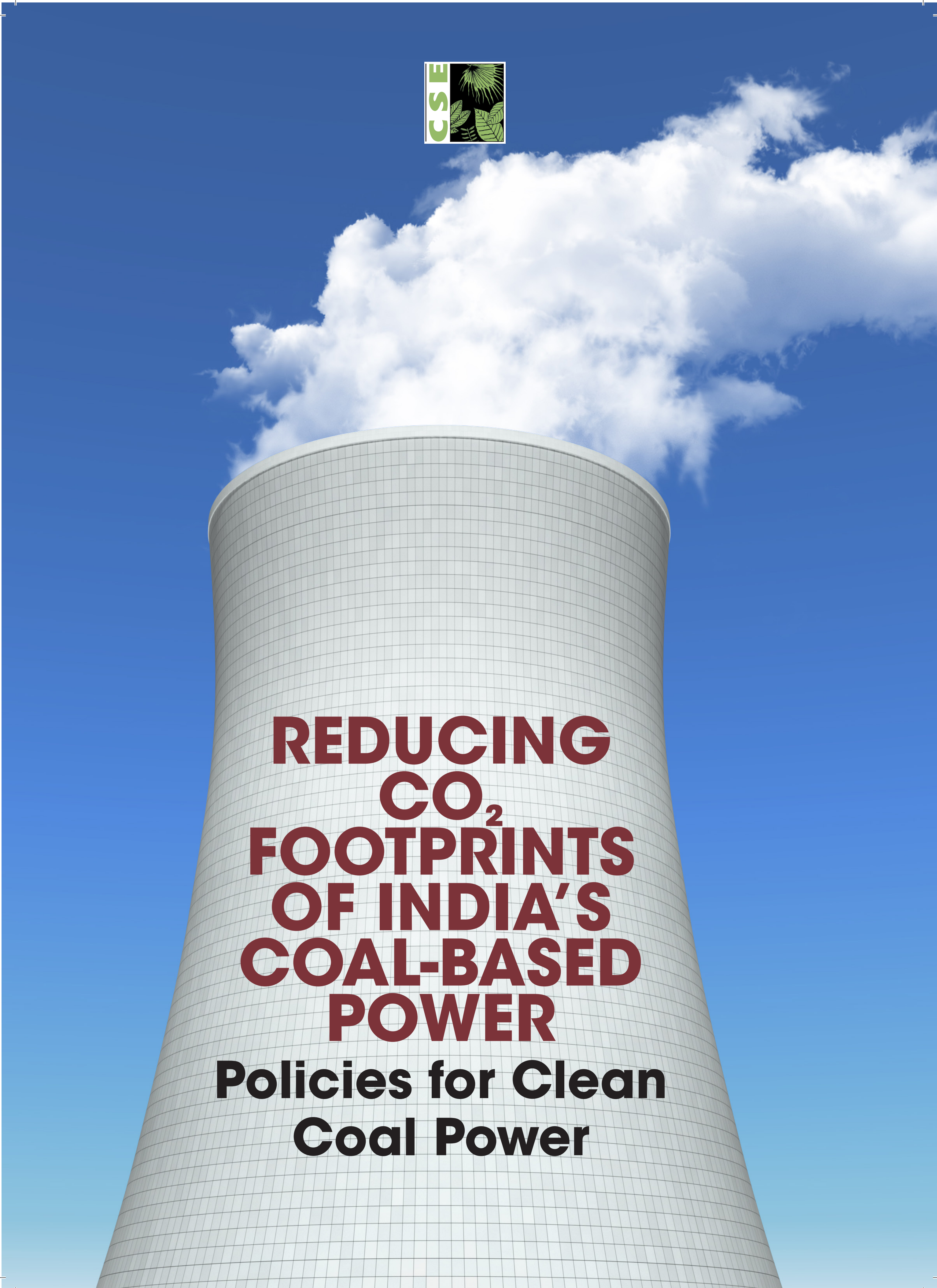

# REDUCING $CO_2$ FOOTPRINTS OF INDIA'S COAL-BASED POWER

## Policies for Clean Coal Power

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## Policies for Clean Coal Power

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SHAKTI SUSTAINABLE ENERGY FOUNDATION

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# Contents

## List of figures



## List of graphs



## List of maps



## List of tables





Reducing CO2 footprints of India's Coal-Based Power print.indd 6 29/09/20 5:27 PM

# Executive summary

With rapid expansion in the coal-based power generation in India, the sector's coal consumption increased from 300 million tonnes in 2006–07 to 600 million tonnes in 2017–18 (which is about two-thirds of the country's total coal consumption). Carbon dioxide ($CO_2$) emissions from the sector have also risen, from 500 million tonnes in 2005 to 1,000 million tonnes in 2015. In 2016, India generated 3.1 giga tonnes (Gt) of $CO_2$ equivalent ($CO_2$ eq) emissions—nearly 6.5 per cent of global GHG emissions.[1] India's coal power generation's contribution was nearly 1.1 Gt $CO_2$ eq; approximately 2.4 per cent of global emissions and 50 per cent of the country's fuel-related emissions. As per Central Electricity Authority's (CEA) projections, coal-based power will continue to play a crucial role in India's energy security, with the capacity expected to rise from 205 GW in 2020 to 266 GW in 2030. As our reliance on coal extends into the future, we need to identify pathways to decarbonize our fleet through technological, regulatory and policy interventions and decisions. This paper takes an in-depth look into this matter.

Specific $CO_2$ emissions are a function of the efficiency of a thermal power plant, which in turn depends on its size and age, and the technology it utilizes. India has a relatively young fleet—around 64 per cent of the capacity is less than a decade old. Less than one-third of India's coal capacity is supercritical, only 1 per cent in ultra-supercritical and the rest is subcritical, whereas China and Japan have significant portions with ultra-supercritical technology. Due to additions to the supercritical fleet and retirement of old plants, the average design efficiency of India's fleet has risen from 32 per cent in 2014 to 37.2 per cent in 2016, which is close to the world average of 37.5 per cent. However, our average efficiency is still lower than China's (39 per cent) and Japan's (43 per cent) average efficiency. India has the second highest specific $CO_2$ emissions, standing at 983 g/kWh; 22 per cent higher than the world's lowest specific $CO_2$ emissions.

Efficiency of a thermal power plant directly affects its $CO_2$ emissions, i.e., a 1 per cent rise in efficiency reduces $CO_2$ emissions by 2–3 per cent. When an ultra-supercritical plant replaces a supercritical plant, it can reduce $CO_2$ footprints by 6–9 per cent. However, there is no clear roadmap for induction of ultra-supercritical or advanced ultra-supercritical technology in India.

India needs to retire around 40–50 GW of its existing capacity by 2030. These units are subcritical with a design efficiency of 35 per cent. When they are replaced by ultra-supercritical plants of 43 per cent efficiency, $CO_2$ footprints of the sector will be reduced by 14–21 per cent. Renovation and modernization (R&M), and life extension of coal power plants can contribute substantially to reduction in India's overall $CO_2$ emissions. Under the new policy, the primary focus will be on 500 MW units that are more than 15 years

**3.1 Gt**

**India's carbon dioxide equivalent emissions in 2016**

**40–50 GW**

**Coal power capacity India needs to retire by 2030**

old. Introduction of efficient coal technology will need larger investment and has limited $CO_2$ reduction scope whereas R&M is cost effective. If old power plants are shifted to biomass co-firing or waste-to-energy plants through life extension projects, significant reduction can be achieved in coal-based power's $CO_2$ footprints.

CEA's notification on co-firing 5–10 per cent biomass can potentially replace 50–100 million tonnes of coal by 2030. It will be equivalent to a 90–180 million reduction in $CO_2$ emissions. Biomass co-firing has been accepted as the most economical method to reduce carbon footprints of coal power plants.

Carbon capture storage (CCS) can also reduce $CO_2$ emissions by 80–90 per cent but, at present, CCS does not look very promising for coal-based thermal power plants. CCS is absent from the Intended Nationally Determined Contributions (INDCs) of most countries—only 11 out of 189 countries have mentioned CCS technology. By 2019, only 19 CCS facilities were operational, of which only two were in the coal-based power sector. Commercialization of CCS in industrialized countries will decide its future in India. It can only be expected to gain credence after 2030.

Carbon pricing and trade systems have played a crucial role in the decarbonization of developed economies. Many developing countries have also executed or planned carbon pricing or trading regimes. Currently, India does not have any carbon pricing regime since coal tax was subsumed into GST. As per an Ernest and Young (E&Y) estimate for India, a carbon tax equivalent to US $10 can reduce $CO_2$ emissions by 8 per cent from business-as-usual (BAU) levels and a carbon tax equivalent to US $35 can reduce $CO_2$ emissions by 22 per cent from BAU levels.

Merit Order was designed to automatically incentivize efficient plants. However, at the national level, it has been observed that many stations with low energy charge rate are not fully scheduled whereas costlier stations are scheduled. Thus, Merit Order needs to be implemented considering the efficiency of operations at the national level. Bureau of Energy Efficiency's (BEE) 'perform, achieve and trade' (PAT) scheme needs to play a bigger role by setting more stringent targets for stations. Through deeper analyses of performance of thermal power plants, BEE's 2020–30 PAT cycles can achieve higher efficiency improvements and $CO_2$ reductions.

As per CSE analysis, based on various interventions, more than 20 per cent reduction in $CO_2$ emissions is possible by 2030 from a BAU scenario.

# 1. Introduction

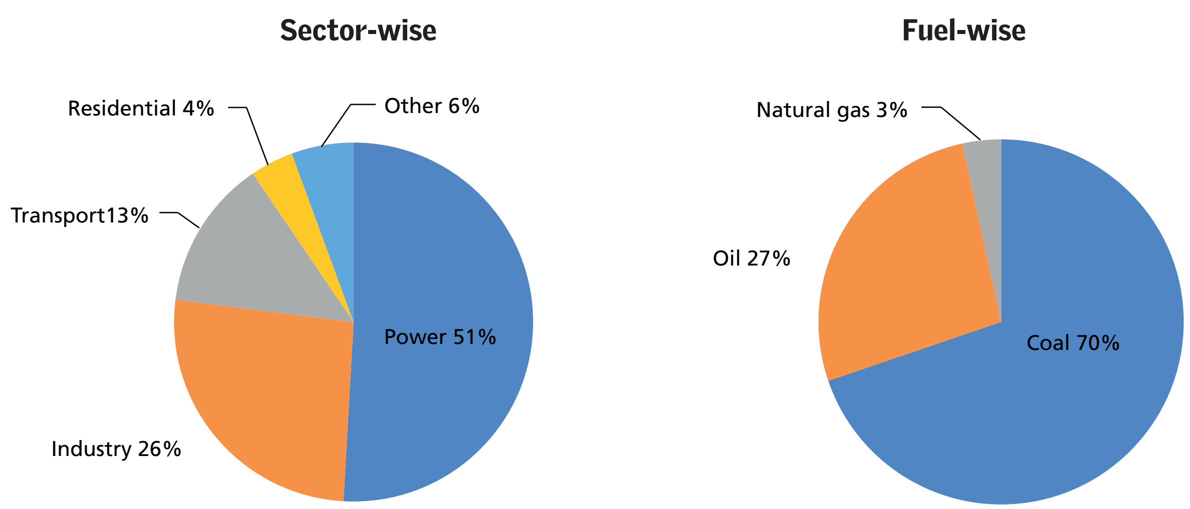
During the last two centuries, there has been a rapid rise in $CO_2$ levels in the atmosphere due to anthropogenic activities. Being a greenhouse gas (GHG), increasing levels of $CO_2$ are resulting in rise in global temperature. The global average annual concentration of $CO_2$ in the atmosphere averaged 407.4 ppm in 2018, a substantial increase from pre-industrial levels, when it ranged between 180 and 280 ppm.[2] The world has already witnessed a temperature rise of 0.8ºC, which is further set to increase up to 2ºC if stringent action to curb GHG emissions is not taken.

