Thermal Power Industry|2018

B. Prakash & Associates

Disclaimer

The conclusions reached, and views expressed in the study are matters of opinion. Our study is based on the general understanding and the dynamics of the Thermal Power Industry prevailing as on the date of the study and our experience. However, since Thermal Power Industry just like any other industry is impacted with changes in the political, economic, environmental and regulatory factors, there can be no assurance that the market may not take a contrary position to our views. This study covers Thermal Power Industry, its background, dynamics of the industry, sectorial performance and future growth and potential of India and some other countries. This study is based on the information gained from various industry reports, news articles and journals. We have no responsibility to carry out any review of our comments for changes in the industry dynamics occurring after the date of issue of this study. Further, this study shall not be used or quoted in whole or in part or otherwise referred to in any document or delivered to any other person or entity without our prior written consent. This study contains observations and comments based on our review and neither B Prakash & Associates nor its employees and associates are responsible for any loss or damage occurring on implementation of views expressed in this report.

Aim and Objective of the Study

The aim and objective of this study is to understand the background, current fundamentals and the future growth aspects of the Indian Thermal Power Industry and study Thermal Power market of other countries. Further, the study aims to understand current position of India as compared to the other countries.

Basis for the Study

The basis for the entire study is continuous accumulation of knowledge and data through various reports, news articles and journals.

Scope of Work

The scope of our work specifically includes the following:

(i) Historical Background

(ii) Regulating and Administrating Institutions

(iii) Factors impacting the thermal power industry

(iv) Industry Performance

(v) Future of thermal power industry

List of Abbreviations

˚C	**Degree Celsius**
FSA	Fuel Supply Agreement
CAGR	Compound Annual Growth Rate
CEA	Central Electricity Authority of India
CERC	Central Electricity Regulatory Commission
ckm	Circuit Kilometres
CO2	Carbon Dioxide
DISCOM	Distribution Companies
EIA	Energy Information Administration
EU-28	28 Member States of the European Union
GCV	Gross Calorific Value
GW	Gigawatt
GWh	Gigawatt Hour
HT	High tension
IEA	International Energy Agency
IPP	Independent Power Producer
Kcal/Kg	Kilo-calorie per Kilogram
Kg	Kilogram
KWh	Kilowatt Hour
LT	Low Tension
MW	Megawatt
NTPC	National Thermal Power Corporation Limited
OCED	Organisation for Economic Co-operation and Development
PLF	Plant Load Factor
PPA	Power Purchase Agreement
PX	Power Exchange
ROE	Return on Equity
TWh	Terawatt Hour
US	United States

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1. Introduction

A country's economic development and the level of industrialization is dependent on the growth and progress of its core sectors one of which is power industry. A major portion of this installed capacity in power sector consists of thermal power stations mainly because of their lower gestation period, flexibility of their site selection, ease of augmentation of existing facilities and lesser investment cost required as compared to hydro stations. Despite the fact that the thermal generation results in higher costs/kWh, and it has to have major dependence on the logistics of coal supplies and problems of ash disposal, etc. it has assumed significant importance and will continue to play an important role in the power development scenario for long time to come.

The generation of thermal power revolves around three objectives: low carbon emission, low cost of production, and low transmission losses. Though, thermal power is reliable, sometimes it hampers CO_2 emission targets. Other methods of power generation such as offshore wind power, solar power, hydro-electric power have low carbon emission but are not supporting continuous power supply. Hence, to fulfil the growing demand of power, thermal power will remain the major source of electricity for at least few years.

In India, electricity production has grown at CAGR of 7.03 % from year 2010 to year 2017 and has coal based thermal power installed capacity of 214.19 GW as of year 2017.

To study thermal power sector, it is also important to understand the structure of Power Sector. It is majorly divided into 3 stages.

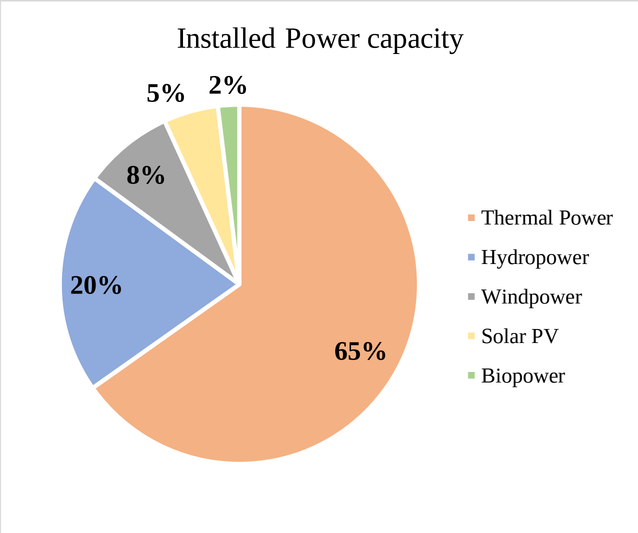
- Generation of electricity
- Transmission
- Distribution

1.1 Generation of electricity

Sources of power generation range from conventional sources such as coal, lignite, natural gas, oil and nuclear power to non-conventional sources such as wind, hydro, solar, agricultural and domestic waste.

Power plant or power station contains generators and rotors that converts mechanical energy to electrical energy. There are various methods to generate electricity depending upon the availability of the resources.

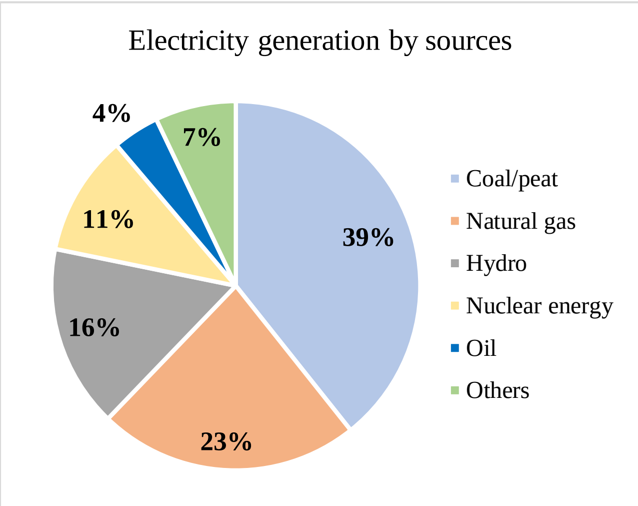
Figure 1: Installed Power capacity by source globally



Source: *Power technology*

Figure **1** shows total globally installed power capacity as of year 2016. Total installed power capacity across the world has increased from 5,047 GW in year 2010 to 6,473 GW in year 2016 of which the largest share of 61.10% is contributed by thermal power.

Figure 2: Global electricity generation by sources



Source: *Statista_electricity generation by source*

Global electricity generation in year 2015 shows that electricity generated using coal/peat contributes the major part of electricity generation i.e., 39.30%. Other sources of energy include geothermal energy, wind power, photovoltaic etc. However natural gas is the 2nd largest source of power generation with 22.90% of total generation.

- **Conventional Thermal power:**

In thermal power station electricity is produced using heat energy. Steam generated by combustion of coal, natural gas, biomass or oil activates the turbine which further drives alternator to produce electricity. It is the largest power generating source with cumulative installed capacity of 3,954 GW in year 2016 globally.

2. Thermal Power energy

2.1 Revolution in Thermal Power Generation

Thermal power generation is the generation of electricity using heat energy. When Thomas Edison burnt coal to generate electricity during 1870s, it could only convert 2.5% of raw energy into electricity. However, as time passed, electricity production became more prominent activity. Sir Charles Parsons built the first steam turbine generator in year 1884. Manufacturers of boilers & turbines found many ways to boost the efficiency rate of power plants. Generative capacities have grown exponentially, and technologies have evolved dramatically with time. By the early 1900s, coal-fired power units featured outputs in the 1 MW to 10 MW range, outfitted with a steam generator, an economizer, evaporator, and a superheater section. Today's combined-cycle plants operate with greater efficiencies and lower emissions than any other type of fuel plant, and it's realistic to expect these numbers to continue to evolve and improve.

Samuel Insull was the first person who achieved economies of scale by consolidating small electricity providers to provide large and more efficient power. By year 1907 he acquired 20 utility companies to provide large and efficient power. After buying the firms, he used to turn generating stations into substations, relegating the generating equipment to back up spares and then he used large, efficient steam-turbines to produce power for all customers. Insull had also used high voltage transmission line to sub urbans and country-side. He also used two-part pricing model to handle customers whose electricity demand fluctuated widely. He implemented demand charge in addition to usual usage charges for peaky customers. Edison provided the novelty of electric light to upper class people, Insull’s innovations like consolidation, mass production, two-part pricing model, rural electrification made electricity accessible to all

2.2 Raw material used for Thermal power generation

Heat energy which is used to generate electricity can be produced in many ways i.e., by burning coal, oil, gas or wood; it can be taken from steam from geothermal field or it can be generated by nuclear reaction.

Global power sector has been witnessing a change from conventional thermal power production to renewable power production since last few years.

Some major resources contributing to generation of thermal power are as follows:

- Coal:

Coal plays very crucial role in thermal power production worldwide. As per world bank data, coal contributes about 40.66% of total electricity produced across the world. Coal mines are limited to their natural ability hence, the expansion of coal mining has limitations.

One of the efficiency parameters of a power plant which uses coal as a fuel is dependent on quality of coal which is measured by its Gross Calorific Value (GCV). Higher the GCV of coal, higher is the efficiency of power plant. In India coal of GCV 2200 Kcal/Kg to 7000 Kcal/Kg is available.

