of instructions issued	3,968	1,609
Average daily instructions	11	4
Energy scheduled (MU)	4,811	665

Emerging scope of the ancillary services market in India

In September 2018, CERC published a discussion paper titled 'Re-designing ancillary services mechanism in India' which attempts to assess the performance of the current framework of frequency support and balancing of the ancillary services (AS) mechanism in India and suggests next-generation reforms by introducing auction-based procurement of AS.

The table below presents a comparison of the existing AS market and the proposed changes by CERC.

Particulars	Existing regulation	Proposed regulation
Eligibility of RRAS	Only regional entities whose tariff for full capacity is determined	All inter-state/intra-state generating (public or private) resources
Schedule of RRAS	The State Load Dispatch Centre (SLDC) schedules power from RRAS as per merit order stack	Traded in day-ahead bidding in power exchanges. Final settlement done through a real-time market Generators will bid simultaneously in day-ahead energy and day-ahead AS market
Clearing mechanism	Continuous trading	Auction-based market mechanism
Pricing methods	Fixed, variable, mark-up price determined by CERC	Pricing of AS with respect to the opportunity lost by the RRAS in foregoing the energy market or other AS market
RE reserves as tertiary	Not allowed to participate	Whether RE resources will be considered or not is to be notified at a later date

Reactive energy and black start support

Reactive energy (denoted as kilo-volt-ampere-hours or kVARh) support will be needed to cater to the transient stability issues due to the frequent frequency oscillations caused by the intermittent nature of variable renewable energy sources.

At present, India has the capacity of 9 GW as reactive energy support. Per unit cost of providing such support is 14-16 paise/kVARh.[20]

20 www.erpc.gov.in

Reactive power (kVAR) support

Synchronous condenser capability in India			
Region	**Number of stations**	**Number of units**	**Capacity (MW)**
East	2	10	2,100
North	5	11	1,188
South	10	39	2,867
West	8	27	2,904
Northeast	0	0	0
Total	25	87	9,059

As per the Indian Electricity Grid Code (IEGC) clause 6.6, the pricing of VAR is done as follows:

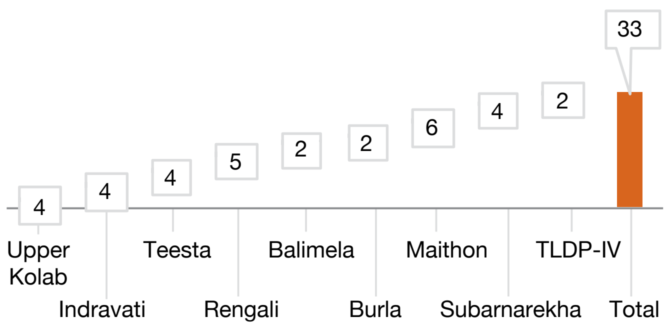
- The Regional Entity except Generating Stations pays for VAR drawal when voltage at the metering point is below 97%.
- The Regional Entity except Generating Stations gets paid for VAR return when voltage is below 97%.
- The Regional Entity except Generating Stations gets paid for VAR drawal when voltage is above 103%.
- The Regional Entity except Generating Stations pays for VAR return when voltage is above 103.

Black start support

Stations with black start capacity

Region	Number of stations
East	13
Northeast	9
North	16
South	33
West	16
Total	87

Black start drills in the last five years



33 black start drills have taken place in the last five years in India, with a majority of the plants owned by the state power utility of Odisha (17). The rest of the drills took place at plants owned by Damodar Valley Corporation (DVC), NHPC and state utilities of Jharkhand, West Bengal and DVC.

Impact of RE on conventional generators

Large-scale integration of RE will reduce the minimum thermal load (MTL) of thermal plants. A recent report titled 'Flexible operation of thermal power plant for integration of renewable generation', published by the CEA in January 2019, specifies that thermal power plants would be required to operate below the 55% MTL in most of the months in 2022 to integrate the RE into the grid and maintain grid security.[21]

The table below represents projected installed capacities for 2021–22 from renewable and coal-based thermal plants corresponding to specific scenarios such as:

1. maximum demand
2. maximum RES
3. the MTL on some specific days (highest demand day, lowest demand day, highest RE day, highest ramp down day, highest ramp up day, lowest MTL day).

21 http://www.cea.nic.in/reports/others/thermal/trm/flexible_operation.pdf

Month	Max. total power demand (MW)	Max RE (W + S) (MW)	Min. coal generation (MW)	Max. coal generation (MW)	MTL (monthly average)	Critical day of the month	MTL of critical day
April	199,528	81,274	65,863	153,321	50.27%	19	41.23%
May	199,811	92,496	59,368	146,312	46.22%	29	39.41%
June	205,164	105,715	40,589	149,471	43.22%	25	29.91%
July	203,396	108,926	32,665	129,603	34.56%	27	25.73%
August	207,558	101,046	37,897	140,967	42.46%	15	29.29%
September	209,907	80,771	70,462	157,679	54.29%	1	47.60%
October	225,751	62,580	94,310	175,611	60.93%	18	58.04%
November	201,763	71,101	82,151	156,651	58.90%	16	51.77%
December	198,987	83,154	80,071	158,497	56.23%	29	50.67%
January	202,651	81,285	79,493	160,862	54.26%	27	50.96%
February	206,484	82,015	81,150	161,981	54.79%	4	50.01%
March	206,749	75,316	73,474	161,301	54.57%	13	48.21%

Source: Flexible operation of thermal plant for integration of renewable generation, CEA

The MTL of thermal units decreases during the high cumulative RE generation months, i.e. May–August; whereas it increases during low cumulative RE generation months, i.e. October–February. Also, the least efficient coal plants will be rarely dispatched in a high-RE scenario.