Global $CO_2$ emissions stand at 46 Gt, in which the energy sector contributes 36 Gt (or 78 per cent). Coal is the single biggest contributor to anthropogenic climate change. Coal-based electricity contributes nearly 15 Gt (30 per cent) of global GHG emissions and contributes 41 per cent of GHG emissions from energy-related activities.[3] A major portion of these emissions occur in Asia, where the average plant is only 12 years old and can still look forward to many years of economical feasiblity.

In 2016, India generated 3.1 Gt of annual $CO_2$ eq emissions, which contributed nearly 6.5 per cent to total global GHG emissions.[4] India's annual fuel-related $CO_2$ emission are 2.16 Gt. Coal, being the primary fuel of the Indian economy, contributes 70 per cent to the overall fuel-related $CO_2$ emissions. Power sector contributes nearly 50 per cent of the sector-wise $CO_2$ emissions. Coal-based power generation contributes nearly 1.1 Gt, which is about 50 per cent of the total fuel-related emissions.

**Graph 1 : $CO_2$ emissions based on sector and fuel usage in India**

*Coal and coal-based power are the single largest contributors of $CO_2$ emissions in India*



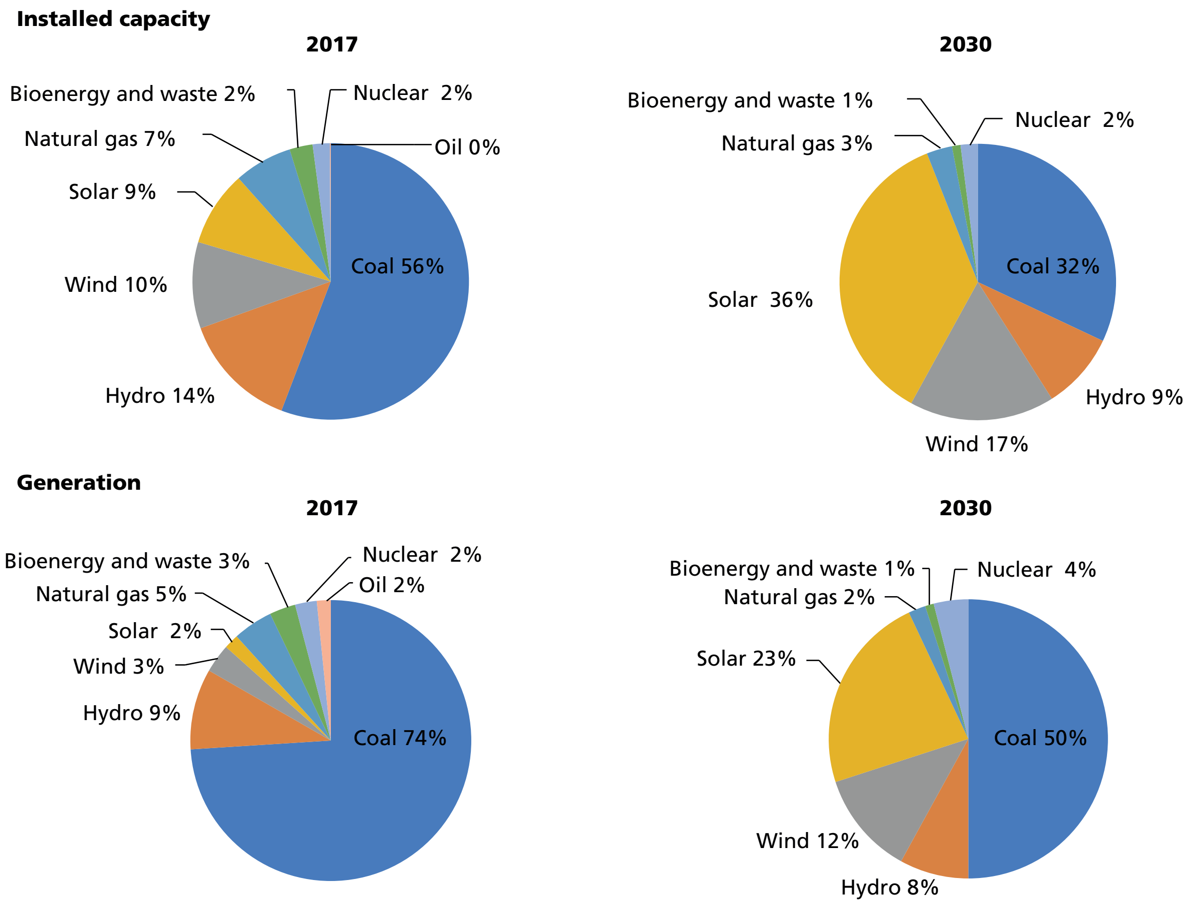

*Source: IEA, 2020*

## Indispensable for India's energy security

More than two-thirds of India's coal consumption happens in coal-based power generation (around 600 million tonnes). Coal-based power generation sector contributes around 50 per cent of India's fuel-related $CO_2$ emissions. The sector has played a vital role in meeting India's growing energy needs. During the last two decades, India has witnessed a rapid expansion in its coal-based power generation. During the period 2010–17, India's coal capacity almost doubled from 95 GW in 2010 to 195 GW in 2017. Electricity deficit has also gone down from 7 per cent to 0.8 per cent. Between 2012–17, coal power's contribution in total installed capacity and total generation have been around 60 per cent and 73 per cent respectively. In 2017, it was 56 per cent and 74 per cent respectively. By 2030, even with rapid increase in renewable energy as per India's INDC under the Paris Agreement, 60 per cent of installed capacity will remain fossil fuel-based, 90 per cent of which will be coal-based and the rest (10 per cent) oil- and gas-based. Installed capacity of coal-based power generation is expected to increase to 266 GW by 2030. It will contribute 32 per cent to the total installed capacity and 50 per cent to electricity generation (see *Graph 2: Installed and generation capacity of coal-based power plants*).[5]

### Graph 2 : Installed and generation capacity of coal-based power plants

*Coal capacity will increase to 266 GW by 2030, contributing 50 per cent of the total electricity generated*




*Source: IEA, 2020*

In recent decades, with the rapid expansion in coal-based power generation, coal consumption has increased from 300 million tonnes in 2006–07 to 600 million tonnes in 2017–18. Simultaneously, $CO_2$ emissions related to coal-based power have almost doubled, from 500 million tonnes in 2005 to almost 1,000 million tonnes in 2015. To keep global warming to less than 2°C from pre-industrial levels, countries agreed to INDCs to reduce GHG emissions. India, being the world's third largest emitter of GHGs after China and the US, promised to reduce its GHG emissions intensity by 33–35 per cent by 2030 from 2005 levels.[6]

**300 million tonnes**

**Consumption of coal in India in 2006–07**

Despite our drastic shift towards renewable power, coal-based power generation will remain the prime contributor to India's installed capacity and electricity generation for some time to come. Although some reports suggest India will be able to meet its INDC targets with renewable installation alone, without efforts to reduce the GHG footprints of India's coal-based fleet rapidly, the country will find it difficult to do so. So, while India is expanding its coal capacity, it cannot afford to do so without a clear policy roadmap to decarbonize the country's coal fleet. Standing in 2020, time is running out to make these changes. India cannot delay policy decisions and their implementation in this regard.

**600 million tonnes**

**Consumption of coal in India in 2017–18**

The objective of this paper is to present various possible methods based on technological, financial and regulatory policy decisions to improve $CO_2$ emissions performance of India's coal power sector, including (but not limited to) improvements in fleet efficiency; renovation of old and inefficient plants; introduction of new technologies, biomass co-firing, and carbon capture and storage; and implementation of carbon pricing, more stringent BEE PAT cycles and tariff-based incentives.

# 2. Current $CO_2$ emissions from India's coal fleet

Specific $CO_2$ emissions from a coal power plant are a function of its size, vintage, and the technology it employs. These parameters determine the efficiency of operation. Overall, India has a relatively young fleet—around 64 per cent (132 GW) of the capacity is less than a decade old. About 73 per cent (150 GW) is less than 15 years old. About 16 per cent (33 GW) is older than 25 years. Of the 33 GW of older capacity units, a major share (about 76 per cent) belongs to small units of up to 250 MW and less.

**Table 1: Age distribution of India's coal fleet**

*Most Indian coal power plants are young, and can look forward to many years of financial viability*

| Unit capacity | Vintage | | | | | Total |
|---|---|---|---|---|---|---|
| | > 35 | 26–35 | 16–25 | 3–15 | 0–2 | |
| Up to 250 MW | 9 | 16.15 | 12.95 | 20.78 | 1.95 | 61 |
| > 250 and < 500 MW | 0 | 0 | 0.6 | 14.71 | 2.67 | 18 |
| 500 MW and < 650 MW | 0.5 | 7 | 7 | 55.29 | 1.7 | 72 |
| 650 MW and above | 0 | 0 | 0 | 38.39 | 16.16 | 55 |

*Source: CSE, 2020*

## Technology

Till 2009, all installed capacity was subcritical. In 2010, India installed its first supercritical plant, which has 3–4 per cent higher design efficiency than subcritical plants. In 2012, under the 12th five-year plan, it was decided that 50 per cent of subsequent coal capacity will be supercritical and from the 13 five-year plan onwards, 100 per cent capacity will be supercritical. There was no clear roadmap for ultra-supercritical plants or advanced ultra-supercritical plants. By 2019, less than one-third of India's coal capacity was supercritical, the rest was subcritical (see *Graph 3: India's coal fleet technology*). In that year, NTPC installed the first ultra-supercritical plant in Khargone, Madhya Pradesh, with a capacity of 1,320 MW. NTPC is also planning to install ten such plants in the near future.

## Efficiency of the existing coal fleet

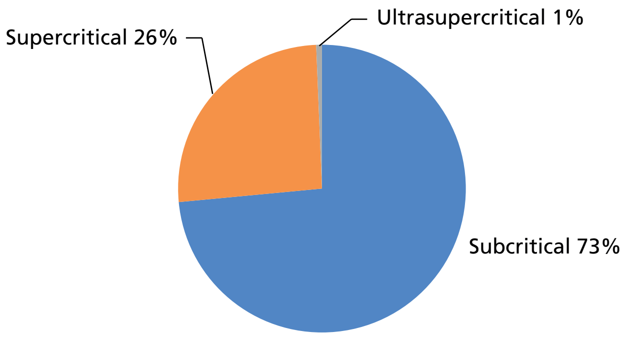
**64 per cent**

**Of India's coal power capacity is less than ten years old**

India's power plant fleet has remained among the least efficient in the world. In 2005, the average net efficiency of the entire fleet was merely 29 per cent.[7] In 2014, CSE's green rating of thermal power plants (*Heat on Power*) highlighted critical issues with India's coal-based power plants, and the fleet's poor efficiency was one of the them.[8] As per the CSE study (for the years 2012–14), India's fleet efficiency was 32.8 per cent, lowest in the world. However, as per the International Energy Agency (IEA), there has been a dramatic increase in India's average fleet efficiency, which has risen to 37.2