- Natural Gas:

Natural gas is considered as clean fuel as compared to coal. Contribution of natural gas in global electricity production is nearly 22.9%. Largest producer of natural gas is United States, which produces approximately 681.4 billion cubic meters yearly.

- Oil:

Power stations that uses oil to generate electricity are called oil fired power plant. The basic principle of working remains same as coal fired power plant

2.3 Types of technologies available for thermal power generation

- **Subcritical technology:**

Sub critical power plants operate at critical temperature of 540° C and critical pressure of water 170-220 bars respectively and has operating efficiency below 38%.

- **Supercritical technology**

Supercritical is a term of thermodynamics which describes the state of substance where there is no exact change of state between the liquid and the gaseous state. Water which is used in super critical thermal power plant reaches this supercritical state at a pressure above 221 bar and temperature between 538-566° C.

- **Ultra-Supercritical technology**

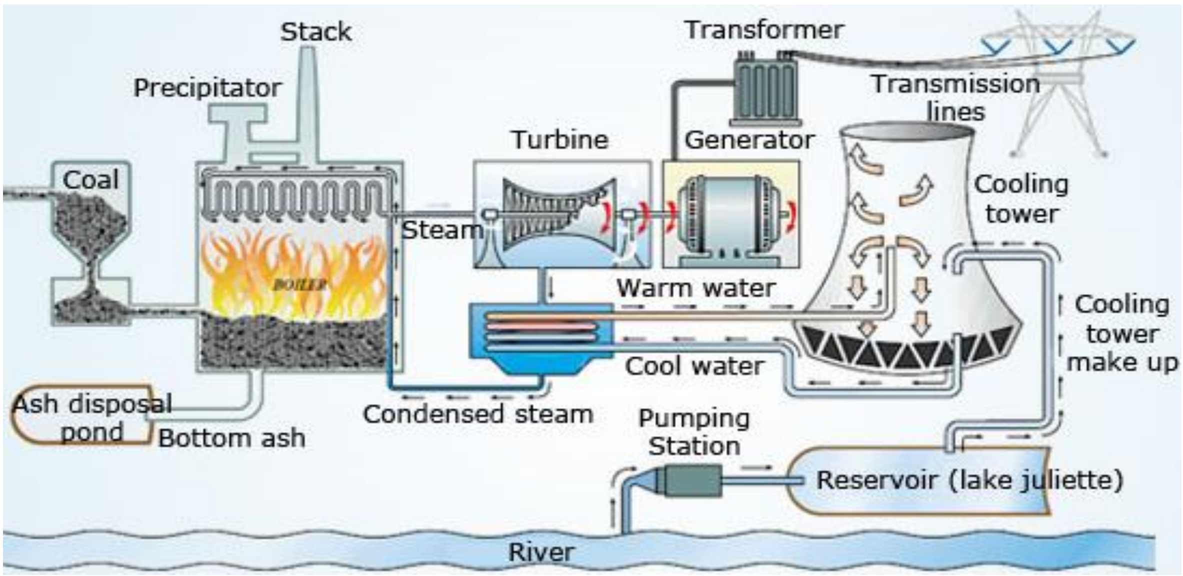
Ultra-supercritical technology represents increase in steam cycle efficiency. It operates above super-critical pressure and at an advanced steam temperature above 593°C resulting in more efficient steam cycle. This increased efficiency reduces fuel consumption, solid waste, water use and operating cost.

2.4 Process of Thermal Power Generation

The prime mover of thermal power plant is steam. The way heat energy from fuel gets transformed into steam which is further used to generate electricity forms the working of a power plant. Water is made to enter into the system, later which is heated and then converts into the steam. The generated steam is further used to rotate the turbines which are connected to alternators to produce electricity. The efficiency of thermal power plant is dependent on plant availability factor i.e., the availability of power plant during the year in percentage terms and plant load factor (PLF). Unlike in other industries, where the installed capacity is measured on an annual basis, the installed capacity in this industry is measured on an hourly basis. A company having an installed capacity of 1 MW will generate1 MW of power, i.e. 1000 units of electricity every hour. This electricity is enough to light 10,000 bulbs of a capacity of 100 Watt every hour.

The Basic Components of the Thermal Power Station are:

- Boiler
- Steam turbine
- Generator
- Condenser
- Cooling towers
- Circulating water pump
- Ash precipitators
- Step up transformers



- Boiler:

Boiler is a closed vessel in which water is boiled to convert it into steam. For better heat energy flow from fire to water, boilers are large in length. They are made up of 100 miles of pipes which are welded together. The temperature in a boiler depends upon the capacity of the power plant. It should be lower than ash fusion temperature which is usually 1100℃

- Steam Turbine:

Steam generated in boiler is high pressure and high temperature steam. This is fed to turbine. Turbine extracts thermal energy from high pressurised steam and converts it into mechanical energy by using shaft.

- Generator:

In simple language generator is an electric motor. Generator uses mechanical energy of turbine to convert it into electrical energy.

- Condenser:

As there is no heat addition or removal in steam, its entropy remains same. If we can bring back this steam to low pressure - low temperature, steam comes back to its original state and it is possible to generate electricity continuously. But huge amount of energy is required to compress gas. Hence, before compressing a fluid which is in gaseous state, it should be converted into liquid form and it can be achieved by use of condenser. It extracts heat from steam and converts it into liquid form again.

- Cooling Tower:

Boiling hot water from the steam turbine is cooled in a condenser. Then it's sprayed into the giant cooling towers and pumped back for reuse. Most of the water condenses on the walls of the towers and drips back down again.

- Ash precipitators:

It is a device which is used to remove fly ashes from electric utility boiler emission. Because of the new strict air quality codes use of ash precipitators is increasing day by day.

- Step up transformers:

Once the electricity is generated, it is important to deliver it to the consumers. Losses in energy are higher if electricity is transmitted from one place to another place at low voltage.

Accordingly, step up transformers are used to convert low voltage to high voltage thus reducing losses in transmission.

Thermodynamic efficiency of the steam turbine power plant is dependent on the temperature and pressure conditions. Higher the temperature and pressure, higher is the efficiency. Hence to increase the efficiency of steam turbine, super critical technology is developed. The supercritical steam generator was first tested commercially during the late 1950s but the material available at time were barely supported this new technology for new coal power plant. Afterwards, innovations & advances in metallurgical technology, higher temperature & pressure conditions are allowed in supercritical power plant.

Coal fired plant technology has shown progressive improvement, the overall efficiency, which was about 15% in the first decades of the 20th century, is expected to reach 55% by year 2020.

2.5 Advantages of thermal power

- Production cost of thermal power plant is low due to cheaper fuel.
- Thermal power plants can be placed near to the load centres, hence power losses in transmission can be easily minimized as compared to hydro and nuclear power plants.
- Because of development in technology, boiler and turbines are available in compacted form. Due to these reasons thermal power plant requires less area as compared to other power stations.

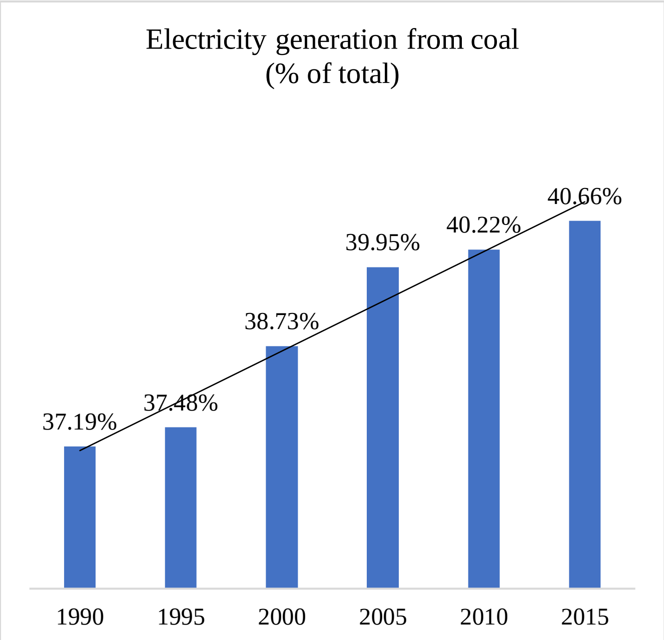
2.6 Disadvantages of thermal power

- Air pollution is the major problem with thermal power plant.
  Mitigation: Use low sulphur containing fuel; Use of closed unloading of coal with adequate suction device.
- Transportation of fuel is one of the major difficulties for the plants located away from coal field.
  Mitigation: Encourage bulk transportation by train. Only pollution certified vehicles should be engaged in transportation.

3. Thermal power Industry: Global

Improvements in thermal electricity generation technology over the past century have been made in many different areas, including boilers, turbines, generators, and transmission–distribution systems.

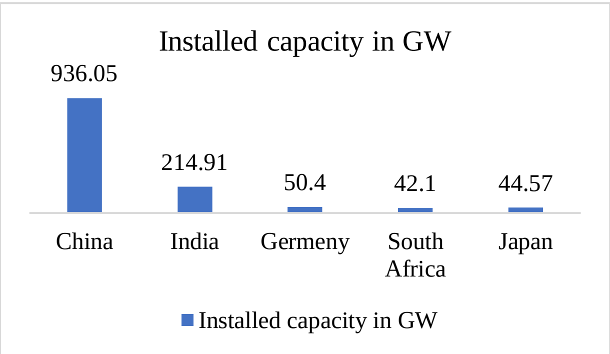
Figure 3: Thermal electricity generation from coal



Source: *world bank data*

Figure 3 shows that share of electricity generation from coal had increased to 40.66% in year 2015 and it is expected to increase further in coming years. Some of the reasons for increasing share of electricity generation from coal are, it has consistently outperformed oil and gas on an equivalent energy basis and price volatility is lesser than oil and gas. Hence, coal is likely to remain most affordable fuel for power generation in many developing countries for some decades. Also, still there is no technology which would generate power from renewable sources 24x7 as renewable energy generation is dependent on atmospheric conditions, hence, to fulfil the demand of power 24x7, thermal power generation is required.