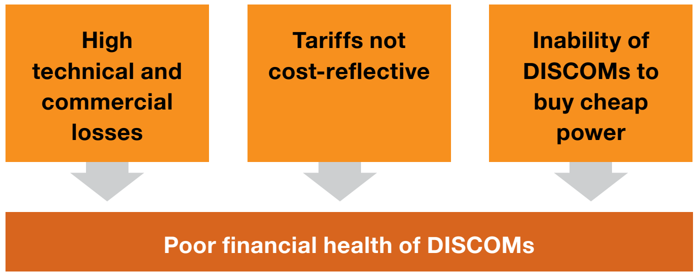
Addressing VRE integration challenges – a summary

Challenges	Recommendation
Meeting net load (high ramp-up/ramp-down) Meeting variability and intermittency	• Additional flexible source addition (pumped storage, battery, hydro, demand side management) • Deeper short-term markets and ancillary markets • Full implementation of secondary and fast tertiary RRAS • Strong enforcement of regulations like DSM regulations • Co-ordinated scheduling and despatch
Maintaining MTL of conventional generators	• Joint operation of solar and hydro energies because of their complementary nature • Flexible power from hydro and gas, with both sources generating less during the day and more during peak hours compared to the present trend of generation • Flexible power from pump/battery storage and coal to provide peak support • RE curtailment
Existing power market design (90% long-term access [LTA], no mature market for ancillary, short-term or capacity market)	• Improve volume, liquidity and flexibility of the power market • Design of new power market structure with key characteristics such as: – retail competition – compulsory participation in exchange – introducing financial products (forwards, futures and options) and financial transmission rights (FTR) – zonal pricing – security-constrained economic despatch – gate closure closer to real-time (e.g. one hour ahead) – implementation of capacity market – competitive ancillary market

04 Distribution reforms

Current issues and challenges

A robust transmission and distribution network is required to support a country's growing power generation capacity. The Indian electricity distribution network consists of 73 distribution utilities and serves close to 200 million consumers, with a connected load of around 400 GW.[22] Since the enactment of the Electricity Act, 2003, Indian power distribution utilities have come a long way but distribution continues to be the weakest link in the entire value chain of the electricity sector.



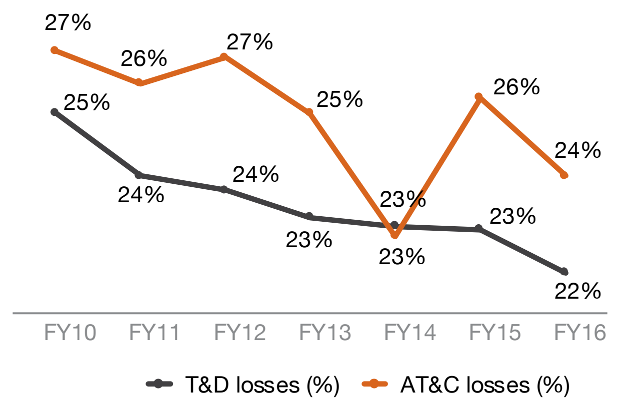
The viability of the power sector depends on the financial health and operational efficiency of distribution utilities. Supply of power at heavily subsidised rates, delayed receipt of subsidies and inefficient power purchase have resulted in poor financial health of DISCOMs. Some of the key challenges faced by distribution companies (DISCOMS) are highlighted below.

Performance of state power utilities

High technical and commercial losses: Despite concerted efforts by the central and the state governments over the last few years, the AT&C losses have remained significantly higher compared to the international standards. Empirical computations suggest that AT&C loss of 1% point translates to financial under-recovery of approximately INR 4,000 crore on a pan-India basis and has a direct impact on the financial health of the sector. GoI is currently undertaking various steps to bring down the overall AT&C losses to the targeted level. Some of the steps taken include but not limited to feeder and distribution transformer (DT) metering, consumer indexing, geographic information system (GIS) universal metering and an introduction of distribution franchisees in high loss-making areas.

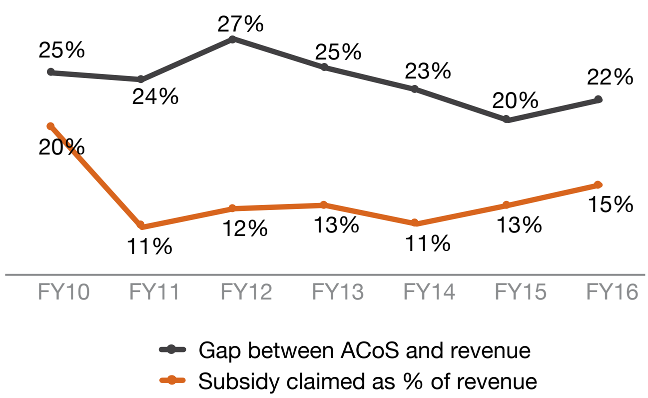
Tariffs not being cost-reflective: Inadequate tariff increases, deferred tariff filings, delayed receipt of subsidies from the state government for providing power to below poverty line (BPL) and agricultural consumers at subsidised rates and increase in regulatory assets have led to lower cost-coverage, leading to poor financial health of DISCOMs.

T&D and AT&C losses



Source: CEA, Power Finance Corporation's (PFC) 'The Performance of State Power Utilities' reports

Recovery by DISCOMs and government subsidies



Source: PFC's 'The Performance of State Power Utilities' reports

22 https://indianpowersector.com/home/electricity-board/electricity-distribution/

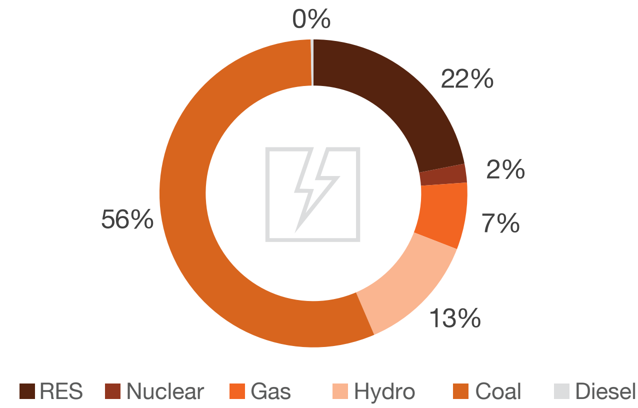
Based on credit rating reports published by the Investment Information and Credit Rating Agency (ICRA),[23] the median tariff hike for DISCOMs at an all-India level had reduced from 8% for FY15 to 4% for FY16 and FY17 and further to 3% and 1% for FY18 and FY19. Further, the regulators in 17 states have allowed for a tariff increase in FY19 against 22 states in FY18, which may further lead to an increase in gap between revenue and the average cost of supply for the DISCOMs in FY20.

Total dues against government departments for DISCOMs for 2018–19 are around INR 41,700 crore.

Inability of DISCOMs to buy cheaper power due to legacy power purchase agreements (PPAs): Thermal projects continue to be the mainstay of power generation in India constituting approximately 56% by installed capacity and accounting for nearly 72% of the country's power generation. Most of the thermal power projects in operation have a significant portion of the power contracted through long-term PPAs consisting of a two-part structure, i.e. capacity charge and energy charge.

With the increasing penetration of renewable energy in the Indian power sector and renewables being given a 'must run' status, the dispatch from thermal generators have reduced leading to low PLFs of approximately 60%. This adds to the burden of DISCOMs as they continue to pay the capacity charge (around 45–50% of the total tariff) for the contracted thermal capacities although power is not scheduled, and cheaper power may be available in the spot markets.