**Graph 3 : India's coal fleet technology**

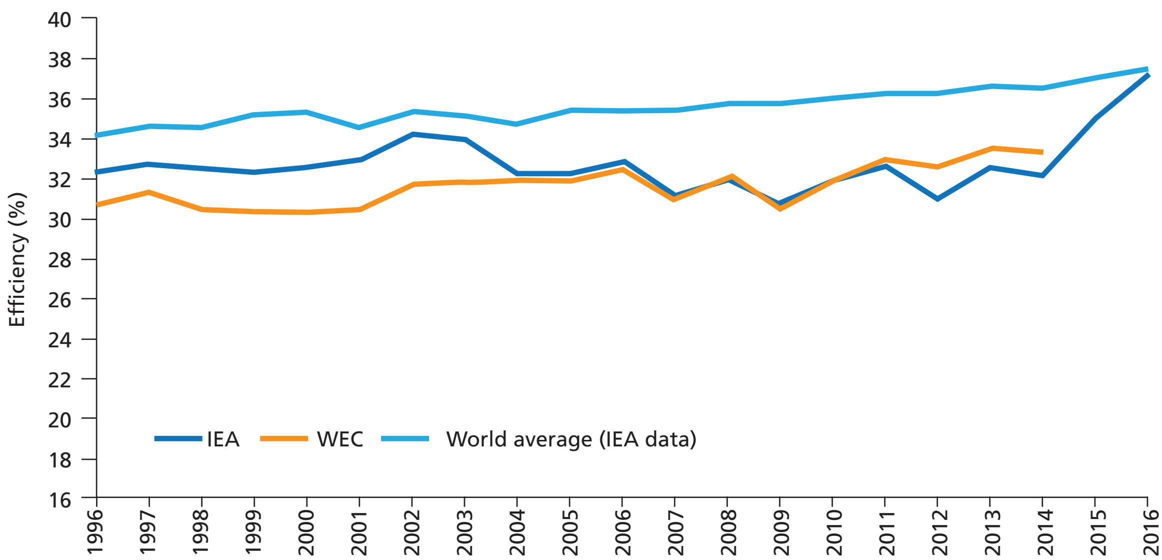
*Less than one-third of the capacity is supercritical*




*Source: CSE analysis*

**Graph 4: Efficiency of India's coal fleet over the years**

*Efficiency of India's coal fleet has increased by 5 percentage points between 2014–16*




*Source: IEA, 2020*

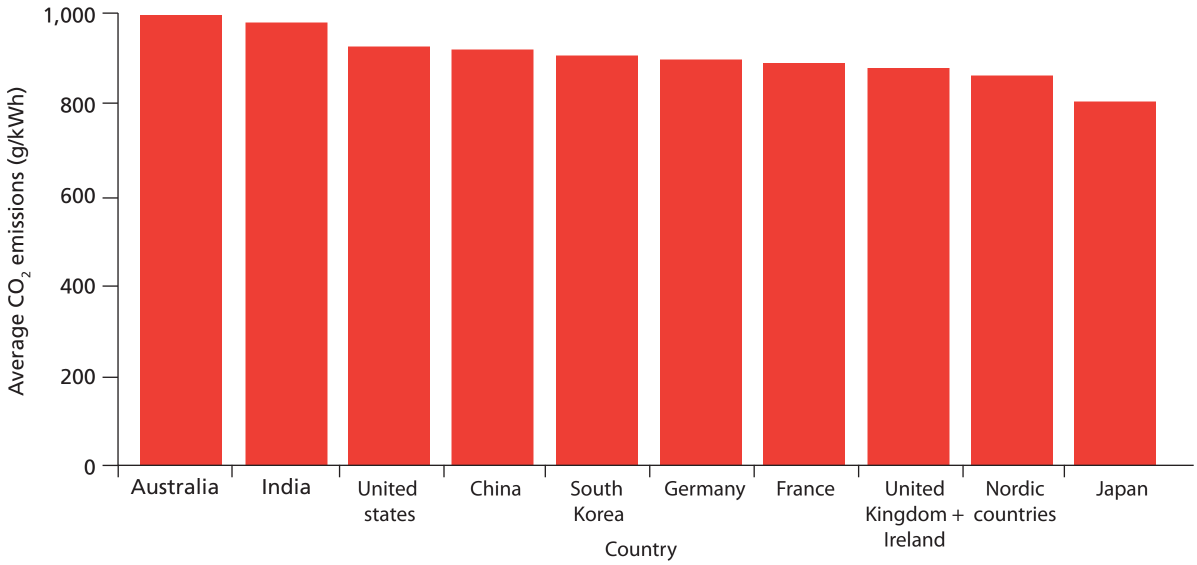
per cent in 2016, from 32 per cent in 2014.[9] An Ecofys (2018) analysis yielded similar numbers.[10] India is now only the third-lowest performer (in front of Australia at 35.2 per cent and the United States at 36.7 per cent). This change is likely due to significant supercritical capacity being installed and inefficient older plants being retired.

$CO_2$ emissions per unit electricity generated are an important indicator of the rate of increase in $CO_2$ emissions in the country. In 2015, CSE's green rating study, based on 2012–14 data, found that India's coal power generation was the worst performer with specific $CO_2$ emissions standing at 1,080 g/kWh, significantly higher than the world's best figures of 790 g/kWh. However, the situation has improved for the Indian fleet due to the installation of supercritical plants and the retirement of old and inefficient plants. During the period 2014–16, average $CO_2$ emissions intensities for coal-fired power generation ranged between 804 g/kWh for Japan to 995 g/kWh for Australia. India had the second highest specific $CO_2$ emissions, standing at 983 g/kWh, about 22 per cent higher than the world's lowest.

Due to higher GHG emissions intensity with respect to the world's best, there is significant scope of improvement in India's coal-based power sector. The country can potentially achieve a 26 per cent reduction in specific emissions from thermal power plants.

**Graph 5: Global comparison of specific $CO_2$ emissions of coal-based power**

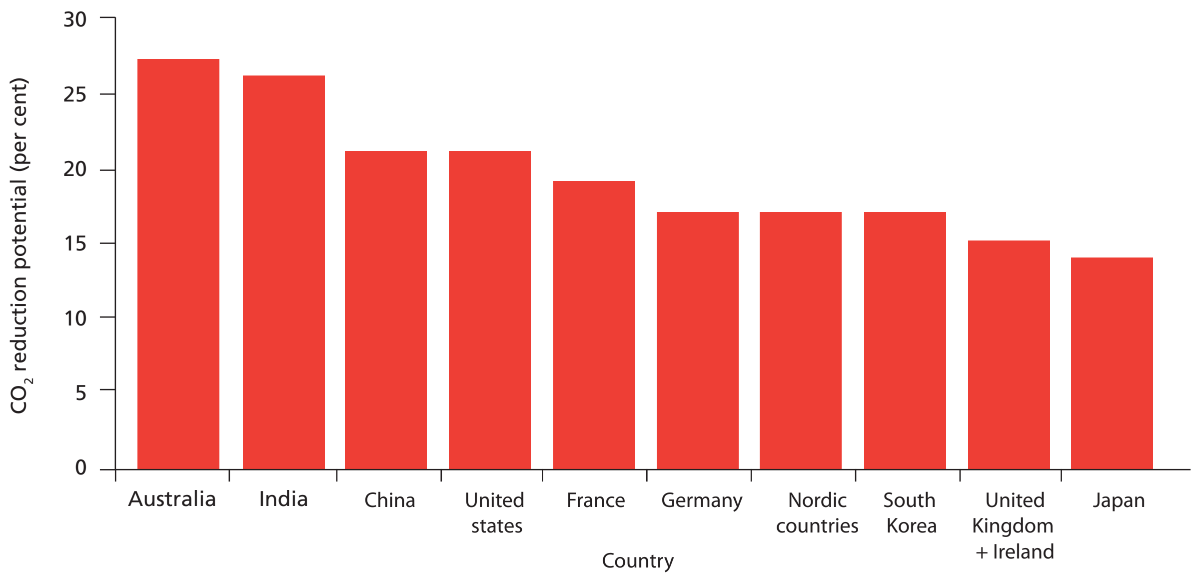
*India's coal-based fleet has the second highest specific emissions of $CO_2$*




*Source: Ecofys, 2018*

**Graph 6: Average $CO_2$ reduction potential by country**

*Australia and India have the highest $CO_2$ reduction potential*




*Source: Ecofys, 2018*

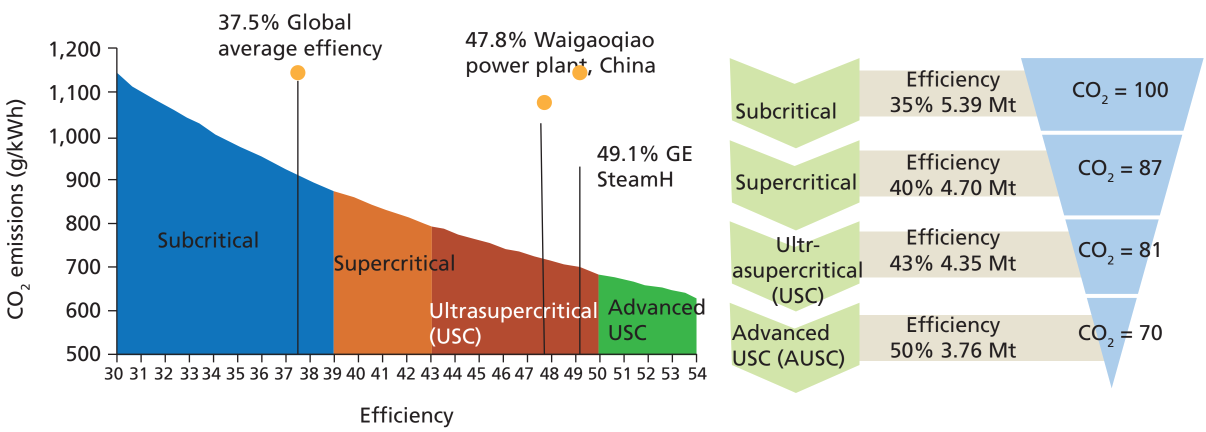
# 3. Potential pathways to reduce $CO_2$ emissions from India's coal fleet

## Introduction of new technology

Design efficiency of a thermal power plant—its coal consumption and $CO_2$ emissions—is mainly determined by the technology it utilizes. The main difference between subcritical, supercritical, ultra-supercritical and advanced ultra-supercritical technologies are the temperature and pressure at which they operate, which affect the heat carrying capacity of the steam and, consequently, its efficiency (see *Graph 7: Comparison of efficiency and $CO_2$ emissions of thermal power plant technologies* and *Box: Various available coal technologies*). Efficiency can be measured in terms of heat rate. Heat rate is the energy required to produce one unit of electricity and is measured in kcal/kWh. Lower the heat rate, more efficient the plant and lesser will be the coal consumption at and $CO_2$ emissions from the plant. Estimates of $CO_2$ emissions for a plant are primarily based on coal consumption. However, if we want to correlate $CO_2$ emissions directly with a plant's efficiency, about 1 per cent rise in efficiency reduces $CO_2$ emissions by 2–3 per cent. So, if a subcritical plant of 35 per cent efficiency is replaced by an ultra-supercritical plant of 43 per cent efficiency, the $CO_2$ footprints will be reduced in the range of 16–24 per cent.

**Graph 7: Comparison of efficiency and $CO_2$ emissions of thermal power plant technologies**

*Replacing a subcritical unit with an advanced ultra-supercritical unit can reduce $CO_2$ emissions by 30 per cent*




*Source: IEA, 2020*

## Progress on advanced thermal technology in some countries

In the last decade, China and Japan have taken giant strides forward in the development of advanced thermal power technology. China has increased the efficiency of its coal power fleet by 0.5–0.7 per cent annually and its present average efficiency stands at 39 per cent, which is 1.5 per higher than world average coal efficiency. This is largely due to a shift from subcritical plants to supercritical and ultra-supercritical plants. By 2018, only 50 per cent of the Chinese coal power fleet remained subcritical, around 28 per cent was supercritical and the rest was ultra-supercritical. Some plants in China are operating at as high efficiency as 47.8 per cent.

Similarly, Japan has made tremendous progress in ultra-supercritical technology. Most new coal power installations in the country during the last decade have been ultra-supercritical, with an efficiency of over 50 per cent. With the result, the average efficiency of Japanese coal power sector has risen to 43 per cent, 5.5 per cent higher than the world average.

## Various available coal technologies[11]

**Subcritical technology:** It is the most commonly used technology in coal-based plants in India. Pulverized coal is injected into a boiler and burned to raise the steam for subsequent expansion in a steam-turbine generator. Subcritical units are typically designed to achieve thermal efficiencies of up to 38 per cent. The capital cost of a project is around 4.5 crore/MW, approximately 10–20 per cent lower than the cost of a supercritical unit.[12]

**Supercritical technology:** Here, steam is generated at a pressure above the critical point of water. Supercritical plants can typically reach an efficiency of 42–43 per cent. The initial capital cost of the project could be Rs 5 crore/MW. The cost of generation of 1 kWh of power in a supercritical plant is Rs 2–2.5, almost half of that of a typical subcritical power (Rs 4).[13] All new units in India are required to have at least supercritical technology.