Figure 4: Installed capacity of coal power plants worldwide (2018)

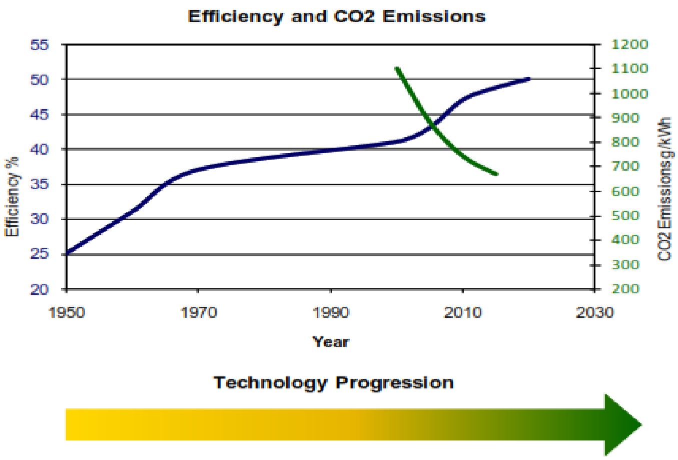


Source: *world bank data*

Figure 4 shows that China has the highest installed capacity of coal power plants which is 936.05 GW followed by India having installed capacity of 214.91 GW as of September-2018.

- **Efficiency of thermal power industry over last 30 years**

Figure 5: Efficiency of thermal power industry

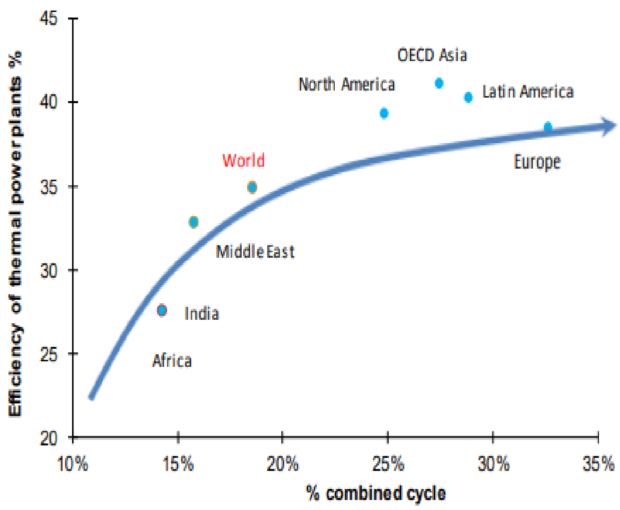


Source: *Thermal power plants efficiency report by Scottish Enterprise*

Figure 5 shows historical and expected improvement in generation efficiency (%) and reduction in emission of CO_2 (%) for coal fired power plant. Here we can see that, higher efficiency with low carbon emission is achievable only with the use of complex technologies such as supercritical plant, ultra-supercritical plant. The energy efficiency improvement in thermal power generation is closely linked to the spread of gas combined cycle plants since the year 2000.

- **Penetration of gas combined cycle technology and efficiency of thermal power generation (2010)**

Figure 6: Gas combined cycle technology and efficiency of thermal power generation



Source: *Global energy efficiency report*

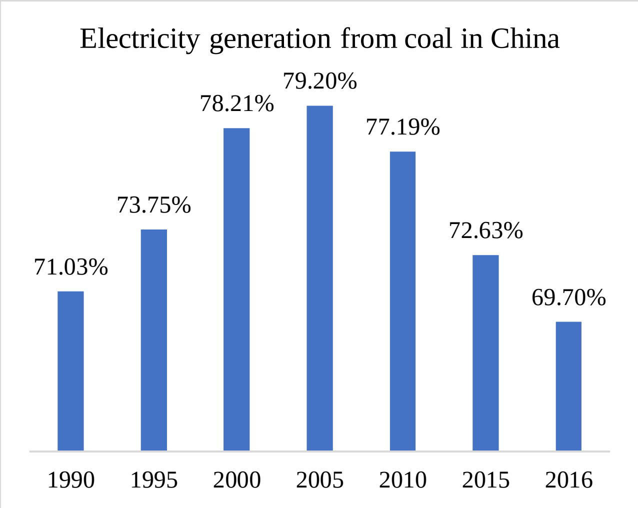
A combined-cycle power plant uses both gas and steam turbine together to produce electricity from the same fuel. In year 2010, at the world level, 19% of total thermal power installed capacity are combined cycle plants. Europe, North America, OECD Asia and Latin America whose thermal energy efficiency of thermal power plants is amongst the highest in the world, are also the regions with the largest penetration of combined cycle technologies.

Prior to year 1990, in thermal power industry, performance of a thermal power plant was measured by heat energy utilization only. According to WEC-2010, performance of a thermal power station is generally measured by availability factor, plant load factor, planned capacity loss factor and unplanned capacity loss factor etc. Environment performance is judged by the level of nitrogen oxide, sulphur oxide and suspended particulate matter emission in the air. The best practices for performance measurement across the different power generation assets globally has concentrated its focus on the value of generation as a composite benefit delivered to the grid and benefit delivered to the owners.

3.1 China

After year 1950, a complete system of electric power industry i.e. generation, transmission and distribution was built in 30 years.

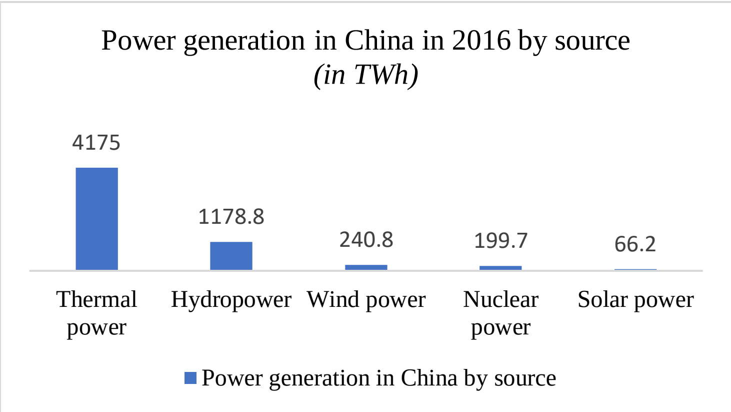
Figure 7: Electricity production from coal in China since 1990



Source: *World Bank data*

The average proportion of coal powered energy increased to 75% during 1990s because of neglect of environmental protection and increasing dependency on power, China's power generation sector relies heavily on coal and fossil-fuels. This is because, the coal users and suppliers could negotiate prices freely since year 1993. Price controls in all provinces and regions were removed in year 1994. The government then only issued guidance prices for coal used for specific purposes, such as power generation. Power generation from coal was highest during year 2005. After year 2005 it has been declining due to rise in nuclear power, wind power, hydro power, solar power. Still coal remains the major source of energy in China contributing almost 69% of total power in China.

Figure 8: Power generation in China in 2016 by source



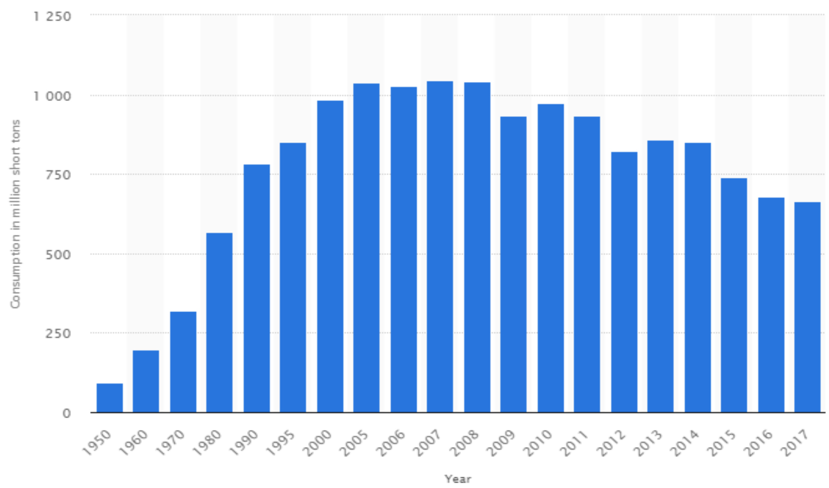
Source: *Statista-China power generation*

In year 2016 total power generated in China was 5990 TWh out of which, contribution of thermal power was almost 69.7%.

According to EIA's report, coal fired electricity generation in China which is world's largest coal consumer is expected to remain flat through 2040. Contribution of other sources in China's electricity generation such as natural gas, other renewable sources, nuclear gas is expected to increase. Though coal generation in decreasing, IEA 2017 (International Energy Outlook) projected that, coal will remain China's main source of energy generation nearly generating 4400 million KWh by 2030.