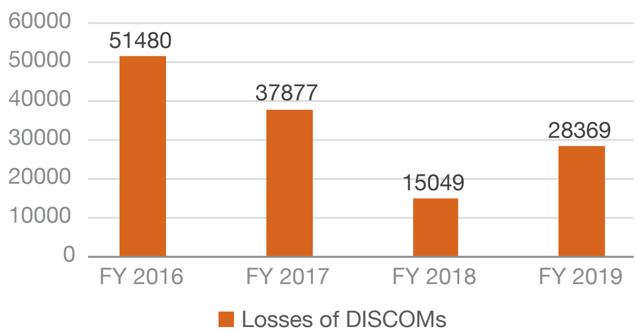
Installed capacity (June 2019): 357 GW



Source: CEA monthly reports

Poor financial health of DISCOMs: High transmission and distribution (T&D) and AT&C losses have adversely affected the financial sustainability of state utilities. The revenue gap for DISCOMs widened between FY14 and FY16, as the rate of increase in average revenue was lower (7.42%) than the rate of increase in the average cost of supply (8.3%). Further, a constant increase in regulatory assets (nearly INR 1.35 lakh crore) due to inadequate tariff hikes has led to huge increase in working capital requirements. Combined losses of DISCOMs that signed for the Ujjwal DISCOM Assurance Yojana (UDAY) programme was about INR 270 billion for 2018–19, significantly impacting their ability to pay dues to power-generating companies, jeopardising the overall viability of the sector.

Losses for DISCOMs (in INR crore)*



Source: Ministry of Power, Government of India
*2019 figures based on provisional data

On account of this poor financial condition of DISCOMs, power is not procured, even though there is significant demand for it. Consequently, this lack of procurement of power by DISCOMs is also impacting the generation sector with many thermal assets currently under stress due to lack of PPAs.

The total outstanding due for the distribution companies to generators (as of Sep 2019) was around INR 81,388 crore.
(Source: PRAAPTI portal; https://www.praapti.in/)

23 Credit rating report for West Bengal State Electricity Distribution Corporation dated October 29,2018, Credit rating report for Bangalore Electricity Supply Company Ltd dated March 12,2019 and Credit rating report for Gujarat State Electricity Company Ltd dated March 20,2019

Operational initiatives: Improving power supply and system performance	Financial reforms: Reducing financial reforms of DISCOMs
• Pradhan Mantri Sahaj Bijli Har Ghar Yojana – "Saubhagya" • Rajiv Gandhi Grameen Vidyutikaran Yojana • Deendayal Upadhyaya Gram Jyoti Yojana (DDUGJY) • Integrated Power Development Scheme (IPDS) • Power System Development Fund (PSDF) • Restructured Accelerated Power Development and Reforms Programme (R-APDRP)	• Ujwal DISCOM Assurance Yojana • Financial Restructuring Programme (FRP) • National Electricity Fund (NEF)

Source: Ministry of Power (MoP), Power Finance Corporation Ltd. (PFC)

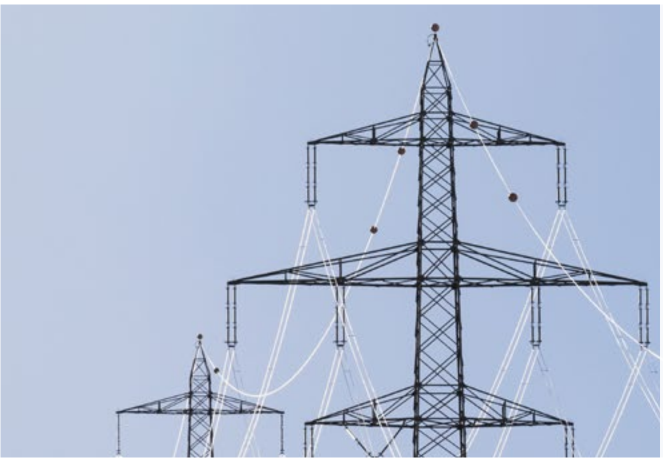
Key reforms undertaken in the power distribution sector

GoI has unveiled various reforms in the distribution sector to improve the operational and financial performance of the DISCOMs, with the basic objective of ensuring access to reliable and affordable power to all the citizens. These have led to various changes in the distribution sector, including reduction of losses, rationalisation of tariff and financial packages leading to lowering of interest costs, etc. A list of the key initiatives undertaken by GoI can be broadly categorised under two separate heads, namely operational initiatives and financial reforms.

Details about the various schemes, their key objectives and targets, and their achievement against the objectives are given in the table below.

Scheme	Year of approval	Financial outlay (in INR crore)	Objectives	Achievements
Rajiv Gandhi Grameen Vidyutikaran Yojana	2005	~50,000	• Electrification of all villages and habitations • Providing access to electricity to all rural households • Free access to be provided to BPL families	**Electrification (as on March 2013)** • Village electrification – 1,06,474 • BPL households – 2,05,15,472
Deendayal Upadhyaya Gram Jyoti Yojana (DDUGJY)	2014	~82,300	• Separation of agricultural and non-agricultural electricity feeders to improve supply for consumers in rural areas • Improving sub-transmission and distribution infrastructure in rural areas • Rural electrification by carrying forward targets specified under the RGGVY	**Electrification** • Village electrification – 93% • Household connectivity – 100% • Electrification impact analysis – 77% **Physical infrastructure** • 11kV – 640,432 ckt km • LT – 1,168,989 ckt km • DTR (no.) – 15,01,580
Pradhan Mantri Sahaj Bijli Har Ghar Yojana – "Saubhagya"	2017	16,320	• Universal household electrification (in both rural and urban areas) by providing last mile connectivity • Provide electricity to about 3 crore households	• 2.63 crore households have been electrified up to March 2019