**Ultra-supercritical technology:** This is similar to supercritical generation, but operates at even higher temperatures and pressures. Thermal efficiencies may reach 45 per cent. Current ultra-supercritical plants operate at temperatures of up to 620°C, with steam pressures ranging between 25 MPa and 29 MPa. The capital cost is around 15–20 per cent higher than that of supercritical technology.

**Advanced ultra-supercritical technology:** Uses the same basic principles as ultra-supercritical technology. This technology aims to achieve efficiencies in excess of 50 per cent, which will require materials capable of withstanding steam conditions of 700°C to 760°C and pressures of 30 MPa to 35 MPa. Developing super-alloys and reducing their cost are the main challenges to the commercialization of this technology.

**Integrated gasification combined cycle (IGCC):** Coal is partially oxidized in air or oxygen at high pressure to produce fuel gas. Electricity is then produced via a combined cycle. In the rest of the phase, fuel gas is burnt in a combustion chamber before expanding the hot pressurized gases through a gas turbine. The hot exhaust gases are then used to raise steam in a heat recovery steam generator before expanding through a steam turbine. IGCC incorporating gas turbines with 1,500°C turbine inlet temperature are currently under development, and may achieve a thermal efficiency approaching 50 per cent. IGCC plants require appreciably less water than pulverized coal combustion technologies. The capital cost of current IGCC units ranges between US $1,100/kW and US $2,860/kW.[14]

### Future trajectories of India's coal fleet and $CO_2$ emissions reduction

India's average fleet efficiency rose to 37.2 per cent in 2016, from 32 per cent in 2014. The 5 percentage points increase in efficiency means India achieved 10–15 per cent reduction in $CO_2$ emissions. Under the 12th five-year plan (2012–17), half of the new capacity planned was supercritical and from 13th plan (2017–22) onwards, all new capacity was to be supercritical. In 2018, supercritical technology contributed about 26 per cent to India's total capacity. All new planned capacity (with units of 660–800 MW) is supercritical. No official roadmap or projection for the coal-power fleet by 2030 is available.

**94 GW**

**New coal-fired capacity planned in India between 2017–18 and 2026–27, mainly supercritical**

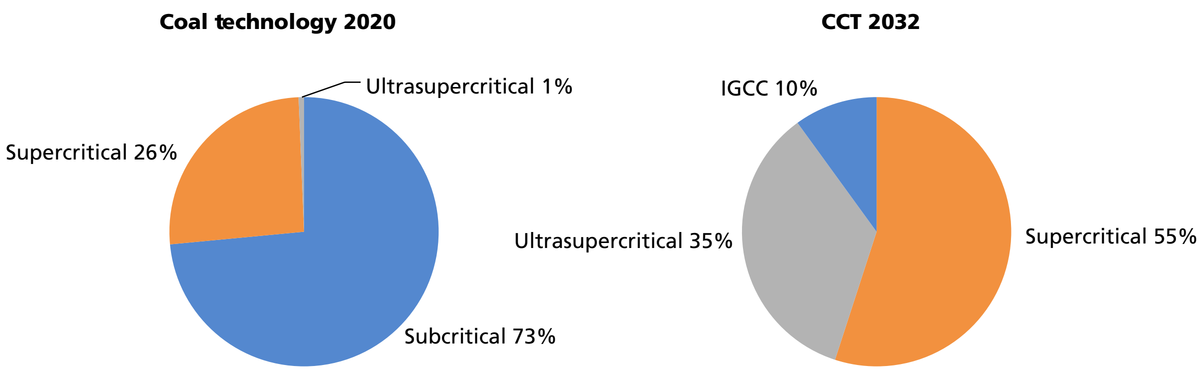
The 2018 National Electricity Plan (NEP) included plans to build 94 GW of new coal-fired capacity (mainly supercritical) between 2017–18 and 2026–27. CEA has outlined a large potential investment in new coal plants up to 2030 (105 GW of pithead plants and 44 GW of load-centered plants). In its draft report *Optimal Generation Capacity Mix, 2029–30* the authority has projected that India will have 266 GW coal capacity in 2030, which roughly translates into 100 GW of capacity addition, considering NEP retirement plans. NITI Aayog, in its generation mix projection for 2030–47, has considered significant contribution from ultra-supercritical technology or IGCC. As per NITI Aayog's clean coal technology (CCT) projections for 2032, the share of supercritical, ultra-supercritical and Integrated Gasefication Combined Cycle (IGCC) plants will be 35 per cent, 45 per cent and 10 per cent respectively in total electricity generation (see *Graph 8: Future trajectories of India's coal fleet technology*). All subcritical coal-based power capacity is projected to retire by 2032.[15] These projections seem to be unreliable as they require nearly 100 GW of subcritical capacity to retire by 2032. On the other hand, as coal capacity has been continuously missing installation targets since 2017, it is extremely difficult to predict future installations of coal power in India.

## Renovating old and inefficient plants

The designed life of a plant is considered to be 25 years, and the performance deteriorates over time. While plants can run for up to 30–40 years and

**Graph 8 : Future trajectories of India's coal fleet technology**

*There will be a discernible movement towards supercritical and ultra-supercritical technologies*




*Source: CSE analysis and Niti Aayog, 2017*

**60 per cent**
**In 2016, old coal power capacity (totalling 34 GW) in India with gross efficiency of less than**
**33 per cent**

more, they need to undergo life extensions, renovation and modernization to maintain and improve their performance. Based on their vintage and performance, government either plans for their renovation or retirement.

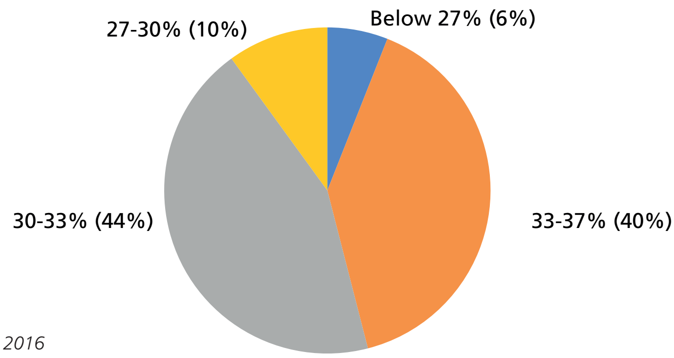
In 2015, CEA identified 34.2 GW of capacity which is more than 25 years old. Renovation and retirement plans for 32.83 GW capacity (under Central and state ownership) were drafted. Out of the total capacity, 22.17 GW was planned to be renovated, 5.86 GW scheduled to retire and the final plan for the rest 4.8 GW capacity was to be decided based on renovation feasibility. In 2016 and 2017, nearly 6 GW of the capacity was retired. However, taking a decision on the retiring capacity, other parameters—i.e., whether environmental norms were being met—were not considered. With the introduction of new environmental norms, many old plants in operation with high heat rates have become non-compliant. Thus, making them efficient will not resolve the issue unless they meet stipulated air and water norms. More comprehensive and inclusive retirement plans are needed to decide the economic feasibility of renovation of these plants.

As per a CSE analysis in 2016, gross efficiency of around 60 per cent of the old capacity (34 GW) is lower than 33 per cent, a significant share of these units are candidates for shuttering since material improvement in efficiency would be difficult even after significant investment in renovation and modernization (see *Graph 9: Gross efficiency of old power stations*). Poor efficiency results in excessive coal consumption. Replacement of this 34 GW capacity by supercritical capacity will reduce coal consumption by over 20 million tonnes per annum and $CO_2$ emissions by 35–40 millon tonnes.[16]

In 2018, the NEP included a new target for the closure of 48.3 GW of end of-life coal plants. Coal-based capacity of 22,716 MW is under consideration for retirement during 2017–22. This is based upon an assessment made by CEA and consists of 5,927 MW of capacity assuming that the normal trend of past retirement process would continue along with a coal-based capacity of 16,789 MW which doesn't have space for installation of flue gas desulphurization(FGD) systems to curb $SO_2$ emissions. Additionally, a coal-based capacity of 25,572 MW has been considered for retirement during 2022–27, which will be completing 25 years of operation by March 2022.

**Graph 9 : Gross efficiency of old power stations**

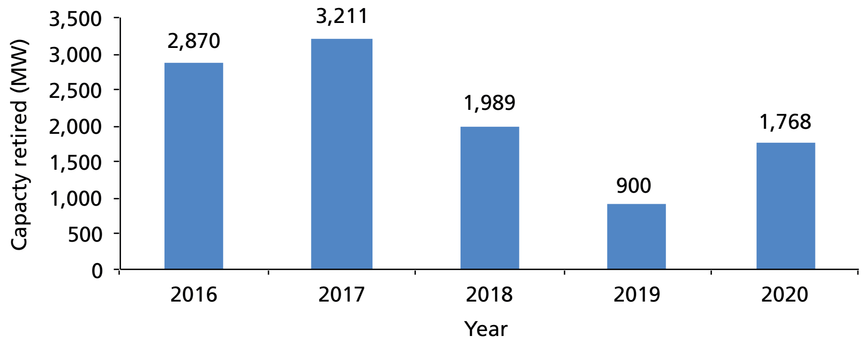
*Efficiency of almost 60 per cent of the capacity is lower than 33 per cent*




*Source: CSE, 2016*

**Graph 10 : Retirement of capacity over the years**

*On an average, 1–2 GW capacity is retired every year. At that pace, India will not be able to retire the targeted 48 GW capacity by 2027*




Till March 2020

*Source: CSE, 2020*

India is missing out on the benefits it could obtain by timely retirement of old capacity. Only 4.67 GW capacity has been retired between 2018–20 (March 2020) (see *Graph 10: Retirement of capacity over the years*). This is a far cry from the 22.72 GW retirement plan under the NEP. Along with this capacity, an additional 20 GW capacity will be ready for retirement during 2022–27 and can be retired by 2030. Overall, this capacity, when replaced by supercritical capacity, can reduce coal consumption by 30 million tonnes and $CO_2$ emissions by 55–60 million tonnes.

The retirement of old and inefficient units of thermal generating stations and their replacement with new and more efficient units is one of the major initiatives required to improve average efficiency of the fleet and reduce its $CO_2$ emissions footprints.

Since employees and land are the important assets for these power plants, better utilization of existing resources will be critical in prudently reducing $CO_2$ emissions with minimum economic investment.

- Identify capacity located near cities with high population densities. These plants should be immediately assessed for converting into biomass co-fired plants or biomass power plants or waste-to-energy plants.
- Pithead plants should be replaced by new and highly efficient coal technology.
- Rest of the plants can be retired immediately or can be converted into solar parks.

**India is missing out on the benefits it could obtain by timely retirement of old capacity**

## Renovation and modernization, and life extension projects

The objective of renovation and modernization of thermal power plants is to equip operating units with the latest modified and augmented technology, equipment and systems with a view to improve their performance in terms of output, reliability, efficiency and availability, and reduce the requirement and ease of maintenance. A renovation and modernization programme is

**R&M projects should catalyze biomass co-firing**

primarily aimed at generation sustenance and overcoming problems such as rise in heat rate, specific coal consumption and auxiliary consumption; and reduced gross generation and plant load factor. Mid-life renovation and modernization should preferably follow 100,000 hours of operation.

Life extension programmes are meant for operation of a plant beyond its original designed life and after carrying out life assessment studies of critical components. Life extension of old thermal power units is carried out with an aim to extend their useful life beyond the originally designed economic life of 25 years. These projects also play a critical role in ensuring safety at a plant as the equipment of a thermal power plant faces stresses due to high temperature and pressure. Although most components are designed for a fatigue life of about 25–30 years, many equipment or components might become weak prematurely due to various operational and maintenance variations. Thus, there is a need to check the remaining life of these components after about 20 years of life or 160,000 hours of operation lest it may lead to serious failures and safety issues.