3.2 USA

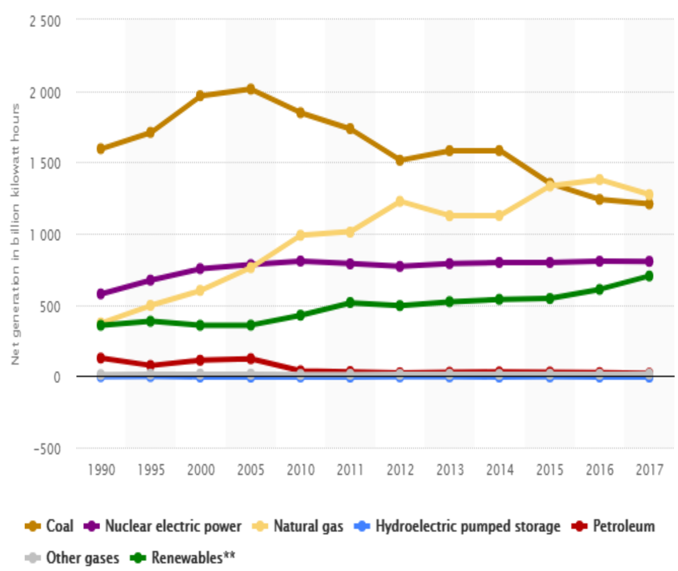
Figure 9: Consumption of coal for generation of electricity in the U.S from 1950 to 2017



Source: *Statista-US power generation from coal*

Figure 9 shows the consumption of coal in USA for generation of electricity from 1950 to 2017 in million short tons[1]. The consumption of coal has risen steadily from the 1950s to 2007 at CAGR of 4.36%. Recently, coal-fired electricity consumption has decreased in the United States from 1.1 billion short tons in 2007 to 664.75 million short tons in 2017.Though the demand for power has been increasing, coal consumption for power generation has reduced gradually since 2007 and reason for reduced consumption is availability of renewable resources and natural gas. Environmental concerns surrounding coal and its emissions have also driven its gradual decline.

Figure 10: Total U.S electricity generation from 1990 to 2017 by fuel in billion KWh.



Source: *Statista-US electricity generation by fuel*

The United States uses many different energy sources and technologies to generate electricity. Coal has seen a steeper decline than gas in the US power generation sector contributing 1.21 trillion kWh in year 2017, down from 1.5 trillion kWh in year 1990. Still coal was the 2nd largest source contributing about 30% of electricity generation in year

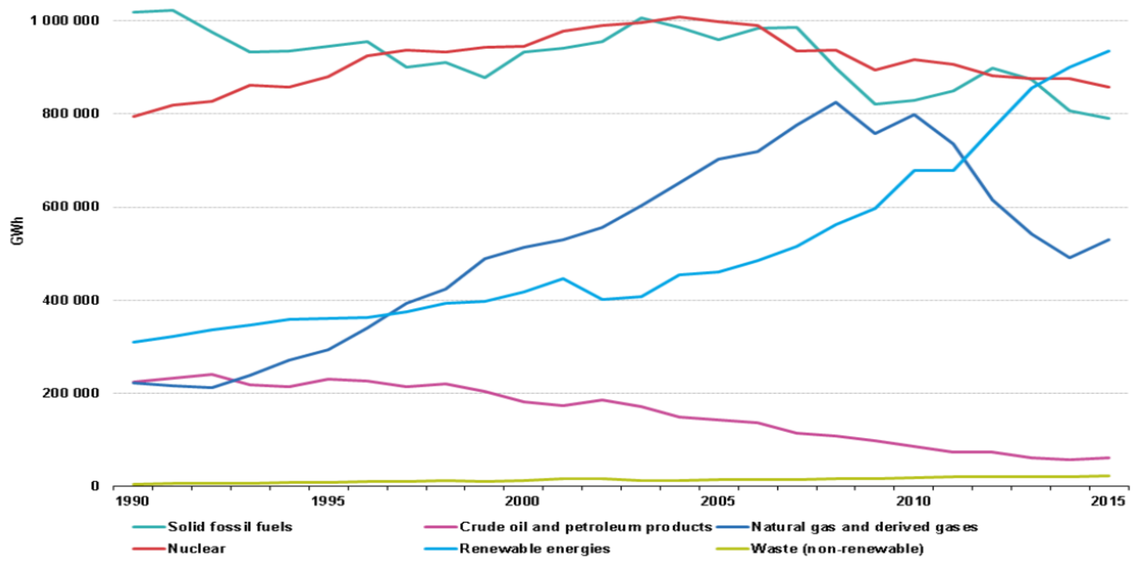
[1] *In the United States, a short ton is referred to as simply a ton.*

2017.Very few coal fired power plants convert coal to gas to generate electricity, all other power plants use steam turbines to generate electricity. Residual fuel oil and petroleum coke are used in steam turbines. Petroleum was the source of less than 1% of U.S. electricity generation in 2017.

3.3 Europe

European power sector is undergoing radical change. The decades old infrastructure mainly runs on fossil fuels. Thermal power generation remains necessary to compliment other renewable resources of energy and to ensure continuous supply of power.

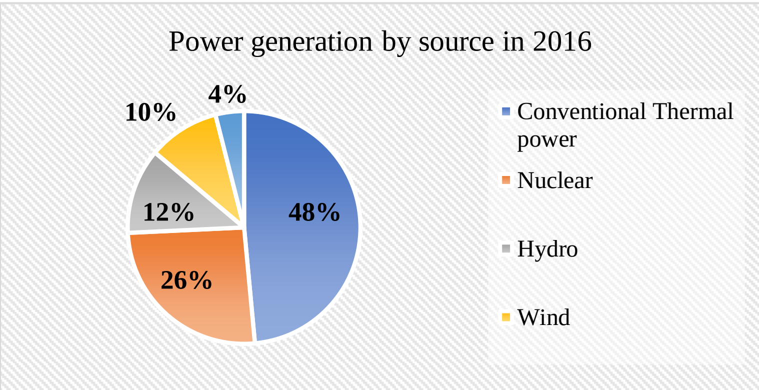
Figure 11: Gross electricity production by fuel from 1990 to 2015 (in GWh)



Source: *Eurostat- electricity generation by fuel*

There has been significant changes in generation of electricity in Europe during last two decades. Coal fired power plant were at lowest electricity production in the EU-28 since year 1990 due to increasing competition from cleaner energy sources as well as governments efforts to cut down carbon emissions.

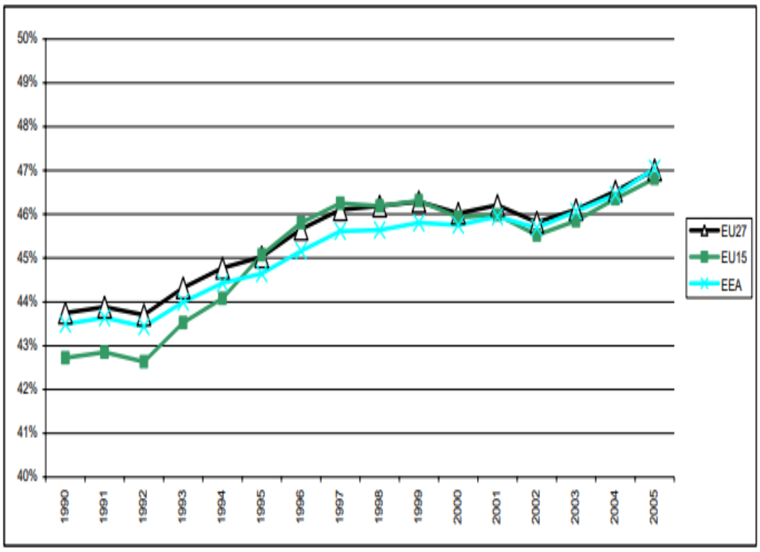
Figure 12: Power generation in Europe in 2016 by source



Source: *Eurostat- electricity generation by source*

Overall conventional power generation rose in year 2017. The increase in power demand and decline in hydro power generation were the main reasons for increase in conventional power generation.

Figure 13: Efficiency of conventional thermal electricity production in Europe



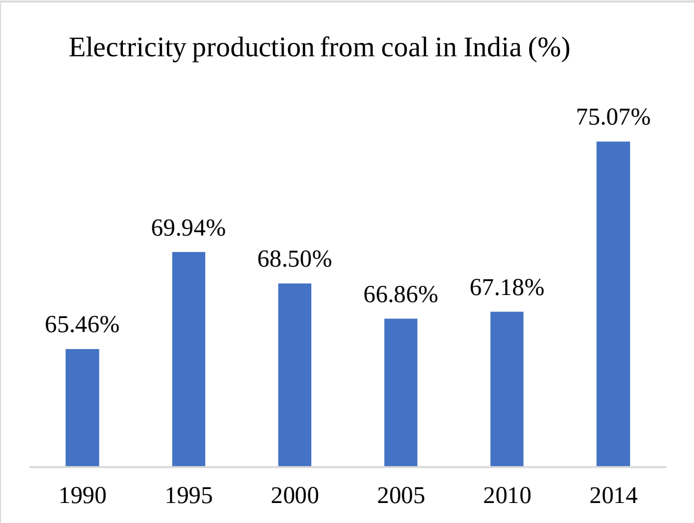
Data source: Eurostat

The efficiency of electricity production from conventional thermal power plants improved steadily between year 1990 to year 2005. The average efficiency increased was around 46% over the year 1990 to year 2005. This energy efficiency has increased due to a combination of factors including the closure of old inefficient plants, improvements in existing technologies, installation of new and more efficient technologies switch to fuels with better generating efficiency, such as from coal power plants to high efficiency combined cycle gas-turbines.