Scheme	Year of approval	Financial outlay (in INR crore)	Objectives	Achievements
Restructured Accelerated Power Development and Reforms Programme (R-APDRP)	2008	~44,000	• Establishment of base line data • Reduction of AT&C losses up to 15% level through strengthening and upgrade of sub-transmission and distribution network and adoption of information technology (IT)	Part A • 1,363 towns have been declared 'go-live' • SCADA control systems have been established in 52 towns • 20 out of 21 data centres have been commissioned Part B • Projects completed in 970 towns
Integrated power Development Schemes (IPDS)	2014	32,612	• Strengthening of sub-transmission and distribution network in the urban areas • Metering of distribution transformers/ feeders/consumers in the urban areas • IT-enablement of the distribution sector and strengthening of the distribution network	Sanction of funds under the following heads[24] • Distribution strengthening: INR 27,626 crore in 546 circles • IT-enablement: INR 985 crore in 1,931 towns • ERP: INR 640 crore • Smart metering: INR 754 crore
UDAY	2015	The states shall take over 75% of DISCOM debt as on 30 September 2015 over two years. 50% of DISCOM debt shall be taken over in 2015–16 and 25% in 2016–17. Balance 25% of the DISCOM debt was to be issued as state-backed DISCOM bonds or repriced by banks.	• Financial turnaround • Operational improvement • Reduction of cost of generation • Development of renewable energy • Energy efficiency and conservation	• Decrease in AT&C losses from 20.7% in FY16 to 18.7% in FY18 • Reduced book losses to INR 15,049 crore in FY18 from INR 51,480 crore in FY16 • Reduction in average cost of supply (ACS) – aggregate revenue requirement (ARR) gap from INR. 0.58/kWh (in FY16) to INR 0.17/kWh (FY18) • Increase in billed energy from 694 BU to 824 BU (FY16 vs FY18)



GoI has introduced multiple reforms, including amendments in the Electricity Act, for both financial and operational improvement of the DISCOMs. Reforms such as IPDS and UDAY have been introduced to improve the operational and financial health of the DISCOMs, while schemes such as SAUBHAGYA and DDUGY have been launched to provide enhanced electricity access across the country. GoI's reforms and initiatives have been able to reduce the AT&C losses, improve the financial health of the DISCOMs and provide power at competitive prices to the consumers.

24 As on June 30,2018

Power distribution reforms – what's next?

On 11 December 2014, the Union Cabinet approved amendments to the overarching Electricity Act, 2003, through the Electricity Amendment Bill, 2014. The proposed amendment touches upon various aspects of the power sector, right from segregation of carriage and content to RE and open access to tariff rationalisation.[25] The 2014 Bill was examined by the Standing Committee on Energy, which suggested certain changes to the bill. Based on the committee's recommendations and consultations with other stakeholders, the Ministry of Power proposed a Revised Electricity Bill, 2018, which will have far-reaching implications on the distribution sector. Some of the key provisions proposed in the Electricity Bill, 2018, which will shape the future of the distribution sector in India include:

01 **Issue separate licences for the distribution system and supply of electricity**

02 **Supply companies to ensure 24x7 power supply to all consumers**

03 **Limit cross-subsidies to 20% and to eliminate them within three years**

04 **Penalty for non-compliance to renewable energy purchase obligation (RPO) targets**

05 **Subsidies to be provided directly to consumers through direct benefit transfer (DBT)**

06 **Focus on smart grid and metering**

Wire and supply segregation: The Revised Electricity Bill, 2018, proposes issuing and granting of separate licences for maintenance of the distribution network (distribution licence) and for the supply of electricity (supply licence), in order to introduce competition and ensure value to the end consumers. It also provides for a transfer scheme to be notified by the state government for such segregation. This will provide the consumer with more options in terms of choosing a supplier, as more than one supply licensee can share space within the same distribution area. The segregation of wires and supply business is expected to benefit all the stakeholders and is expected to improve the network performance and the viability of the distributors and the suppliers. The benefits of the proposed amendments are given below.

Distribution licensee	Supply licensee	Consumers	Generators
• Cleaner balance sheets with existing assets • Reasonable rate of return on investments • No power procurement costs • Only monitors and entends network to supply power to consumers	• Low investment required to set up a business • Minimal regulatory compliances • New supply licences can be provided on an annual basis • Better management of power purchase cost	• Can benefit from procuring power at competitive costs • Can avail direct transfer of subsidy • Reduction in AT&C losses due to efficient metering	• Can allocate power from stressed assets at competitive rates • Better cost recovery

Though the proposed amendments are yet to be implemented, the mindset of consumers requires to be reformed for changes to be brought to the power sector. In addition, experiences from other countries which have implemented such reforms are to be considered and have to be imbibed to ensure smooth and efficient implementation of the proposed amendments.

25 Press Information Bureau, Government of India, Ministry of Power

Segregation between wires and supply businesses in the UK

The UK has one of the most successfully implemented models in the retail electricity sector. One of the significant highlights in terms of the privatisation process was the formation of the Electricity Pool of England and Wales, which was functioned by the national transmission company. The pool worked as a clearinghouse between generators and wholesale consumers of electricity (primarily the rural electrification companies [RECs]). However, several flaws gradually became prominent in the system, and hence, there was a requirement for several regulatory interferences to control the monopolistic behaviour and avert re-integration in the electricity industry.

From April 1990 to May 1999, competition came into action in the supply market in three phases. The retail side has two divisions comprising 'franchise' and 'non-franchise' customers. Non-franchise customers were given the opportunity to opt for their supplier among any of the twelve RECs or from the pool of retailers.

The Utilities Act, 2000, eliminated the then present distribution/retail licences, and with this, a UK-wide licence came into action with the provision for all the suppliers to serve customers nationwide. It also made a division in the supply and distribution businesses of former public electricity suppliers (PES). To smoothen the process, price controllers were introduced to facilitate all categories of consumers to take advantage of the competitive market.

Source: Joint Report by Forum of Regulators (FoR) and PwC titled 'Introducing competition in retail electricity supply in India'

UDAY 2.0: Proposed as a succession scheme to UDAY, GoI has planned to unveil a new package to provide funds to DISCOMs for system strengthening, expansion of access, loss reduction, etc., provided they meet certain performance benchmarks. Funds are proposed to be provided to DISCOMs to reduce their losses by introducing steps like building of new police stations to monitor power theft, etc. Further, there could be a reduction in allocation of funds to the states that do not meet the performance benchmarks, including reduction in loans DISCOMs take from financiers such as the Power Finance Corporation (PFC). Further, the funding from the power sector focused lenders such as PFC will be based on prudential norms with no provision for working capital loans.

Uday 2.0 is a much-needed reform to provide financial discipline to DISCOMs through disincentives, stricter financial regulations and penalties in case of non-compliance.

Tariff policy amendments: GoI proposes to enact an amendment to the Tariff Policy, 2016, to ensure round the clock electricity to all the citizens of the country. The policy is currently pending with the Union Cabinet. Here are some of the key provisions under the proposed new tariff policy:

- The DISCOMs/licensees need to ensure before the respective commissions that they have signed long-term and medium-term PPAs to meet the power requirements.
- A penalty is proposed to be levied on DISCOMs for voluntary load shedding and the amount will be credited to the account of the respective consumers.
- Enable CEA to set rules of service and penalty for not meeting the set standards.
- AT&C losses to be capped at 15% for computation of tariff.
- Simplification and rationalisation of retail tariff by maintaining a lower number of categories and sub-categories of consumers and making them harmonious across all states.