A Centrally sponsored renovation and modernization scheme was launched in India in 1984. The renovation and modernization programme continued in different forms during the 9th, 10th, 11th and 12th five-year plan periods, which resulted in improved performance of thermal generating units. Over the years, the philosophy of renovation and modernization projects has evolved. The objective has shifted merely maximizing generation to achieving performance optimization as well. As the country moves towards renewable power, the objective is shifting to 'efficient flexible operation with lower emissions'. In the initial years, plants with less than 200 MW capacity were provided renovation and modernization assistance. Subsequently, the government focused on renovation and modernization of plants with capacities of 200–500 MW. As per the recent draft notification, the government will now focus on plants with a capacity of 500 MW and above for renovation and modernization.

The rationale for renovation and modernization (R&M) has been:
- New installation is capital-intensive, it is considered prudent to maximize generation from existing power stations to ensure optimal utilization.
- Thermal power stations were designed for a given quality of coal which has deteriorated over a period of time. These power plants need to augment systems such as coal feeding and ash handling systems to burn coal of worse quality while maintaining the rated capacity.
- To bring down the cost of energy to consumers, Merit Order Dispatch is being adopted at the plant level, which may require renovation and modernization for improving operating performance.

Other rationale considered under in India's 2019 renovation and modernization policy:
- Renovation and modernization projects should not only focus on operation and efficiency enhancements, but also on the reduction of pollution parameters with respect to environmental norms.
- Renovation and modernization projects should catalyze biomass co-firing or the shift of coal plants to biomass plants.

- Integration of mega-capacity renewable installations in the power system would require lowering the minimum load and adopting high ramp rates at thermal power plants. Hence, power plants may have to be refurbished to meet the new operational regime, i.e., changing from base load to flexible mode of operation. Thus, the new operating regime will lead to part operation of plants that were earlier operating as base load stations. Renovation and modernization interventions may be needed to improve plant efficiency at part load operations as well.

### Table 2 : Summary of India's renovation and modernization, and life extension policy

*Unlike old renovation and modernization policies, the new policy can significantly contribute in $CO_2$ reduction if utilized strategically*

| | **1984–2005** | **2005–19** | **2019 onwards (as per the latest draft guidelines)** |
|---|---|---|---|
| Primary objective | Generation maximization | Performance optimization and generation maximization | Efficient flexible operation with lower emissions |
| Primary focus unit | < 200 MW<br><br>Renovation and modernization after 15 years and life extension after 20 years | > 200 – < 500<br><br>Renovation and modernization after 15 years, and life extension after 20 years | > 500 MW<br><br>Can be done before the stipulated time based on improving flexible generation |
| Key focus areas | Maximize the generation from existing power stations to ensure optimal utilization of resources, reliability, efficiency and availability | Included specific issues for renovation and modernization to maintain rated capacity and to deal with issues such as deteriorated coal quality and lower plant load factor.<br><br>Environmental protection was considered, but it was limited to ESP upgradation.<br><br>Renovation and modernization after 15 years. Life extension after 20 years. | High level of automation to ensure flexible and improved dynamic operations to work in tandem with renewable energy.<br><br>Renovation and modernization interventions may be needed for refurbishments to improve plant efficiency at part load operation as well.<br><br>Need for new emissions control equipment installations in power plants for environmental compliance.<br><br>Biomass utilization for power generation through co-firing in thermal power plants.<br><br>Conversion of coal-fired plants to biomass power plants.<br><br>Lowering water consumption in coal-fired power plants.<br><br>Due to uncertainties in the future operational regime of thermal power generation, life extension of shorter duration may have to be considered. |

*Source: CSE compilation*

**Along with efficiency, safety, reliability and plant availability are also critical components of renovation projects**

### Achievements and failures of India's renovation and modernization policy

It is very difficult to assess and analyze the benefit of India's renovation and modernization projects with reference to efficiency reduction alone, as safety, reliability and plant availability are also critical aspect of such projects. However, a skeleton analysis has been presented in *Table 3: Achievement of renovation and modernization projects over the years*).

Under the 12th plan, the renovation and modernization, and life extension work on 37 units with a total capacity of 7,202 MW was completed. At present, 71 units of 14,929 MW capacity have been identified for renovation and modernization, and life extension work during 2017–22.

Renovation and modernization have played a limited role in improving efficiency as the larger focus has remained on maximizing generation with improved availability, especially in smaller units. No estimates have been compiled by the government on how much renovation and modernization projects have helped in reducing $CO_2$ emissions and pollution in general from coal power plants. As per the new 2019 draft policy for renovation and modernization, there is significant scope of improvement if renovation and modernization projects are utilized efficiently to move the sector towards use of biomass.

**Table 3 : Achievement of renovation and modernization projects over the years**

*Renovation and modernization have played a limited role in improving efficiency as the larger focus has remained on maximizing generation*

| Five year plan | Number of units | Capacity (MW) | Additional generation achieved* (MU/Annum) | Equivalent MW** |
|---|---|---|---|---|
| 7th | 163 | 13,570 | 10,000 | 2,000 |
| 8th<br>(Renovation and modernization)<br>(Life extension) | 198<br>(194)<br><br>(4) | 20,869 | 5,085 | 763 |
| 9th<br>(Renovation and modernization)<br>(Life extension) | 152<br>(127)<br><br>(25) | 18,991 | 14,500 | 2,200 |
| 10th<br>(Renovation and modernization)<br>(Life extension) | 25<br>(14)<br><br>(11) | 3,445 | 2,000 | 300 |
| 11th<br>(Renovation and modernization)<br>(Life extension) | 72<br>(59)<br><br>(13) | 16,146 | 5,400 | 820 |
| 12th<br>(Renovation and modernization)<br>(Life extension) | 135<br>(65)<br><br>(70) | 7,202 | Not available | Not available |
| 2017–22 | 71 | 14,929 | | |

*Tentative figures.
** Equivalent MW has been worked out assuming the PLF prevailing during that period.
*Source: CEA, 2019*

### Impact on $CO_2$ emissions due to part load operation of coal-based power plants[17]

Efficiency of coal-based power plants varies with the load on the plant. Increasing renewable energy penetration will have an impact on coal-based power plants due to part load operations. Coal-based power plants need to equip themselves for frequent cycling and ramping up of power. Due to this, there will be impact on the efficiency of power plants. The impact on efficiency due to part load operation will be felt more at subcritical power plants than at supercritical coal-based power plants. To understand this impact and the shape of the demand curve, a study has been carried out by CEA. The study observed that $CO_2$ emissions may increase by up to 1 per cent due to efficiency drop during part load operation of coal-based power plants.

- Under the new policy, the primary focus will be on units with a capacity of 500 MW or more. Almost 10,000 MW of the total installed capacity of 46,000 MW of 500 MW or more units has been in operation for more than 20 years and would need renovation and modernization, and life extension interventions. Improving efficiency of this capacity by 1–2 per cent can reduce $CO_2$ emissions by 2–6 per cent.
- The policy has included biomass conversion in its renovation and modernization, thus, existing plants can use renovation and modernization for biomass co-firing and old plants can be converted into biomass power plants.

## Biomass co-firing

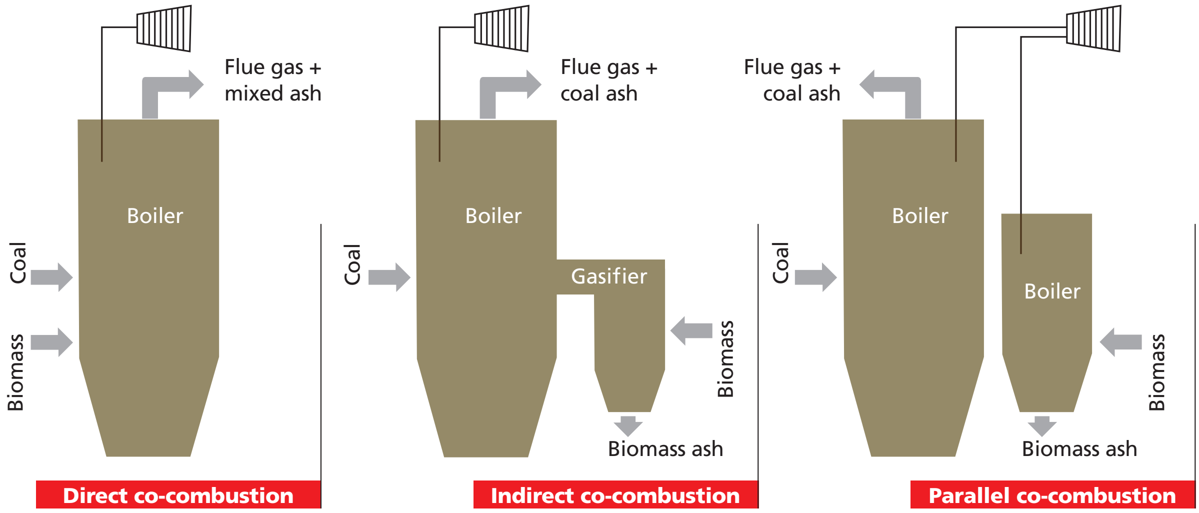
Biomass co-firing consists of combusting biomass and fossil fuels together at thermal power plants. In most cases, biomass co-firing in coal power plants takes place by mixing biomass with coal before burning, but biomass can also be gasified and burned in separate burners, after which the gaseous fuel or steam is mixed with the boiler streams of the coal-fired power plant. It has been generally accepted that co-firing biomass with coal can offer a quick, cost-effective way to partially decarbonize power generation in the short-to-medium term. Biomass co-firing has an enormous potential to reduce $CO_2$ emissions with minuscule investment. The substitution of only 10 per cent of coal in the current globally installed coal-fired electrical capacity would result in installation of about 160–180 GW biomass power capacity, which is 2.5 times more than the current globally installed biomass power capacity.

**Biomass co-firing has an enormous potential to reduce $CO_2$ emissions with minuscule investment**

Co-firing is the process of utilization of a certain portion of biomass with the existing base fuel. Currently, three co-firing technologies are widely used in coal plants: direct, indirect, and parallel. The purpose of co-firing is to maximize the use of biomass within the existing system without impacting efficiency.

Biomass co-firing in existing thermal power plants has emerged as the most economical way of utilizing biomass. Currently, about 230 power and combined heat and power plants using co-firing techniques are in operation.

### Figure 1: Various methods of biomass co-firing




*Source: Gil, María V., and Fernando Rubiera, 2019*[18]

**230**

**Number of power plants with biomass co-firing globally**

A significant portion of them are in Europe. UK, Denmark, Germany and Netherlands are the leaders and many other European countries such as Finland, Sweden, Russia, Belgium, Austria, Hungary, Italy and Spain also use biomass co-firing technologies at power plants. All major coal-fired power plants in UK have adopted biomass co-firing.

Biomass co-firing can be considered as a transition towards a completely carbon-free power sector. Several European countries and the US already offer policy incentives or have mandatory regulations to increase the share of renewables in the electricity sector. As such incentives and policies support the use of biomass co-firing, these countries lead the world in terms of biomass co-firing projects.

Net electric efficiency of dedicated state-of-the-art biomass power plants is 25–36 per cent, whereas conventional subcritical coal-fired power plants in Organization for Economic Cooperation and Development (OECD) countries operate at efficiencies of around 36 per cent, and modern ultra-supercritical units can exceed 45 per cent lower heating value. Thus, co-firing enables power generation from biomass with the high efficiency achieved in modern large-sized coal-fired power plants, which is much higher than the efficiency of dedicated 100 per cent biomass power plants. At present, co-firing projects in coal-fired power plants exceed the biomass capacity of dedicated biomass plants. The total energy efficiency can be increased even further if biomass co-firing takes place in combined heat and power plants. The other advantage of biomass co-firing is that the incremental investment required for burning biomass in coal-fired plants is significantly lower than the cost of dedicated biomass power. Co-firing also helps to extend the life of the plant. Co-firing has played an important transitional role in the decarbonization of the coal fleet and has extended the lives of power plants in Europe.[19]

Co-firing offers an advantage to developing countries since the use of agricultural residue will increase the economic value of this sector. Instead of being burned on the fields, as is commonly done, agricultural waste could be used profitably in co-firing power plants. International cooperation is needed to ensure the environmental and social sustainability of biomass exploitation, especially in the case of wood or forestry-based biomass usage.