4. Thermal Power Sector- India

Electricity generation is among the eight core infrastructure sectors of India. Its importance is evident from the weight that has been assigned to it which is 10.3. India is the 3rd largest producer of electricity in the world after China and US and in year 2016 India became world's 3rd largest power consumer too. Out of total electricity generated in India, thermal power generation accounts for about 65%. Coal-based plants account for the bulk of the thermal power capacities, followed by gas-based units. That is not surprising, given that India is third-largest producer of coal globally, and yet, is also the fourth-largest importer of coal.

Figure 14: Electricity production from coal in India

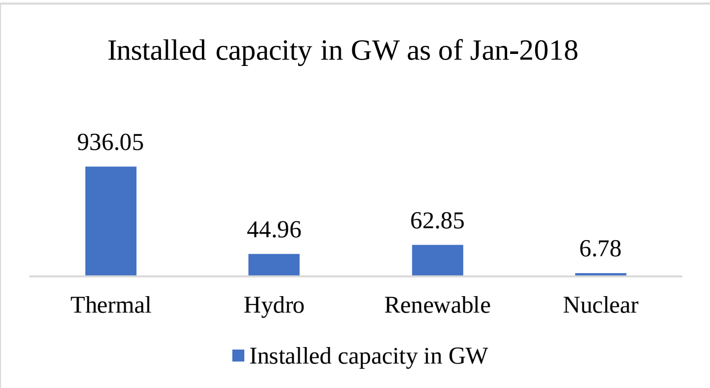


Source: *World Bank data*

India's power sector is most diversified in the world. Figure 14 shows how electricity generation from coal has increased from year 1990 to year 2014.

In India, coal-based power generation capacity was increased to 936.05 GW in January 2018 to meet the deficit arising out of low generation from hydro, nuclear and renewable power plants. Subsequently, coal offtake by power sector grew at more than double. Coal India Ltd. (CIL) recorded 10.1% growth in coal production in September-2017. As a result, cumulative growth of production till September turned positive, after staying negative till August-2017.

Figure 15: Installed power capacity in India



Source: *Quartz India*

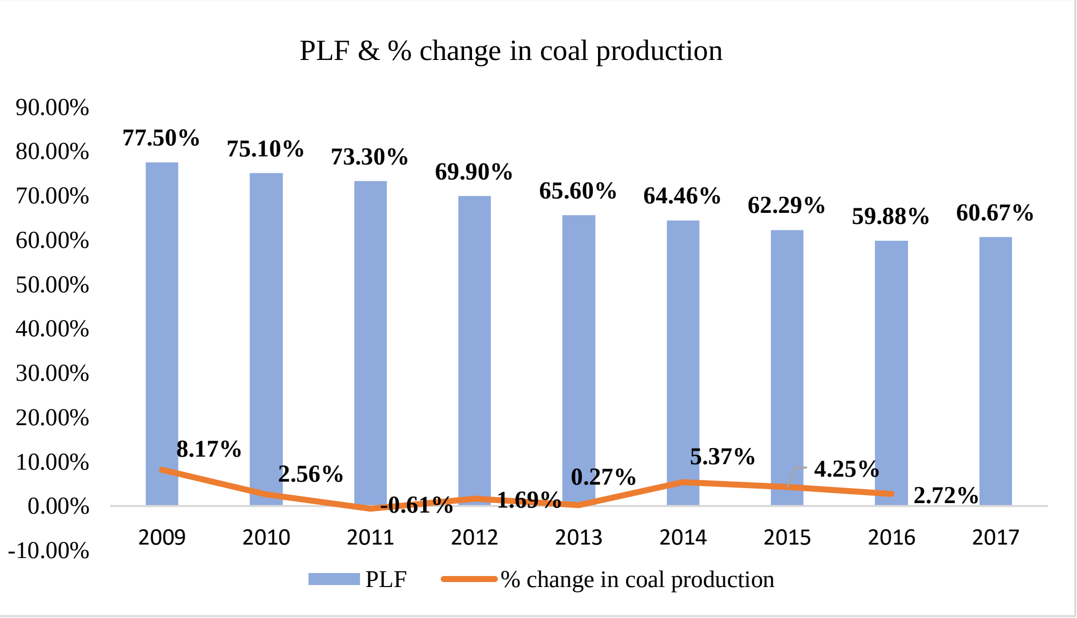
Total power generating capacity of India is 936.05 GW as of January 2018. Installed capacity of thermal power has increased at CAGR of 11% over last 10 years. Almost 88% of thermal power is obtained from coal and rest is from diesel and gas. Private sector generates almost 45.6% of thermal power, state sector generates 24.6% of thermal power and central sector generates 29.9% of thermal power. It is expected to add generation capacity of 36.6 GW of thermal power to the grid by the end of year 2019.

4.1 Efficiency of Thermal Power sector in India

As per CEA data, more than 32,000 MW of existing coal and gas-based capacity is older than 25 years and needs to be phased out. Further, most of the state-owned thermal generating stations tend to have low PLF and high station heat rates, which leads to inefficient fuel utilisation and increased per unit costs. The rise in gas-fired capacities, mostly combined cycles -which are much more efficient than coal power plants led to a smaller drop in the efficiency of thermal power plants. In year 2010 thermal power plants had an efficiency rate of 28 %, compared with 30 % in year 1990. In year 2010, gas combined cycles accounted for 14% of thermal capacities.

According to CEA, thermal power generating plants which have completed 25 years of commercial operations are either shut down or renovated. Across the country, 40037 MW of thermal power capacities were commissioned before 1993 and are headed for orderly closure, marking the end of inefficient, sub-critical plants.

Figure 16: PLF & % change in coal production



Source: *Ministry of Power India & CEIC data*

The major issues impacting most of India's coal-based power plants are lower Plant Load Factor (PLF). The PLF for coal-based plants has been progressively declining since it achieved a high of 77.5% in year 2009. PLF hit the lowest point in year 2016. The situation for private thermal power plants is worse with the drop in PLF in same period from 83.9% to 55.32%.

Coal production in India has gone down during year 2009 to year 2016 due to imbalance between the demand and supply of coal and this is one of the reasons for decreasing PLF during this period. The power sector reported shortage in supply of coal from state-run coal mines which has been affecting the operational performance of thermal power plants. The shortage can be equated to the shortfall in CILs coal production targets. Inadequate rail-connectivity and rake availability have been some of the major hurdles which led to shortage of coal during the year at thermal power plants.

Import of coal by power plants which are designed to use imported coal fell about 15% from year 2017 to March 2018. Higher coal prices and a weaker rupee forced them to cut generation.

Another reason for low PLF values is the low operating availability of thermal power plants due to high forced outage rates. Forced outages[2] are high because of the use of inferior quality coal i.e. coal having a low GCV, high ash content and high carbon emissions, unsatisfactory plant maintenance, poorly functioning transmission systems, and design defects in equipment.

India added nearly 115 GW of coal-based capacity over year 2011 to year 2017. However, demand growth did not keep pace with such capacity addition. This has put pressure on the PLFs of coal-based thermal power plants. Increasing demand, solar capacity addition and DISCOMs financial health will be the major factors putting pressure on PLF in future.

In India the cost of production of electricity from thermal power plants also fell to Rs. 3.04 per KWh during year 2016. This is mainly because the reduction in freight charges for domestic coal and reduction of import of coal.

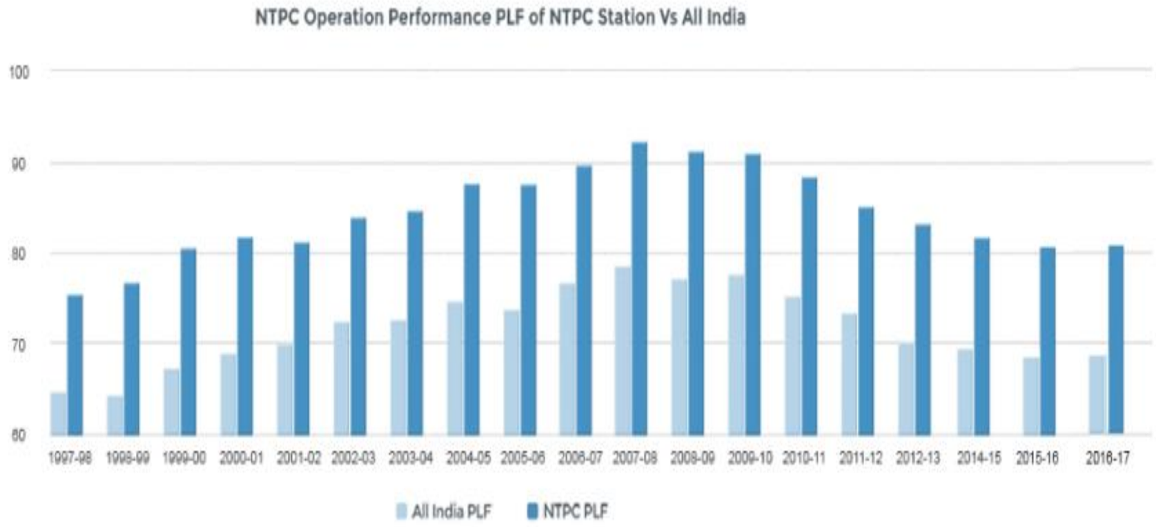
4.2 Public Sector in Thermal Power

- **NTPC:**

NTPC is India's largest power producer and the sixth-largest thermal power producer in the world, with installed capacity of 53.651 GW including 21 coal-based, 7 gas-fired stations, 1 hydro-based and 1 wind-based stations. Also 9 joint ventures are coal-based stations. By year 2032, NTPC plans to reach 128,000 MW of power capacity. Coal-based power accounts for more than 84.7 % of the total capacity.