Despite the proposed amendments covering various issues such as AT&C losses, unaffordable electricity, etc., a clear road map in terms of its execution and resolution for any procedural and legal issues also needs to be drawn. The amendments, coupled with the supportive resolutions, are expected to pave way for the progress of the power distribution sector in India.

Technology interventions in DISCOMs: The smart combination of IT and operational technology (OT) in DISCOMs will allow optimisation on both the supply and demand side to achieve the goal of ensuring 24x7 uninterrupted power supply to consumers. Some of the key technology interventions include, but not limited to, benefits such as:

- advanced metering infrastructure and meter data management (MDM) system
- IT-based metering, billing and collection system, customer relation management (CRM) and enterprise resource planning (ERP) system
- advanced business analytics and forecasting to ensure optimal resource planning in power procurement.

Improved reliability	**Improved asset utilisation**
Manage peak demand	**Improved customer engagement**
Integrate distributed energy resources	**Reduce theft**
Reduce operational costs	**Electrification**

Deployment of AMI infrastructure: As per the draft plan prepared by CEA, GoI plans to replace all traditional meters with smart meters by 2022. The Energy Efficiency Services Limited's (EESL) Smart Meter National Programme (SMNP) has taken up the task of replacing 25 crore conventional meters with smart meters across India. These meters are expected to ease integration in the power sector, reduce capital loss and enhance efficiency in billing and collection. The rollout has been proposed under the build-own-operate-transfer (BOOT) model where EESL takes up all the capital and operational expenditure with zero investment from states and utilities and recovers the cost of these smart meters through savings monetisation, enhanced billing accuracy, avoided meter costs and other losses caused due to inefficiencies. As of August 2019, around 5 lakh meters have already been installed by EESL in the states of Uttar Pradesh, Delhi, Haryana, Bihar and Andhra Pradesh.[26]

National Tariff Policy, 2016, mandates the following:

- Meters of consumers (~5.7 million) with monthly consumption of 500+ units to be replaced with smart meters by December 2017.
- Meters of consumers with monthly consumption between 200 and 500 units (~18.3 million) to be replaced by December 2019.
- Under the UDAY scheme, GoI targets to have 35 million smart meters installed in India by FY 2019–20.

The above targets may not be achieved as per the set deadlines. However, policy level interventions to meet the deadline will augur well in the longer run.

Proposed amendments in the **Electricity Act, 2003**:

- promotion of smart grid in general
- installation of smart meters for specific consumers to ensure proper accounting

Proposed amendments in the **National Tariff Policy, 2016**:

- meters compatible with time of day (ToD) tariff to be installed on priority
- smart pre-paid meters mandatory for all large consumers
- two-way smart meters to be installed for all 'prosumers'

Leveraging blockchain technology for distributed energy generation and supply: The increasing use of smart applications increases the flow of information in various directions, which makes the electric grid vulnerable to hackers. Blockchain technology addresses this issue by managing transactions through a decentralised tamper-proof ledger and offers an efficient, secure and cost-effective solution. Blockchains can make the smart meters infrastructure more robust by providing accurate data to the supplier, without the need for a direct link to specific users. With the rapid increase in usage of electric vehicles (EVs) in the country, blockchain can help in peer-to-peer (P2P) sharing and interconnectivity, thereby balancing the demand from multiple sources and direct sharing and making the grid smarter and modular.

The electricity regulator of a large state in India has recently approved a pilot project for P2P transactions of power from rooftop solar systems, using blockchain-based technology. Under this pilot project, the designated government agencies will carry out P2P transactions for the trading of rooftop solar power installed in government buildings. The fees for the blockchain technology will be recovered in the ARR of the concerned distribution licensee. The results will be evaluated to formulate appropriate regulations to further promote P2P trading of solar energy in the state.

Source: Uttar Pradesh Regulatory Electricity Commission (UPERC)

26 https://www.eeslindia.org/

05 Conclusion

Given the shift in the generation mix, increasing focus on sustainability and advancement in technological interventions driving operational efficiency in the power sector, significant coordination between policymakers, investors and consumers will be necessary to drive successful transformation of the sector. The interventions need to be planned, designed and implemented by factoring in the requirement for new policies and regulations, reform measures, process and technology dimensions, people capabilities, and customer requirements. This paper has touched upon three challenges that are inhibiting sector transformation and presented suggestions to address them.

Coal power generation for sustainability

- Retirement of older coal assets in a time-bound manner to avoid supply/demand mismatch
- Adherence to stricter environment norms leading to reduction in emissions
- Implementation of sustainable technologies to address carbon emission issues
- Focus on supercritical technology to attain higher efficiency and reduce fuel consumption
- Commercialisation of coal mining

RE scenario and grid integration challenges

- Focus on development of flexible sources addition to the grid, viz. pump storage project (PSP), battery, hydro
- Expansion of ancillary market products by full implementation of secondary and tertiary RRAS
- Flexible operation of RE in complementarity with thermal, hydro, and balancing sources, viz. PSP and battery
- Design of new power market structure with key characteristics like retail competition, zonal pricing, gate closure, FTR and capacity market

Distribution reforms

- Segregation of wire and supply business to introduce competition which is envisaged to improve network performance, services to customer, and viability of distribution and suppliers
- Introduction of UDAY 2.0 to aid revival of financial health of DISCOMs
- Amendments to tariff policies to pave the way for advancement of the distribution sector
- Deployment of advanced metering infrastructure (AMI) to increase collection efficiency and reduce losses
- Leveraging advanced technologies to improve efficiency and robustness of system