With the focus on renewable energy, biomass-based power generation is also increasing rapidly. As per International Energy Agency's (IEA) *Roadmap on Biomass Heat and Power*, biomass-based power generation will increase by at least a factor of ten from today until 2050, accounting for 7.5 per cent of world electricity generation. For the foreseeable future, this biomass-based power generation will almost entirely be based on combustion and co-firing technologies.[20]

As per Ministry of Power's (MoP) policy on biomass utilization, for every 1 GW capacity at 7 per cent co-firing, nearly 0.25–0.3 million tonnes of biomass pellets are required.[21] Thus, for 100 GW capacity, nearly 25–30 million tonnes of biomass pellets will be required.

CEA and Japan Coal Energy Center (JCOAL) are working on biomass co-firing in India. Technology to be adopted will be clarified and recommended by JCOAL considering environmental and economic factors. Punjab, Haryana and Uttar Pradesh were selected for biomass resource surveys. Since the fuel cost in these states is much higher because of the long distance coal has to travel from mines, alternative fuel possibilities are worth their weight in gold.[22]

A November 2017 CEA notification on *Biomass Utilization for Power Generation through Co-firing in Pulverized Coal-fired Boilers* for power plants can be a game changer in agro-residue utilization in the country. CEA has issued an advisory to all thermal power generating plants and utilities to endeavour to use 5–10 per cent blend of biomass pellets, made primarily from agro-residue, along with coal, after assessing the technical feasibility and safety aspects. The notification states, 'biomass co-firing is a well proven technology. With increasing environmental awareness, power plants all over the world have adopted biomass co-firing as a strategy to combat pollution, United Nations Framework Convention on Climate Change (UNFCC) recognizes biomass co-firing as a carbon-neutral technology for mitigation of carbon emissions from coal-based power plants. National Thermal Power Corporation (NTPC) has successfully demonstrated co-firing of 7 per cent blend of biomass pellets with coal at its Dadri power plant. This can be replicated in other coal-fired power plants having bowl mills, vertical roller mills or beater mills.'

**0.25–0.3 million tonne**

**Biomass pellets required to produce 1 GW of electricity at 7 per cent co-firing**

In September 2018, CEA released the *Technical specification for agro-residue-based bio-mass pellets (non-torrified and torrified) for co-firing in coal-based thermal power plants*. The document states the permissible quality of agro-residue that can be utilized at a power plant. Any by-product of woodwork factories (such as wood pieces, shavings and chips, saw dust, and furniture waste) shall not be used in manufacture of biomass pellets. This can be a

### NTPC has taken leadership in biomass co-firing in India

NTPC's Dadri unit became the first plant in the country to commercialize biomass co-firing with up to 10 per cent of agro-residue-based bio-fuel being used in co-firing along with coal. The power plant has been co-firing close to 70–80 tonnes of agro-residue fuel along with coal. It receives non-torrified biomass pellets from a large number of suppliers from Haryana, Punjab, Madhya Pradesh and Rajasthan. The tendering process for procurement of pellets for other NTPC plants is in process. NTPC has projected the consumption of six million tonnes of pellets in 2020 in power plants. The purpose behind usage of agro-based pellets is two-fold: one, it turns off stubble burning in farms and brings down pollution, and, two, it reduces coal usage in power production.

**Biomass co-firing power is eligible for non-solar renewable purchase obligation**

base document for pellet or briquette manufacturers to fulfill the quantity and quality demand of power plants. In September 2019, Ministry of New and Renewable Energy (MNRE) notified that power produced from biomass co-firing in coal-based power plants is renewable energy and will be eligible for non-solar renewable purchase obligation (RPO). MNRE requested CEA to formulate a methodology to quantify the energy produced from biomass co-fired thermal power plants. This step is a significant push towards utilization of agro-residue in the country.

In December 2019, Central Electricity Regulatory Commission (CERC) took suo moto cognizance of an MNRE request on the matter and came out with a *Methodology for Estimation of Electricity Generated from Biomass in Biomass Co-fired Thermal Power Plants*. This regulation, notified on 7 March 2019, introduced the regulatory framework for allowing use of biomass in coal-based thermal power plants.

The methodology to estimate the energy generated from co-firing of biomass has been framed on the actual consumption of biomass and coal rather than on normative operational parameters of station heat rate and auxiliary power consumption. Further, based on the request of captive power producers that they should also be included in this policy, CERC clarified that, 'Biomass can also be used in thermal captive power plants similar to thermal generation stations.'

Thus, if both utility and captive capacity attempts to utilize 5–10 per cent co-firing, it can amount to large-scale agro-residue utilization. Coal consumption in utility power generation in India is around 600 million tonnes and is expected to rise to 1,000 million tonnes by 2030. Based on the present use of biomass co-firing of 5–10 per cent, some 50–100 million tonnes of coal will be replaced by biomass by 2030. It is equivalent to reducing 90 to 180 million of $CO_2$ emissions.

To reap these benefits, power plants should be given timelines to assess biomass availability and based on that its utilization should be made mandatory at least in states like Punjab, Haryana and Uttar Pradesh, where stubble burning is prominent and coal needs to be transported from distant regions. Coal power plants are also using the biomass co-firing approach to extend their life. If this is planned and executed properly, old power plants can even be co-fired at higher biomass ratios, utilizing agro-residue, and can lessen India's municipal solid waste management woes as well.

In March 2020, MNRE directed biomass-based power plants and biomass non-bagasse cogeneration plants to upload biomass consumption and energy generation data on their respective websites. This will help in tracking actual bagasse and non-bagasse biomass utilization in the country. Biomass consumption in industries should also be tracked. It will help in determining the exact amount of surplus agro-residue that can be utilized by the nearest power plants through co-firing.

## Carbon capture and storage (CCS)

The problem of climate change cannot be dealt with through a single strategy. Thus, along with increasing overall efficiency of the coal power fleet, adoption of carbon capture and storage (CCS) will play a crucial role in combating global warming.

CCS technology is designed to capture $CO_2$ emissions from fossil fuel combustion. It has the capacity of absorbing 85–95 per cent of $CO_2$ emissions. The process starts with the capture of generated $CO_2$, which then undergoes a compression process to form a dense fluid. This eases the transport and storage of the captured $CO_2$. The dense fluid is transported via pipelines and then injected into an underground storage facility.[23] Captured $CO_2$ can also be used as a raw material in other industrial processes such as urea making or methanol production. NTPC has signed a memorandum of understanding with Larson and Turbo Hydrocarbon Engineering (L&THE) to build a $CO_2$-to-methanol demonstration plant at an NTPC power station. Under this agreement, L&THE and NTPC will also collaborate on accelerated development and commercialization of $CO_2$ to methanol plants.[24] Since $CO_2$ storage is a major bottleneck, the success of the project will be a positive sign for adoption of CCS technology.

### Global scenario of CCS

Global progress on the development of CCS technology has been poor. It is not on track to fulfill a prominent role in GHG emissions reduction. CCS's 2°C scenario indicates a capture target of around 400 million tonnes per year by 2025, but it is very unlikely to be met. By 2019, less than 10 per cent of the capacity was created. CCS is absent from INDCs of most countries, only 11 out of 189 countries have mentioned CCS technology in their INDCs. Thus, it is clear that national policies have not accepted CCS as a promising technology. By 2019, there were only 19 operational CCS facilities capturing around 36–40 million tonnes of carbon per year. Four facilities are under construction, 10 are at an advanced design stage, and another 18 are in the early stages of development. Key regions for development of CCS technology are North America, Europe and the Middle East. In Europe, the technology is used largely to neutralize industrial emissions, whereas in North America

**19**

**Number of operational CCS facilities, capturing around 36–40 million tonnes of carbon annually**

**China is the only country in Asia Pacific to initiate CCS projects**

power plants are retrofitting CCS. In the Middle East, CCS is being used to capture emissions from natural gas plants. Presently, North America is taking the lead—having 12 out of the 19 operational CCS facilities.[25]

### CCS in Asia Pacific

Asia Pacific accounts for 72 per cent of global coal consumption (with China contributing 48 per cent of it) and more than 50 per cent of global $CO_2$ emissions. Nearly 350 GW of coal capacity is under construction or in the planning stages. Still, only China has initiated projects on CCS in the region. One facility is in operation, two are under construction and five are in the planning stage in the country.

### Barriers for CCS

- Involves significant energy consumption in terms of capture and compression of $CO_2$. This may reduce the energy conversion efficiency from 48 per cent to 36 per cent and, ironically, increase coal consumption.[26]
- Net zero emissions are almost impossible with fossil-fuel based CCS, and still incur higher costs than renewable energy-based energy systems.[27]
- Advanced flue gas treatment for clean flue gas input to CCS is required. To meet this requirement, significant investment is needed.
- Insufficient national carbon pricing has impacted installation of CCS.
- Lack of shared transport and storage networks raises per unit CCS cost.

### Opportunities

- Capital cost of CCS has been reduced significantly, from US $105 per tonne of $CO_2$ in 2011 to US $45 per tonne of $CO_2$ in 2019. It will further decrease by 50–75 per cent by 2060. Countries with cheap labour and materials, like China, will have the lowest cost of CCS installation.[28]
- Combination it with biomass co-firing can further reduce capital and operating costs of CCS.
- In developing countries, hotspots of power generation, where power plants are located in clusters, should be targeted to reduce material, transportation and storage costs.[29]

### CCS in India

It is essential to understand the progress of CCS in the context of the scale of its implementation. Out of the 19 facilities having CCS worldwide, 17 are in the industries and only two are coal-based power plants. In industries, the future of CCS looks promising as they generate much lesser $CO_2$ in comparison with coal-based power plants, and the generated $CO_2$ can be utilized as an input to other industrial processes, thus avoiding the cost on storage and transportation, which is the major bottleneck for implementation of CCS in coal-based plants.

Commercial availability of CCS in India depends largely on successful implementation of CCS technology in industrialized countries and presently this is not the case. The most crucial requirement of a long-term CCS strategy for coal-based power in India is a reliable $CO_2$ storage capacity assessment for the country. At the moment, CCS technologies are not economically feasible. In the near-term, substantial energy penalty and high costs of electricity negatively affect the perception of CCS, so it does not have promising prospects in India at least before 2030.

## Coal beneficiation: Impact of coal quality

India has the world's third largest proven coal reserves and it is the third largest coal producer (when reported in terms of volume). However, it drops to fifth place, after China, US, Indonesia and Australia, when reported in energy terms. The average gross calorific value of coal supplied to power plants in India has declined from about 5,900 kcal/kg in the 1950s to just over 3,500 kcal/kg at present. High ash content is among the reasons why Indian coal scores poorly on energy value. Most varieties of coal mined in India have calorific value in the range of 3,500–5,000 kcal/kg, which is lower than the calorific value of coal found in other major coal producing countries such as the US, Russia and China (see *Table 4: Quality of coal in major coal producing countries*).[30]

The focus on 'easy-to-mine' coal from shallower depths, given the growth in demand for thermal coal in the last two decades, is said to have contributed to the decline in coal quality and the trend of decreasing energy content per tonne of coal production in India is expected to continue. According to the IEA, since the 2000s, production of high- and mid-energy coal (more than 4,200 kcal/kg) has stagnated in India, while the production of low-energy coal (less than 4,200 kcal/kg) has more than doubled.

High ash content (of 30–50 per cent) creates many problems for coal users, that include difficulty in pulverization, poor emissivity and flame temperature, low radiative transfer, and generation of excessive amounts of fly ash containing large amounts of un-burnt carbon. This reduces the efficiency and increases the auxiliary power consumption of the plant. It is one of the reasons for higher $CO_2$ emissions from Indian power plants.