[2] *Forced Outage Rate (FOR) is the ratio of failure hours of a generator to total service hours.*

Figure 17:PLF of NTPC vs. all India PLF



Source: *NTPC performance statistics*

NTPC has been operating its plants at higher efficiency always. Hence, in terms of operation, NTPC's operational performance is always higher than national average. Although the company has 17.73% of the total national capacity, it contributes 24% of total power generation due to its focus on high efficiency.

Generation cost is one of the most crucial parameters that accounts for more than 70% of the cost of electricity supply. Many newly commissioned thermal power plants have high tariffs and face the danger of being backed down as per merit order dispatch. NTPC has managed to bring down its production cost by 39.5 paise and the main reason for reduction of cost is supply of good quality of coal.

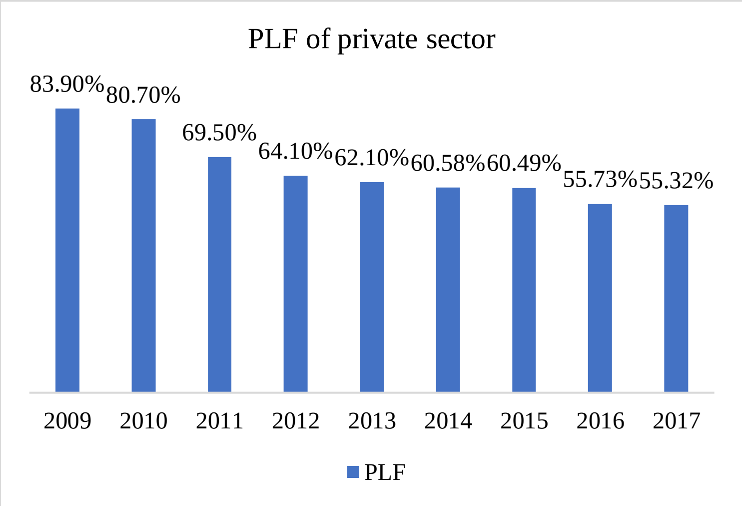
As per CEA data, more than 32,000 MW of existing coal and gas-based capacity is older than 25 years and needs to be phased out. Further, most of the state-owned thermal power generating stations tend to have low PLFs and high station heat rates, which leads to inefficient fuel utilisation and increased per unit costs. However, higher efficiency in new units with enhanced steam parameters as well as new control and operating systems has given a lead for improvement in efficiency of equipment in older units even at part load.

4.3 Private Sector in Thermal Power:

Contribution of private sector in total generation of thermal power has increased from 12% (9.6 GW) to 39% (84.2 GW) in year 2017. The installed capacity of thermal power generation in private sector as of January 2018 is 86,150.30 MW. It has increased at CAGR of 9.68% from year 2014 to year 2018.

Adani Power Ltd has India's largest thermal power capacity (10,440 MW) in private sector. They also commissioned India's first supercritical 660 MW unit at Mundra. Mundra power plant is the largest single-location coal-based thermal power plant in India and one of the top five in the world.

Figure 18: PLF of private sector



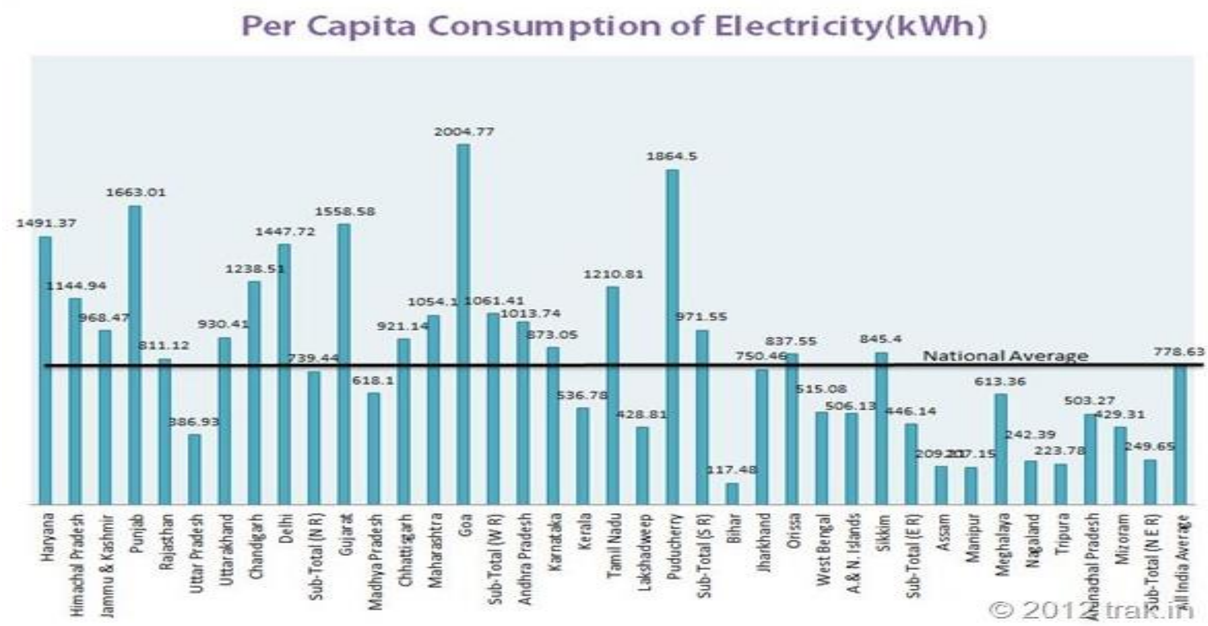
Source: *Ministry of Power India*

The PLF of private sector coal-based plants fell to 55.32% in year 2017 from 83.9% in year 2009. The private sector has been hit harder due to lack of PPA for entire capacity. Given that short-term power prices are likely to remain unchanged and DISCOMs' unwillingness to sign PPAs, these capacities are unlikely to see an increase in PLF. Private sector players face two major risks. One is availability of coal and the other one is landed cost of coal to generating stations. Because of these reasons also there is massive reduction in PLF of private sector.

4.4 Top 5 Thermal Power plants in India as per capacity

Sr. No.	Plant	Location	Capacity in MW	Operator
1	Vindhyachal Thermal power station	Singrauli, Madhya pradesh	4767	NTPC
2	Mundra Thermal power station	Mundra, Kutch district, Gujrat	4620	Adani Power
3	Mundra ultra-mega power station	Mundra, Kutch district, Gujrat	4000	Gujrat power Ltd (CGPL), a subsidiary of Tata Power
4	Sasan Ultra mega power plant	Sasan, Singrauli, Madhya Pradesh	3960	Sasan Power, subsidiary of Reliance Power
5	Jindal Tamnar Thermal power plant	Tamnar, Raigarh district, Chhattisgarh	3400	Jindal Power Ltd, subsidiary of Jindal steel & power

Figure 19 Per Capita Consumption of Electricity in India



Source: *track.in*

The national average per capita consumption of electricity is 778.63 KWh. The State of Goa (2004.77 kWh) & Puducherry (1864.5 kWh) account for maximum per capita consumption of electricity. While states of Bihar (117.48 kWh), Manipur (207.15 kWh) & Assam (209.20 kWh) show the lowest per capita consumption. 15 states in India show lower annual per capita power consumption in comparison of national average.

The eastern states of Bihar, Chhattisgarh, Jharkhand, Odisha and West Bengal are abundantly blessed with coal resources constituting 72% of the coal mine reserves but are reeling under a power deficiency. Development of coal mines, improvement in coal logistics and other similar initiatives can help these states to overcome their power deficit situation.

5. Regulators of power sector in India

State-owned and privately-owned companies are two major players in electricity in India with private sector growing at faster rate. India's central government and state governments jointly regulate electricity sector in India. In India energy sector is manged at the Central Government level, by internal coordination among five ministries: Ministry of Power, Ministry of Coal, Ministry of Petroleum and Natural Gas, Ministry of Renewable Energy and Department of Atomic Energy. Each state has its own power ministers and related departments. One of the major regulations in power sector is the Electricity Act of 2003 which came into force from 15.06.2003. The objective is to introduce competition, protect consumer's interests in terms of supply and tariff and provide power for all. Electricity act 2003 has empowered the Central electricity regularity commission (CERC) to specify the terms and conditions for the determination of tariffs.

5.1 Regulatory norms for tariff calculations

The average power tariff in India is Rs. 5 per KWh. The Indian power market has an organised market based on trading on PX. In India, tariffs have been regulated by CERC. It has specified a Pre-Tax ROE of 15.5% for the tariff period year 2009 to year 2014. Further, it has allowed an additional ROE of 0.5% for projects commissioned after April 2009 within specific timelines. The additional ROE allowed by CERC is acting as an incentive for a project developer to achieve time-bound milestones. Competitive bidding for tariff determination is in place for power procurement. The additional ROE allowed by CERC is acting as an incentive for a project developer to achieve time-bound milestones.

CERC has adopted two-part tariff scheme for thermal power (coal, lignite and gas based) generating station.

i. Capacity charges for recovery of annual fixed cost.

Annual fixed cost includes return on equity, depreciation, interest on loan capital, interest on working capital, operation and maintenance cost etc.

ii. Energy charges for recovery of fuel charges.