Way ahead

Bibliography

- 10 Major challenges facing distribution utilities (2017). Retrieved from https://nmgroup.com/en/resources/news/10-major-challenges-facing-distribution-utilities (last accessed (last accessed on 26 November 2019)
- Accelerated Power Development and Reforms Programme. Retrieved from http://www.economicsdiscussion.net/articles/accelerated-power-development-and-reforms-programme/19203 (last accessed on 4 December 2019)
- ADB: Smart meters in rural India are a win-win solution for all (2018). Retrieved from https://blogs.adb.org/blog/smart-meters-rural-india-are-win-win-solution-all (last accessed on 5 December 2019)
- All India Installed Capacity of Power Stations. Retrieved from http://www.cea.nic.in/reports/monthly/installedcapacity/2019/installed_capacity-03.pdf (last accessed on 27 November 2019)
- Annual Report 2018-19, Ministry of Power, India. Retrieved from https://powermin.nic.in/sites/default/files/uploads/MOP_Annual_Report_Eng_2018-19.pdf (last accessed on 26 November 2019)
- Blockchain and energy (2019). Retrieved from https://cdn.cfr.org/sites/default/files/report_pdf/Discussion_Paper_Livingston_et_al_Blockchain_OR_0.pdf (last accessed on 05 December 2019)
- Blockchain and energy (2019). Retrieved from https://www.thehindubusinessline.com/opinion/blockchain-and-energy/article25891853.ece (last accessed on 05 December 2019)
- CEA Annual Report (2017-18). Retrieved from http://cea.nic.in/reports/annual/annualreports/annual_report-2018.pdf (last accessed on 25 November 2019)
- Central Electricity Regulatory Commission, New Delhi. Retrieved from http://www.cercind.gov.in/2014/regulation/noti132.pdf (last accessed on 27 November 2019)
- Clarification on order related to opening and maintaining of adequate Letter of Credit as Payment Security Mechanism under Power Purchase Agreements by Distribution Licensees (2019). Retrieved from https://powermin.nic.in/sites/default/files/webform/notices/Clarification_on_Order_related_to_Opening_and_Maintaining_of_adequate_Letter_of_Credit_as_Payment.pdf (last accessed on 27 November 2019)
- DeenDayal Upadhyaya Gram Jyoti Yojana (DDUGJY). Retrieved from http://www.ddugjy.gov.in/assets/uploads/1548234273fykio.pdf (last accessed on 27 November 2019)
- Distribution 2.0 (2019). Retrieved from https://powerline.net.in/2019/09/13/distribution-2-0-2/ (last accessed on 28 November 2019)
- Draft Report on Optimal Generation Capacity Mix for 2029-30. Retrieved from http://cea.nic.in/reports/others/planning/irp/Optimal_generation_mix_report.pdf (last accessed on 25 November 2019)
- EESL: Smart Meters. Retrieved from https://eeslindia.org/content/raj/eesl/en/Programmes/Smart-Meters/about-smart-meters.html (last accessed on 5 December 2019)
- Electricity distribution sector in India: key challenges for service to customer & way out (2016). Retrieved from https://www.ijaiem.org/Volume5Issue7/IJAIEM-2016-07-26-27.pdf (last accessed on 02 December 2019)
- Energetica India: Indian Power Prices—How Renewable Energy is Cheaper than Coal. Retrieved from energetica-india.net › download (last accessed on 26 November 2019)
- Energy Statistics (2017). Retrieved from http://www.mospi.nic.in/sites/default/files/publication_reports/Energy_Statistics_2017r.pdf (last accessed on 2 December 2019)
- Energy Statistics (2019). Retrieved from http://www.mospi.gov.in/sites/default/files/publication_reports/Energy%20Statistics%202019-finall.pdf (last accessed on 25 November 2019)
- Energy Statistics 2017. Retrieved from http://www.mospi.nic.in/sites/default/files/publication_reports/Energy_Statistics_2017r.pdf.pdf (last accessed on 29 November 2019)
- Environmental Regulations for Coal based Thermal Power Plant (2016). Retrieved from https://cleanairasia.org/wp-content/uploads/2016/09/06_Sanjeev-Paliwal_CPCB.pdf (last accessed on 28 November 2019)

- Executive Summary on Power Sector (2019). Retrieved from http://cea.nic.in/reports/monthly/executivesummary/2019/exe_summary-03.pdf (last accessed on 25 November 2019)
- Executive Summary on Power Sector, April 2019. Retrieved from http://www.cea.nic.in/reports/monthly/executivesummary/2019/exe_summary-04.pdf (last accessed on 27 November 2019)
- Executive Summary on Power Sector, March 2019. Retrieved from http://cea.nic.in/reports/monthly/executivesummary/2019/exe_summary-03.pdf (last accessed on 27 November 2019)
- GARV Dashboard. Retrieved from http://garv.gov.in/dashboard (last accessed on 27 November 2019)
- Growth of Electricity Sector in India from 1947-2017. Retrieved from http://www.cea.nic.in/reports/others/planning/pdm/growth_2017.pdf (last accessed on 26 November 2019)
- IEEFA: India's Electricity Sector Transformation (2017). Retrieved from http://ieefa.org/wp-content/uploads/2017/11/India-Electricity-Sector-Transformation_Nov-2017-3.pdf (last accessed on 27 November 2019)
- India Energy Outlook, IEA, 2015. Retrieved from https://www.gita.org.in/Attachments/Reports/IndiaEnergyOutlook_WEO2015.pdf (last accessed on 26 November 2019)
- India's Stranded Assets: how government interventions are propping up coal power (2018). retrieved from https://www.odi.org/sites/odi.org.uk/files/resource-documents/12407.pdf (last accessed on 26 November 2019)
- Indian Power Sector: R-APDRP. Retrieved from http://indianpowersector.com/home/electricity-regulation/apdrp/ (last accessed on 4 December 2019)
- India's looming power crisis (2016). Retrieved from https://economictimes.indiatimes.com/indias-looming-power-crisis/articleshow/51051903.cms?from=mdr (last accessed on 27 November 2019)
- India's power market development - 2018 snapshot and way ahead (2019). Retrieved from https://energy.economictimes.indiatimes.com/energy-speak/india-s-power-market-development-2018-snapshot-and-way-ahead/3397 (last accessed on 29 November 2019)
- Integrated Power Development Scheme (IPDS). Retrieved from http://www.ipds.gov.in/Form_IPDS/About_IPDS.aspx (last accessed on 27 November 2019)
- Introducing competition in retail electricity supply in India (2013). Retrieved from http://forumofregulators.gov.in/Data/Reports/6_9_13.pdf (last accessed on 28 November 2019)
- ISGF: Post R-APDRP Strategy (2013). Retrieved from http://www.indiasmartgrid.org/reports/Post%20R-APDRP%20Strategy%20%20-%20A%20White%20Paper%20by%20ISGF%20-%20Final.pdf (last accessed on 4 December 2019)
- Manish Yadav, et al. Commercial Coal Mining in India Opened for Private Sector: A Boon or Inutile (2018). Retrieved from https://www.researchgate.net/publication/328700077_Commercial_Coal_Mining_in_India_Opened_for_Private_Sector_A_Boon_or_Inutile_Characterization_and_Control (last accessed on 25 November 2019)
- Ministry of New and Renewable Energy (MNRE). Retrieved from https://mnre.gov.in/ (last accessed on 05 December 2019)
- Ministry of Power, Annual Report (2018-19). Retrieved from https://powermin.nic.in/sites/default/files/uploads/MOP_Annual_Report_Eng_2018-19.pdf (last accessed on 2 December 2019)
- Ministry of Power: Accelerated Power Development Programme (APDP). Retrieved from https://powermin.nic.in/en/content/accelerated-power-development-programme-apdp (last accessed on 4 December 2019)
- Ministry of Power: Power Sector at a Glance all India (2019). Retrieved from https://powermin.nic.in/en/content/power-sector-glance-all-india (last accessed on 25 November 2019)
- National Electricity Fund (Interest Subsidy) Scheme to subsidize interest rate on loans (2011). Retrieved from https://pib.gov.in/newsite/PrintRelease.aspx?relid=78627 (last accessed on 27 November 2019)
- National Electricity Fund. Retrieved from http://nefgov.in/ (last accessed on 27 November 2019)
- National Electricity Plan (2018). Retrieved from http://www.cea.nic.in/reports/committee/nep/nep_jan_2018.pdf (last accessed on 25 November 2019)
- National Electricity Plan, CEA, January 2018. Retrieved from http://www.cea.nic.in/reports/committee/nep/nep_jan_2018.pdf (last accessed on 25 November 2019)