**5,900 kcal/kg**

**Calorific value of coal mined in India in the 1950s**

Improvements in power plant efficiency through the use of clean (washed) coal can have significant benefits its terms of reduction in $CO_2$ emissions. $CO_2$ emissions can be reduced by 2–3 per cent by using 34 per cent ash coal versus 42 per cent ash coal.[31]

**3,500 kcal/kg**

**Calorific value of coal mined in India today**

In India, 20 per cent of the coal produced is washed, as against a global average of 50 per cent. Though washing increases the overall cost of the coal,

**Table 4: Quality of coal in major coal producing countries**

*Indian coal has one the lowest heating value and highest ash content*

| Type of coal | Heating value | Content (Per cent weight) | | | |
|---|---|---|---|---|---|
| | (kcal/kg) | Moisture | Carbon | Ash | Sulphur |
| Generic anthracite | 7,170–7,528 | 2.1–12 | 72–87 | 6.9–11 | 0.5–0.7 |
| Generic lignite | 3,346–4,134 | 32–33 | 35–45 | 6.6–16 | 0.54–1.6 |
| US Pittsburgh | 7,361–7,409 | 1.1–5.13 | 73–74 | 7.2–13 | 2.1–2.3 |
| Chinese | 4,612–6,046 | 3.3–23 | 48–61 | 28–33 | 0.4–3.7 |
| Indian | 3,107–5,019 | 4–15 | 30–50 | 30–50 | 0.2–0.7 |
| US Powder River Basin | 4,636–4,684 | 28–30 | 48–49 | 5.3–6.3 | 0.37–0.45 |

*Source: Observer Research Foundation, 2017*

**Washing may increase coal cost, but the many benefits it provides make the process financially viable**

the benefits accrued in terms of savings in transportation, operation and maintenance cost, and efficiency make the process financially sustainable. State-of-the-art technologies such as supercritical pulverized coal combustion or IGCC also benefit from the use of upgraded coals.

A 1997 notification required the use of beneficiated coal with an ash content of not more than 34 per cent with effect from 2001. This applied to all thermal power stations located beyond 1,000 km of the pithead and any thermal power plant located in an urban or sensitive area irrespective of its distance from the pithead. In 2014, the then Ministry of Environment and Forests amended the rules with respect to the use of washed, blended or beneficiated coal, strengthening the 34 per cent ash content requirement, and also extended the rule to plants located at a distance of 500–1,000 km from the pithead.

However, in May 2020, the government decided to allow use of coal irrespective of ash content once again. The government claims that significant improvements in the quality of coal mined in India has necessitated this change. It also claims that third party sampling of coal at both the loading and unloading end of coal supply from Coal Indian Limited (CIL) to generators is taking place. It further claims that coal washeries are merely increasing cost of the coal and local pollution due to inefficient operations.[32] Various stakeholders hold different views on the subject. CSE believes this decision has been taken in haste; a wider stakeholder consultation should have been carried out before allowing the use of unwashed coal.

## Heat rate tracking through continuous emissions monitoring systems

In 2009, the Regional Greenhouse Gas Initiative (RGGI) became the first mandatory cap-and-trade programme to limit US $CO_2$ emissions. Environment Protection Agency (EPA) developed strict data quality control measures and issued relevant regulations and guidelines on data quality control, such as the *Mandatory Regulations on Greenhouse Gas Emission Reporting, 2009*, which requires all sources (equipment levels) that emit more than 25,000 tonnes of $CO_2$ eq per year to be fully installed with Continuous Emissions Monitoring Systems (CEMS) from 2011 and to report online to the EPA.[33] EPA also decided to use the heat input values reported by power plants to determine whether they had reduced their heat rates to the required levels. Moreover, EPA tried to estimate heat rates based on two key parameters—flue gas $CO_2$ concentrations and the stack volumetric flow rate, that were being monitored through CEMS.

This heat rate initiative in the US has received a setback as trials have uncovered difficulties in reaching a satisfactory performance level to determine the heat rate, particularly due to flow measurement issues under different load conditions.

### $CO_2$ monitoring through CEMS

In Europe, a vast majority of $CO_2$ and other GHG emissions reporting happens as per factor-based calculations. This method is set and mature with relatively no cost whereas the cost of analytical systems to perform this job is prohibitively high. Power generation cost of a unit using actual measurement-based approach is higher than that of the unit using factor-based approach. The units that adopt CEMS for $CO_2$ measurement will be in an unfavorable position when participating in the power market.

In India, some power plants have already installed analyzers that use $CO_2$ as a reference gas for the analysis of other parameters. Other power plants can also add $CO_2$ monitoring in the existing CEMS. $CO_2$ monitoring may not be issue for the power plants. However, industry experts feel the factor-based method is cheap and reliable.

Further, most suppliers have a negative opinion of the estimation of heat rate based on CEMS. They have stated that heat rate is co-related with $CO_2$ emissions. However, accurate heat rate monitoring based on CEMS is not possible, mainly because accurate flow measurement at varying loads is really a problematic issue. Besides carbon, volatile organic compounds also play a significant role in overall heat rate and calculating it solely through $CO_2$ monitoring will yield a bigger deviation or inaccurate results.

## Other incentives to improve efficiency of the existing fleet

### Tariff-based incentives[34]

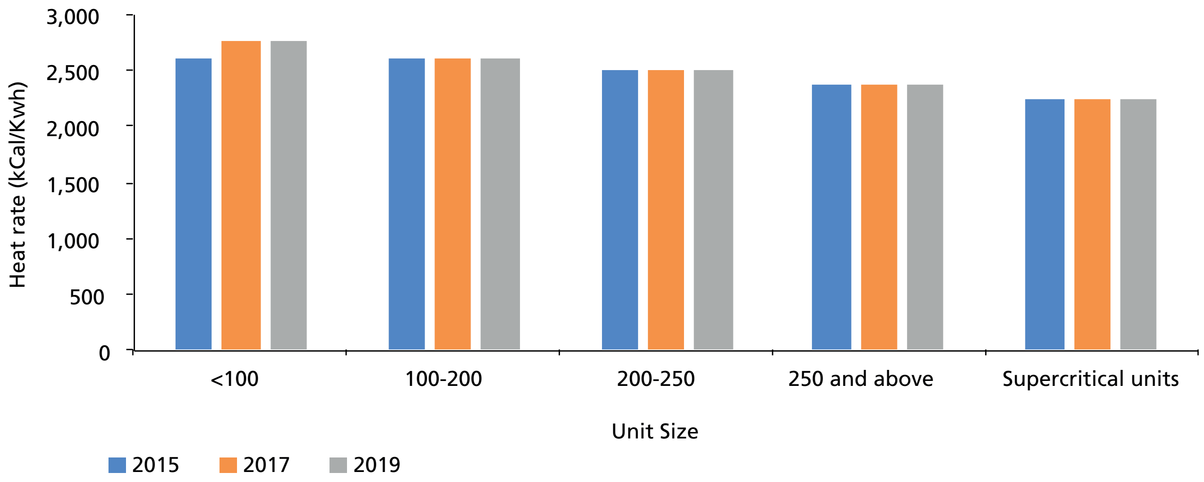
Increasing the efficiency of existing power plants is the most cost-effective method for reducing $CO_2$ emissions, as well other pollutants. Lower efficiency in power plants can be a result of a variety of technical factors, such as poor quality of the coal, old technology and lack of maintenance. However, along with technical factors, the regulatory framework, tariff structure and incentives also play a crucial role in pushing power plants towards improving their efficiency. There will not be significant improvements in the efficiency of power plants unless they are mandated or incentivized to do so.

Under the current approach of 'cost-plus' tariffs, regulators approve fixed and variable costs of utilities based on a range of benchmarks. Profits from the utility (i.e., rate of return on investment and other incentives) are included in the tariff calculation—hence the term 'cost-plus'. Availability of appropriate benchmarks for this calculation for the regulators play a crucial role. However, key information about heat rates is withheld by power plants, so regulators have been unable to set appropriately tight benchmarks (see *Graph 11: Normative heat rate norms for coal power plants of different capacity*).It is clear that the normative heat rate of power plants has not been progressively tightened in the last three revisions of the norms related to them.

**Unit-wise heat rates are not disclosed on any platform by generators**

**Graph 11: Normative heat rate norms for coal power plants of different capacity**

*Heat rate norms have not been tightened (except for a small capacity) during the last three revisions to the norms*




*Source: CSE analysis based on CEA data*

One of the reasons for this is that unit-wise heat rates are not disclosed on any platform by generators. Only station heat rates are disclosed to regulators but even those are not available in the public domain. At the unit level, there are wide variations in efficiency or heat rates, even within a particular technological category, Indian power plants can significantly improve their efficiency, as indicated by the large gap between the actual and design efficiencies in CSE's *Heat on Power* report. While the MoEF&CC regulates air, water and solid waste pollution from power plants, it does not provide any guidelines for overall plant efficiency. Efficiency of power plants is generally considered to be a technical operational issue outside the purview of environmental guidelines, despite the fact that improving efficiency of power plants reduces coal use, thereby directly contributing to a reduced pollution load. The management of operational parameters is left to electricity regulators.

**Role of Merit Order**

At present, distribution companies (discoms) or states tie-up for supply of power with various power stations or generating companies. States generally requisition power from a station on day-ahead basis considering the 'Merit Order' among the stations with which it has a tie-up. 'Merit Order' is primarily based on the energy cost for generators (see *Box: What is Merit Order?*), but contractual obligations (e.g., power purchase agreements) may result in a situation where, at the national level, many stations having low energy charge rate are not fully scheduled whereas costlier stations are scheduled.

**Coal use and pollution load of a plant vary with its efficiency**

Merit Order needs to be implemented considering the efficiency of operations at the national level. MoP, in its draft notification on *Flexibility in generation and scheduling of thermal power stations*, mentions that flexibility needs to be given to generating company to supply power requisitioned by beneficiaries or states through Merit Order operation of its stations on the national level by

### Heat rate a black box for the outer world[35]

Maharashtra State Electricity Distribution Co. Ltd's submission to Central Electricity Regulatory Commission (CERC) in 2013: So far, none of the Central generating stations (CGS) have declared or provided actual station heat rates (SHR) in any filings or reports. There is a need for strengthening the norms for SHR, including transparency in demonstrating actual SHR. CGS make huge profits in normative SHR, hence there is no need of any relaxation of norms for any specific stations unless agreed upon by all beneficiaries or approved by the commission under extraordinary circumstances. Based on the actual past trend and balance, and the useful life of assets after considering renovation and modernization, if any, the commission may decide on strengthened SHR norms.

Alstom India Ltd's submission to CERC in 2013: There is a need to shift the approach from plant heat rate to unit heat rate for achieving overall improvement in the goals or performance of individual units. Tariff regulations should specify normative unit heat rate in the calculation of variable cost of generation instead of station heat rate. Efficiency improvement should be mandated for utilities.

### What is Merit Order?

Tariff is calculated on the basis of capacity charge (fixed cost) and energy charge (variable cost). The various components of capacity charge on which the tariff depends are return on equity, interest on capital loan, depreciation, interest on working capital, operation and maintenance cost, and cost of secondary oil. The components of energy charge are primary fuel costs, secondary fuel oil consumption and auxiliary energy consumption. Thus, energy cost or variable cost depends on heat rate or efficiency of the plant and cost of purchase of coal. Power plants are scheduled based on their variable cost (cheapest first). This principle of scheduling cheapest power generating stations by variable cost is called Merit order Dispatch.

maximizing the electricity generation from cheaper stations before moving to other stations. However, it is quite difficult to estimate the actual benefits that can be achieved annually if Merit Order in implemented in this manner.

### BEE's PAT scheme

BEE's 'Perform Achieve and Trade' (PAT) scheme is a market-based mechanism announced under the National Mission on Enhanced Energy Efficiency (NMEEE), designed to accelerate energy savings in energy-intensive sectors by incentivizing them. Under PAT cycle I, the scheme identified nine energy-intensive sectors and set targets for reduction in energy intensity for each of them. One of nine sectors was thermal power.