Energy charges for thermal power plant are linked to normative operational parameters as specified by the regulator. Normative parameter includes plant availability factor and secondary fuel oil consumption.

5.2 The cost of Thermal Power plant

The cost of power generation depends on various factors. The principal factor is the cost of fuel. Besides, other costs such as land, equipment (BTG – Boiler, Turbine and Generator), BoP (Balance of Plant, which is the requirements of the power station other than the BTG package) are also factored into the cost.

The thermal power plant cost is divided into two categories. One is initial cost and other is operational cost.

Initial cost includes-

- land cost which depends on the location
- new turbines, alternator and related machines and safety equipments
- Cost of boiler – water tube and fire tube
- Cost of building a civil structure for power plant
- Cost of building coal collection, pulverize, transportation, pre-heater, exhaust and cooling tower.
- Obtaining various government related permission.

Operational cost includes-

- Fuel cost
- Employee Cost
- Maintenance of equipment
- Commercial losses during maintenance due to shut down of plant
- Transportation of coal to source to power plant
- Miscellaneous cost

Power companies need to sign Fuel Supply Agreement (FSA) which are generally for long duration of 20-25 years. Coal India plays a major role in the Indian power sector, as it mines nearly 80% of total coal in India. Thus, any action by Coal India has an impact on the power sector.

The cost of setting up a power plant of 1 MW (gas/coal) is about Rs.6 crore. A 1 MW power plant consumes about 350-600 kg of coal per hour, based on the quality of the coal. The major cost associated with a power plant is that of the fuel.

5.3 Power Purchase Agreement

Power purchase agreement is contract between two parties one is purchaser which is generally a state-owned electricity utility and a privately-owned power producer. A PPA allows a facility owner to secure a revenue stream from the project. PPA summary of a base load thermal power plant is:

- Government enters into a contract with a private power company to establish a power plant and sell on the power to the government agency, public agency enters into PPA.
- PPAs usually take place at concession in addition to the sale and purchase of the power generated, PPA also sets out the required design and outputs and operation and maintenance specifications for the power plant.
- Also, PPA needs to provide for what happens on termination including obligation of power producer, calculation price for IPP.
- PPA should address impact on tariff in event of a change in applicable law and the mechanism for tariff adjustment.

Power purchase agreements (PPAs) are used for following purposes:

- To ensure bulk offtake of generated power.
- To ensure consistency and predictability of per unit rates.
- To ensure size of business.
- For planning peak power generation.
- To probably mitigate competition by ensuring customers for long term.

6. Transmission & Distribution of Power:

6.1 Transmission of electricity

Critical factor after generating power is transmission of power. Power stations are mostly located at places where all sources are easily available, but the end consumers of power are far away from power stations. Transmission refers to movement of electricity from power station to sub-station. Electricity is transmitted to sub stations at very high speed and at high voltage to reduce losses.

At the beginning of the 20th century, more than 4,000 individual electric utilities operated in isolation from each other. As the demand for electricity grew, especially after World War II, utilities began to connect their transmission systems. These connections allowed utilities to share the economic benefits of building large and often jointly-owned electric generating units to serve their combined electricity demand at the lowest possible cost. Interconnection also reduced the amount of extra generating capacity that each utility had to hold to ensure reliable service during times of peak demand

As per data released by World bank, losses due to transmission and distribution were about 8.069% as of 2014.These losses are accounted as a percentage of output. Major factors responsible for all technical and commercial losses are:

Technical Losses

- Overloading of existing lines and substation equipment
- Low HT: LT lines ratio- Higher amount of current flow in the system results in higher losses.
- Poor repair and maintenance of equipment
- Non-installation of sufficient capacitors/reactive power equipment

Commercial Losses

- Low metering efficiency
- Theft of electricity and tampering of meters
- Low accountability of employees
- Absence of Energy Accounting and Auditing

  Countries incurring high electricity losses are Togo (87%), Haiti (54%), Republic of the Congo (44%).

In USA, transmission & distribution losses are about 5%, in China it is about 6.47% of total energy transmitted and distributed across the country.

Renewable and non-renewable resources of electricity are unevenly distributed in India. Power grid Corporation of India Limited, central transmission utilities is responsible for planning inter-state transmission system. Similarly, SEBs are also responsible for intra state transmission system. An extensive network of transmission lines has been developed over the past few years for evacuation of power produced by power stations and distribute it to the end consumers. Depending upon the distance and quantum of power to be transferred, lines of appropriate voltages are laid. The capacity of transmission system of 220 kV and above voltage levels, in the country as on 30th November 2017 was 3,81,671 ckm of transmission lines.

6.2 Distribution of electricity

After power transmission last stage is power distribution. Main function of power distribution system is to provide power to the end consumers. Power transmitted from power station is stepped down using transformers at sub stations and then it is distributed to the consumers as high voltage power cannot be consumed by end consumers.

The term “distribution line losses” refers to the difference between the amount of energy delivered to the distribution system and the amount of energy customers are billed.

According to Power Grid Corporation of India Limited current distribution losses is about 30%. Distribution system’s losses can be attributed to technical and non-technical losses. Non-technical losses are those associated with inadequate or missing revenue metering, problems with billing or collection systems, etc. Technical losses in the system are inherently influenced by component like capacitors, resistors etc and system designs.

Ways to reduce Losses:

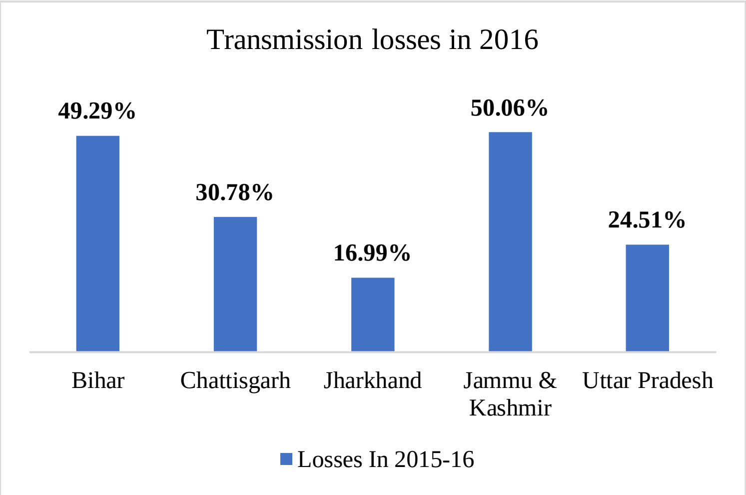
- Network reconductoring: Losses in transmission and distribution also depends on the size of the conductor. A lower size conductor can cause higher losses. Hence the recommended practice is to find out whether conductor is able to deliver peak demand to the consumers at the correct voltage
- Improving joints and connections: Improper joints are source of energy losses.
- HT/LT ratio: For high HT/LT ratio, amount of losses is lower. Higher the operating voltage, lower will be the line losses. Therefore, by increasing the HT lines the losses will be reduced.
- Preventive & regular maintenance: Care should be taken to optimize preventive maintenance, because each shutdown due to preventive maintenance is also a source of revenue loss. It can be minimized by careful design and healthy installation practices.

- Commercial losses are also caused by some deficiencies in commercial function of the utility i.e. defective metering, billing and collection system. To reduce these kinds of losses, ensure proper height for installation of meters, locate meters in fully public view, install clearly accessible & visible scale for better inspection.

Power distribution in India is handled by distribution companies commonly known as DISCOM. Reason of losses in transmission & distribution can be found in the weak financial conditions of DISCOMs.

Power transmission & distribution is critical because power generation and the place of power consumption are located far apart. Coal rich states may generate lot of power, but they may not consume that much of power generated. As a rule of thumb, in India eastern & northern states have more power generation capacity while western and southern states are larger consumers of power.
Hence the challenge before government has been to create reliable power transmission and distribution system across the country such that adequate and affordable power can be available to all citizens of the country as well as to the key sectors of the economy such as agriculture, manufacturing, healthcare etc.

Figure 20: Transmission losses in India in year 2016



Source: *faculty.in*

At an All-India level, the total transmission losses have come down from 26.63% in year 2011 to 21.81% in year 2016. South of India is the only region in the country where every state has an aggregate loss of less than 20%. In all other regions, losses are exceeding 30% as well.

6.3 Ujjwal DISCOMs Assurance Yojana (UDAY)

For many years DISCOMS have been supplying power at tariff rates which are lower than its cost. Inefficiencies in transmission and distribution of electricity such as huge losses during transmission and distribution have increased the load on finances of DISCOMs. Because of all these reasons DISCOM had borrowed heavily from banks to keep themselves running. Total debt on DISCOMs was 4.8 trillion in 2015. UDAY or Ujjwal DISCOMs assurance yojana was launched by government in November 2015 to help loss making state DISCOMs to reduce their burden.