- New Environmental Norms for Thermal Power Stations in India. Retrieved from https://docplayer.net/23056638-New-environmental-norms-for-thermal-power-stations-in-india.html (last accessed on 25 November 2019)
- Office Memo to update status of IPDS on the website of Ministry of Power (2018). Retrieved from https://powermin.nic.in/sites/default/files/webform/notices/Updation_of_contents_in_the_website.pdf (last accessed on 27 November 2019)
- Over 5 lakh smart meters operational across India (August 2019). Retrieved from https://www.thehindubusinessline.com/economy/over-5-lakh-smart-meters-operational-across-india-says-eesl/article29060479.ece# (last accessed on 5 December 2019)
- P.K. Kukde, et al. Accelerated power development and reform programme in India (2004). Retrieved from http://dspace.library.iitb.ac.in/xmlui/bitstream/handle/10054/278/1373304.pdf?sequence=3&isAllowed=y (last accessed on 4 December 2019)
- Perspective Transmission Plan Report (2016-36). Retrieved from http://www.cea.nic.in/reports/others/ps/pspa2/ptp.pdf (last accessed on 27 November 2019)
- PIB, Press release (2019). Retrieved from https://pib.gov.in/PressReleasePage.aspx?PRID=1585979 (last accessed on 26 November 2019)
- Policy | Uday 2.0 – Will it make the end consumer more powerful? (2019). Retrieved from https://www.moneycontrol.com/news/economy/policy/policy-uday-2-0-will-it-make-the-end-consumer-more-powerful-4429801.html (last accessed on 28 November 2019)
- Power Distribution Systems in India (2018). Retrieved from https://www.electricalindia.in/power-distribution-systems-in-india/ (last accessed on 02 December 2019)
- Power Finance Corporation Ltd. Retrieved from https://www.pfcindia.com/Home/VS/23 (last accessed on 27 November 2019)
- Power Minister Shri RK Singh approves implementation of Payment Security Mechanism for purchase of power by DISCOMs as mandated by law (2019). Retrieved from https://pib.gov.in/newsite/PrintRelease.aspx?relid=190967 (last accessed on 27 November 2019)
- Power Sector at a Glance All India. Retrieved from https://powermin.nic.in/en/content/power-sector-glance-all-india (last accessed on 27 November 2019)
- Pradhan Mantri Sahaj Bijili Har Ghar Yojana (SAUBHAGYA). Retrieved from https://saubhagya.gov.in/ (last accessed on 27 November 2019)
- Progress of Substations in the Country up to Oct-19. Retrieved from http://cea.nic.in/reports/monthly/transmission/2019/growth_summary_ss-10.pdf (last accessed on 28 November 2019)
- Progress of Transmission Sector in the Country up to Oct-19. Retrieved from http://cea.nic.in/reports/monthly/transmission/2019/growth_summary_tx-10.pdf (last accessed on 28 November 2019)
- Proposed Amendments in Tariff Policy (2018). Retrieved from https://pib.gov.in/newsite/PrintRelease.aspx?relid=181709 (last accessed on 29 November 2019)
- Proposed amendments in Tariff Policy, 2016 (2018). Retrieved from https://powermin.nic.in/sites/default/files/webform/notices/Proposed_amendments_in_Tariff_Policy_0.pdf (last accessed on 29 November 2019)
- Ravinder Kumar, et al. Status of carbon capture and storage in India's coal fired power plants: A critical review (2018). Retrieved from https://www.researchgate.net/publication/328707618_Status_of_carbon_capture_and_storage_in_India's_coal_fired_power_plants_A_critical_review (last accessed on 27 November 2019)
- Report of the High Level Empowered Committee to Address the issues of Stressed Thermal Power Projects (2018). Retrieved from https://powermin.nic.in/sites/default/files/webform/notices/20_Nov_R1_Draft_Report_HLEC_Final_20_Nov%281%29.pdf (last accessed on 26 November 2019)
- Report on Short-term Power Market in India: 2018-19. Retrieved from http://www.cercind.gov.in/2019/market_monitoring/Annual%20Report%202018-19.pdf (last accessed on 25 November 2019)
- Restructured Accelerated Power Development & Reforms Programm (R-APDRP). Retrieved from http://www.apserc.nic.in/pdf/RAPDRP.pdf (last accessed on 4 December 2019)
- Scheme for Financial Restructuring of State Distribution Companies (Discoms) (2012). Retrieved from https://powermin.nic.in/sites/default/files/uploads/Financial_restructuring_of_State_Distribution_Companies_discoms_Oct2012.pdf) (last accessed on 27 November)
- Separating Content and Carriage (2019). Retrieved from https://powerline.net.in/2019/04/27/separating-content-carriage/ (last accessed on 28 November 2019)
- Smart Cities Mission. Retrieved from http://164.100.161.224/content/ (last accessed on 05 December 2019)
- Smart electricity meters in rural India a win-win: Asian Development Bank (October 2018). Retrieved from https://economictimes.indiatimes.com/industry/energy/power/smart-electricity-meters-in-rural-india-a-win-win-asian-development-bank/articleshow/66400296.cms?from=mdr (last accessed on 5 December 2019)
- Solarquarter. Retrieved from http://solarquarter.com/index.php/4273-solar-power-industry-in-india-trends-and-analysis (last accessed on 25 November 2019)
- States to face cut in funds for missing targets under UDAY 2.0: Power Minister R K Singh (2019). Retrieved from https://

www.financialexpress.com/economy/states-to-face-cut-in-funds-for-missing-targets-under-uday-2-0-power-minister-r-k-singh/1682322/ (last accessed on 28 November 2019)