Under this scheme states were allowed to take over three fourth of the debts of their respective DISCOMs and after that government had issued UDAY bonds to banks and other financial institutions to raise banks to pay off money. The remaining one fourth part of the debt of DISCOMs will be paid off by two ways

i) Conversion into lower interest rate loan by lender banks

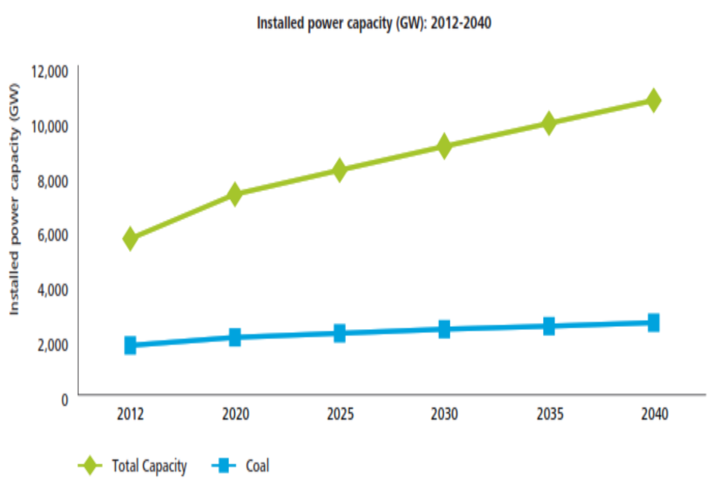
ii) To be funded by money raised by DISCOMs bonds backed by state guarantee.

In return for the bailout, the DISCOMs have been given target dates (2017 to 2019) by which they will have to meet efficiency parameters such as reduction in power lost through transmission, theft and faulty metering, installing smart meters and implementing GIS (geographic information system) mapping of loss making areas. The participating states in this scheme have achieved to reduce Aggregate Technical & Commercial (AT&C or distribution) losses by 1% and Rs.0.17 a Unit in the gap between Average Cost of Supply and Average Revenue Realised in 2016- 17.

7. Forecasting

In some areas coal is an effective fuel to generate electricity due to its availability, low restriction to transport and its prices. But in absence of effective carbon capture and storage technology, power production from coal will be less compatible with greenhouse gas reduction targets.

Figure 21: Global installed power capacity forecasting



Source: *future of global power sector by Deloitte*

Figure 21 shows the future installed power capacity which will be around 11000 GW by year 2040. From year 2012 to year 2040, world's installed capacity will increase to 89% however, the forecast for coal units would only reach to 46%. Though there is coal power generation capacity addition in Southeast Asia, India and China, there will be equivalent reduction in capacity in European Union, Russia, Japan and United States. Due to which contribution of overall coal power generation capacity would be less.

Figure 22: Cumulative power plant capacity additions (2014-2040)

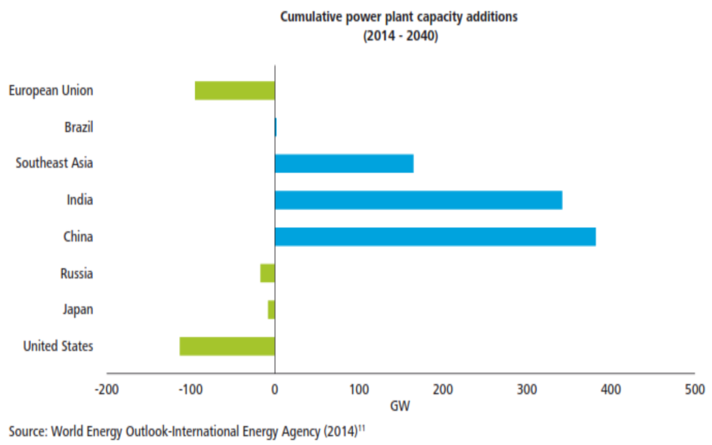
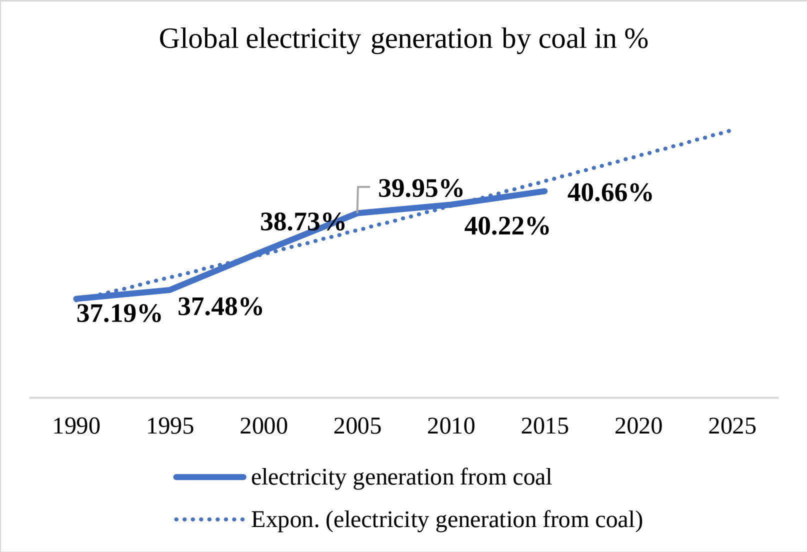


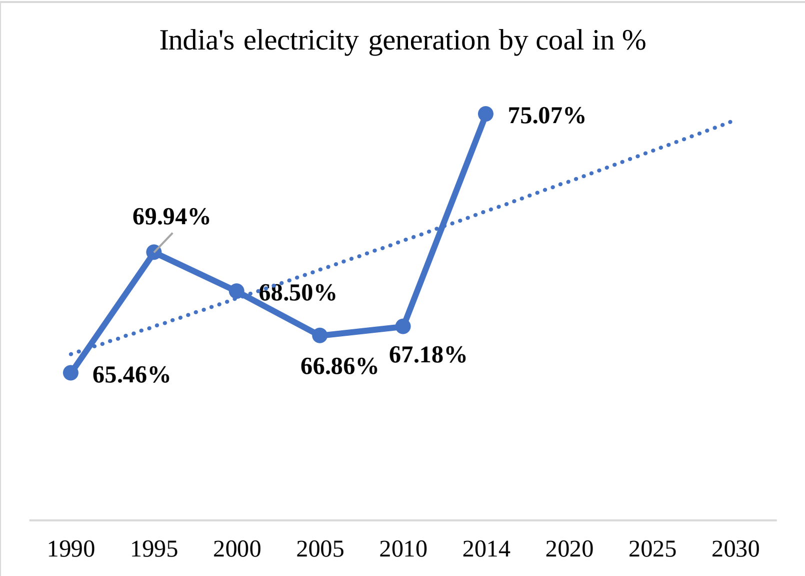
Figure-22 shows region wise coal-based installed power capacity forecasting. By year 2040, in Europe, United states, Japan, Russia natural gas cycle combined cycle turbine could be as competitive as coal due to CO_2 emission allowances and fossil fuel prices. Hence power generation by coal in these counties will go down. Graph given below shows total contribution of coal in generation of electricity by year 2025 worldwide.

Figure 23: Global electricity generation by coal in % (1990-2025)



The generation of electricity by coal will approximately account to 42% of the total worldwide generation of electricity. Out of this 42%, developing economies such as India, China will contribute major part as coal will remain the most effective fuel due to low restriction on transport and availability.

Figure 24: Electricity generation by coal in India's (%)



Electricity generation from coal in India was highest during year 2014 contributing 75.07% of total electricity generation. The pace at which demand, and consumption of power is increasing, coal would remain the main source of electricity in coming decade contributing almost 75% of total power generation of India. Also, electricity generated by renewable sources is seasonal. Sometimes it is unable to provide electricity for fluctuating demand. Until the development of complementary technology which will provide electricity for 24x7 in developing country like India, coal-based power generation would be in demand for next decade.

8. Road Map for the future

Coal supplies a third energy used worldwide and makes up 40% of electricity generation. Despite huge concerns about air pollution and green house gas emissions, coal power will continue to be significant in the future. Hence greater efforts are needed to be taken by government to embrace less polluting and more efficient technologies to ensure that coal becomes much cleaner source of energy in the coming decades. The industry push towards zero carbon coal fired power plants will continue through 2018 with R&D in ultra-supercritical and high efficiency low emission solutions.

In China coal share will continue to remain 70% to produce power. By 2040, in Europe and China natural gas combined cycle gas turbines will become as competitive as coal fired turbines due to CO2 emission norms. By 2040 worldwide power capacity could increase to 89% however the forecast for coal units would only reach 46%.

In USA, the mix of fuels used to generate electricity has changed due to differences in relative increase in cost of technology and fuels. Electricity generation from coal and nuclear energy have gradually declined and lost market share to natural gas and renewables. Renewable generation surpasses nuclear by year 2020 and surpasses coal by the mid-2030s as tax credits and lower capital costs drive solar photovoltaic and wind capacity additions.

In Europe, more than half of its power generation is sourced by non-fossil fuel resources and that share is much higher than USA, China, India, Japan. This trend of generating power from renewable sources will likely to grow further in coming years to reduce emission of CO2 and other air pollutants.

- **INDIA**

India's energy sector is one of the most critical components of an infrastructure that affects country's economic growth. Hence demand of the energy is directly proportional to the growing population, improvement in the living standard and industrialization. Coal has been the core supply for power generation since independence. But considering the present coal supply in the country and our dependency on import of the coal government is now focusing more on renewable energy. The plant load factor of the coal-based power plants may vary between 50% to 60% depending upon the demand and capacity variation of power generation. To ensure right quality of coal is supplied to power plants and help them achieve higher efficiency rates coal ministry is trying to implement third party sampling with domestic coal companies. With the prospect of electricity demand picking up with the new infrastructure being developed in the country, it is essential to focus on sustainable power generation. But to keep the power deficit minimum, thermal power plants are essential. Thermal power generation companies need to do research on how to comply with emission norms. Coal-based power capacity in India is expected to reach about 441GW by 2040. The entire power sector is dependent on the effective implementation of UDAY and the revival of DISCOMs from where the consumers are connected.

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