- TERI, Potential for CCS in India: Opportunities and Barriers. Retrieved from https://sustainabledevelopment.un.org/content/documents/3293dadhich_presentation.pdf (last accessed on 28 November 2019)
- Three Years of DDUGJY Scheme. Retrieved from https://www.recindia.nic.in/press-conference-on-three-years-achievements-of-rural-electrification (las accessed on 27 November 2019)
- Transitions in Indian Electricity Sector 2017–2030. Retrieved from https://www.teriin.org/files/transition-report/files/downloads/Transitions-in-Indian-Electricity-Sector_Report.pdf (last accessed on 2 December 2019)
- Troubled power sector — the way forward (2018). Retrieved from https://www.thehindubusinessline.com/opinion/troubled-power-sector-the-way-forward/article25719209.ece# (last accessed on 29 November 2019)
- UDAY 2.0 to focus on checking power theft, promoting smart meters: RK Singh (2019). Retrieved from https://www.thehindubusinessline.com/economy/logistics/uday-20-to-focus-on-checking-power-theft-promoting-smart-meters-rk-singh/article26063064.ece (last accessed on 28 November 2019)
- UDAY 2.0, to inculcate payment discipline amongst DISCOMs (2019). Retrieved from https://www.eprmagazine.com/epr-personality/uday-2-0-to-inculcate-payment-discipline-amongst-discoms/ (last accessed on 28 November 2019)
- UDAY Scheme for Discoms (2019). Retrieved from https://www.civilsdaily.com/story/uday-scheme-for-discoms/ (last accessed on 28 November 2019)
- Ujwal Discom Assurance Yojana (UDAY). Retrieved from https://www.uday.gov.in/images/newsletter_jan_2019.pdf (last accessed on 27 November 2019)
- UNFCCC: Saskpower CCS. Retrieved from https://unfccc.int/sites/default/files/01_saskatchewan_environment_micheal_monea.pdf (last accessed on 28 November 2019)
- VRE status in India-Installed Capacity-Retrieved from CEA report on Installed capacity (http://www.cea.nic.in/monthlyarchive.html)
- RPC Quarterly Report of each regional power committee http://www.srpc.kar.nic.in/html/index.html, https://nrpc.gov.in/,http://nerpc.nic.in/,http://erpc.gov.in/http://www.wrpc.gov.in/)
- Analysis of Ramping Capability of Coal Fired Generation in India 2019, POSOCO" Retrieved from
- https://posoco.in/download/analysis-of-ramping-capability-of-coal-fired-generation-in-india/
- Report on Optimal Analysis for Optimisation of Hydro Resources ,2017, POSOCO
- https://posoco.in/download/fold-posoco-report-on-operational-analysis-for-optimization-of-hydro-resources/
- Deviation Settlement Mechanism (DSM) Regulations http://www.cercind.gov.in/2019/regulation/DSM(5th%20Amendment)149.pdf
- Discussion Paper on Re-designing Ancillary Services Mechanism in India, Sep 18,2018 (http://www.cercind.gov.in/2018/draft_reg/DP.pdf)

About ASSOCHAM

The Knowledge Architect of Corporate India

Evolution of Value Creator

ASSOCHAM initiated its endeavour of value creation for Indian industry in 1920. Having in its fold more than 400 chambers and trade associations, and serving more than 4,50,000 members from all over India. It has witnessed upswings as well as upheavals of Indian Economy, and contributed significantly by playing a catalytic role in shaping up the trade, commerce and industrial environment of the country.

Today, ASSOCHAM has emerged as the fountainhead of knowledge for Indian industry, which is all set to redefine the dynamics of growth and development in the technology driven cyber age of 'Knowledge Based Economy'.

ASSOCHAM is seen as a forceful, proactive, forward looking institution equipping itself to meet the aspirations of corporate India in the new world of business. ASSOCHAM is working towards creating a conducive environment of India business to compete globally.

ASSOCHAM derives its strength from its Promoter Chambers and other industry/regional chambers/ associations spread all over the country.

Vision

Empower Indian enterprise by inculcating knowledge that will be the catalyst of growth in the barrierless technology driven global market and help them upscale, align and emerge as formidable player in respective business segments.

Mission

As a representative organ of Corporate India, ASSOCHAM articulates the genuine, legitimate needs and interests of its members. Its mission is to impact the policy and legislative environment so as to foster balanced economic, industrial and social development. We believe education, IT, BT, Health, Corporate Social responsibility and environment to be the critical success factors.

Members – Our Strength

ASSOCHAM represents the interests of more than 4,50,000 direct and indirect members across the country. Through its heterogeneous membership, ASSOCHAM combines the entrepreneurial spirit and business acumen of owners with management skills and expertise of professionals to set itself apart as a Chamber with a difference. Currently, ASSOCHAM has more than 100 National Councils covering the entire gamut of economic activities in India. It has been especially acknowledged as a significant voice of Indian industry in the field of corporate social responsibility, environment & safety, HR & labour affairs, corporate governance, information technology, biotechnology, telecom, banking & finance, company law, corporate finance, economic and international affairs, mergers & acquisitions, tourism, civil aviation, infrastructure, energy & power, education, legal reforms, real estate and rural development, competency building & skill development to mention a few.

Insight into 'New Business Models'

ASSOCHAM has been a significant contributory factor in the emergence of new-age Indian Corporates, characterized by a new mindset and global ambition for dominating the international business. The Chamber has addressed itself to the key areas like India as Investment Destination,

Achieving international competitiveness, promoting international trade, corporate strategies for enhancing stakeholders value, government policies in sustaining India's development, infrastructure development for enhancing India's competitiveness, building Indian MNCs, role of financial sector the catalyst for India's transformation.

ASSOCHAM derives its strengths from the following Promoter Chambers: Bombay Chamber of Commerce & Industry, Mumbai; Cochin Chambers of Commerce & Industry, Cochin: Indian Merchant's Chamber, Mumbai; The Madras Chamber of Commerce and Industry, Chennai; PHD Chamber of Commerce and Industry, New Delhi. Together, we can make a significant difference to the burden that our nation carries and bring in a bright, new tomorrow for our nation.

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