Of the 144 thermal power plants covered under the PAT cycle I, 97 were coal- or lignite-fired plants. Of the 31 plants that were assessed for PAT under CSE's Green Rating Project of thermal power sector (*Heat on Power*), the average efficiency improvement required from the baseline to the target was only 0.6

**BEE PAT cycle I was criticized for being unambitious, its targets were easy to meet**

percentage points. In spite of immense potential of efficiency improvements in the thermal power sector, BEE PAT cycle I was criticized for setting easily achievable targets, particularly in the thermal power sector, the stakeholders felt that the targets for heat rate reduction are quite low (in the range of 4–5 per cent) which are possible merely through process optimization, and improved operation and maintenance.[36]

In PAT cycle I, the thermal power sector alone contributed about 50 per cent of $CO_2$ emissions reduction (3.1 million metric tonnes of oil equivalent of the reduction which is equivalent to around 7 million tonnes of coal and 12 million tonnes of $CO_2$). The results of PAT cycle II were scheduled to be declared in December 2019 but have been delayed. As per CSE's analysis, the average heat rate reduction target given to the plants was 2 per cent. Thus, efficiency improvements will be similar to those under the PAT I cycle, i.e., 0.6 percentage points. Hence, $CO_2$ emissions reduction of around 1–2 per cent (10–15 million tonnes of $CO_2$) can be expected. Similar $CO_2$ emissions reduction can be assumed for the upcoming PAT cycles in 2020–30.

But the sector needs more:

- Stringent target setting for aligning PAT cycles with CERCs norms on heat rate. PAT targets should either be at par with or more stringent than CERC norms.
- Deeper analysis of the sector for a better rationale for target setting under PAT.
- Clarity on enforcement or timelines for defaulters on energy targets.
- Transparency and clarity in the trading mechanism and regulations that will build confidence among industries, and control liquidity interactions and balance in the system.

### Carbon pricing and trading systems

Carbon pricing and trading systems play an important role in limiting the consumption of fossil fuels and generating funds for cleaner energy. There are two types of initiatives that put explicit monetary cost on greenhouse gases: Emission Trading System (ETS) and carbon taxes.

An Emission Trading System (ETS)—sometimes referred to as a cap-and-trade system—caps the total level of GHG emissions, allowing industries with lower emissions to sell their extra allowances to larger emitters. By creating supply and demand for emissions allowances, an ETS establishes a market price for GHG emissions. The cap ensures that required emissions reductions takes place to keep emitters within their pre-allocated carbon budget.[37]

A carbon tax sets a price on carbon by defining a tax rate on greenhouse gas emissions or the carbon content of fossil fuels. It is different from an ETS in that the emissions reduction outcome of a carbon tax is not pre-defined but the carbon price is. The choice of the two most important carbon pricing mechanisms (carbon emission trading and carbon tax) should be based on the specific environment and should be consistent with the national economic focus. In fact, carbon emissions trading and carbon tax can play a complementary role in different areas of emissions reduction.

Carbon pricing is much easier and there are more indirect ways of pricing carbon, such as through fuel taxes, the removal of fossil fuel subsidies and regulations that may incorporate a 'social cost of carbon'.

## Global scenario

Of the 185 countries that have submitted their INDCs to the UN, 96 have stated that they are planning or considering to use a carbon pricing mechanism as a tool to achieve their INDC commitments. The total carbon emissions of these countries account for 55 per cent of global emissions. As of 1 April 2020, there were 58 different carbon pricing mechanisms worldwide, of which 28 were carbon emissions trading markets and 30 were carbon tax mechanisms. These carbon pricing mechanisms cover nearly 9 Gt of $CO_2$ eq in 46 countries and 28 regions around the world, accounting for about 16 per cent of the world's GHG emissions. Three more carbon trading systems are scheduled to operate in China, Germany and the US covering 4 Gt of $CO_2$ eq, representing 7.2 per cent of global GHG emissions.

There has been a rapid increase in carbon pricing regimes; still, most of them are in the developed countries. A unified international emissions trading market is yet to be formed.

**16 per cent**
**Worldwide GHG emissions covered by various carbon pricing mechanisms by April 2020**

The first major carbon emissions trading system was initiated in the EU in 2005. EU-ETS is the biggest emissions trading scheme operating in the world. It was initiated in four phases. Currently, the third phase (2013–20) is operational. It covers around 40 per cent of emissions from EU, including those from the power and aviation sectors. In 2018 alone, EU-ETS carbon pricing initiatives covered 2 Gt $CO_2$ eq, accounting for about 3.9 per cent of

### Table 5: Status of carbon pricing and emissions trading systems

*Many developing countries are actively considering carbon tax and emissions trading systems*

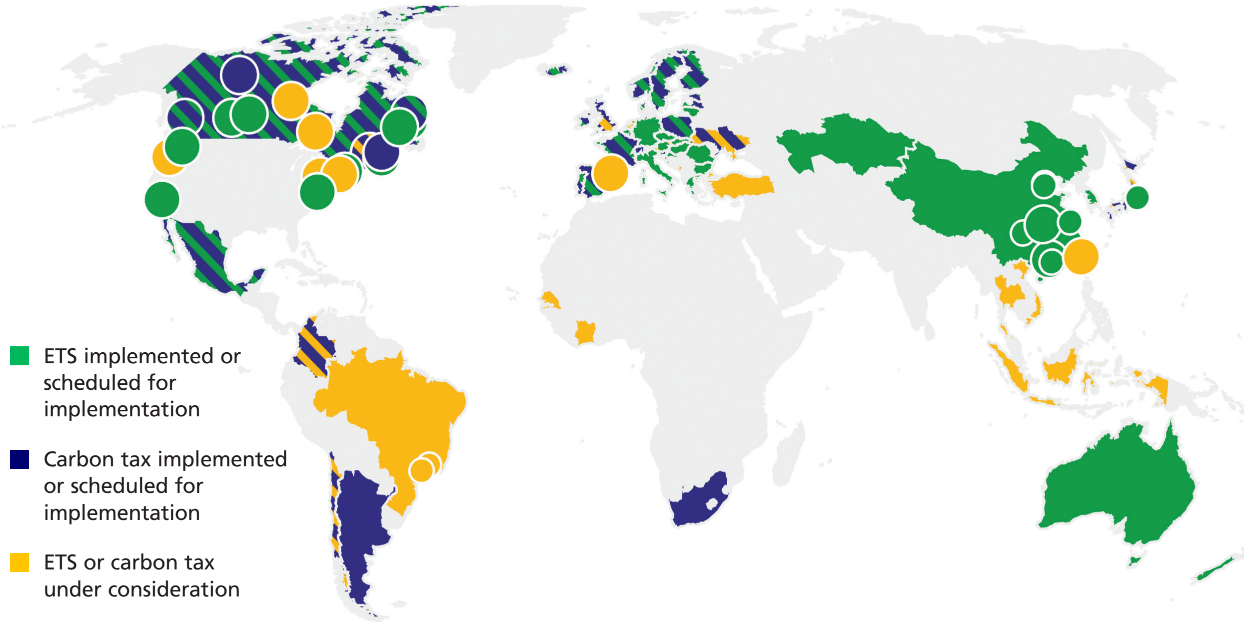
| Status | Carbon taxes | Carbon trading system | Total | Scope | Countries |
|---|---|---|---|---|---|
| Implemented | 30 | 28 | 58 | These initiatives would cover 9 Gt $CO_2$ eq, representing 16 per cent of global GHG emissions | Mainly Europe and the US, also Argentina and South Africa |
| Scheduled | 0 | 3 | 3 | In 2020, these initiatives would cover 4 Gt $CO_2$ eq, representing 7.2 per cent of global GHG emissions | China, Germany and the US |
| Under consideration | Brazil, Thailand, Ukraine, Turkey, Indonesia, Taiwan, Vietnam, and some states of the US are actively considering various carbon pricing regimes | | | | |

Note: Till 1 April 2020

*Source: Carbon pricing dashboard, World Bank*

**Map 1: Global scenario of carbon pricing and emissions trading systems**

*Most developed countries have introduced some form of incentive mechanisms*




*Source: World Bank, 2019*

global GHG emissions, with a total value of US $31.76 billion.[38] The EU-ETS has become a key tool to reduce GHG emissions.

US has the second largest carbon trading market and has built a relatively mature carbon ETS. In China also, seven pilot studies for emissions trading have been under consideration since 2013. An ETS scheme is scheduled to be launched in 2020. It will initially include only the power sector representing 30 per cent of the country's emissions and 8 per cent of global emissions.

Many countries have adopted both a carbon trading market and carbon tax to reduce emissions simultaneously. For example, Switzerland has a carbon market and a carbon tax. France has joined the EU-ETS and implemented a carbon tax in 2014. This signifies the carbon market and carbon tax can complement each other and promote each other to achieve the best emissions reduction effect.[39]

**Carbon pricing regime in India**

A nationwide Clean Energy Tax on coal (or coal cess) was adopted in 2010. It was levied on coal production and imports. The tax was initially set at Rs 50 (US $0.72) per tonne of domestic and imported coal, but was quadrupled to Rs 200 (US $2.88) per tonne of coal in 2015 and doubled again to Rs 400 (US $5.75) per tonne in 2016. The revenue was initially allocated to the National Clean Energy and Environment Fund (NCEEF) to invest in clean energy projects and technologies. A total of US $4.2 billion accrued to the NCEEF until it was

## Challenges for carbon pricing implementation

Although most countries have clearly stated that carbon pricing mechanisms are an important part of their mitigation strategy (as per their INDCs), progress on international carbon pricing and trading mechanisms has been slow. It has been difficult to predict actual costs, as political factors and investors plays an important role. The design of trading mechanism tools is crucial, for example, the defects in the design of EU carbon market have caused huge fluctuations in the carbon market. Carbon pricing has to be based on a country's needs and a 'one size fits all' approach will not work.

subsumed under the Goods and Services Tax (GST) reform in 2017. Earlier known as the Clean Energy Cess, it was renamed GST Compensation Cess in 2017, changing the ambit of the tax towards compensating states for losses incurred due to the GST rather than allocating it for clean energy. However, the Ministry of Finance expressed confidence that financing of clean energy and environment projects should not suffer due to the GST reforms.[40]

In late 2019, the Central government proposed to cancel the coal cess altogether. The savings from removing the carbon tax would improve the financial health of utilities and distribution companies, besides helping power producers install 'pollution-curbing equipment', the government reasoned.[41]

A study by E&Y in 2019 estimates that a carbon tax of US $10 per tonne of $CO_2$ emissions could reduce carbon intensity by 8 per cent against BAU levels. To avoid a sudden increase in tax burden and to make it more acceptable for stakeholders, the carbon tax could be increased in phases such that it reaches US $35 (Rs 2,310) per tonne of $CO_2$ emissions by 2030. This step can reduce emissions intensity by 22 per cent against BAU levels.[42]

In India, a few carbon pricing schemes are in scoping or pilot stages. However, all these schemes are targeting the small- and medium-scale sectors.[43] Based on $CO_2$ emissions reduction potential of the pricing regime, the government should focus on carbon tax and trading schemes for large-scale sectors such as power and cement. Many developing countries are executing or considering carbon tax or trading schemes, while India has not even created a blueprint of any carbon pricing regime. A good trading system requires years to become robust and show results on the ground. We need to initiate such systems now to see them fructify by 2030.

# 4. Scenario of $CO_2$ reduction from India's coal fleet by 2030

In the previous section, various interventions to reduce coal-based power's $CO_2$ footprints in India have been discussed. This section will try to predict $CO_2$ emissions under BAU scenario in India by 2030 and the country's $CO_2$ reduction scenario by collating the impact of the strategies discussed. To understand various possibilities of $CO_2$ emissions reduction from thermal power plants, we first calculate baseline $CO_2$ emissions based on existing capacity, vintage, plant load factor and specific $CO_2$ generation. Based on the present installed capacity of 206 GW and average plant load factor of 60 per cent, baseline $CO_2$ emissions come out to be approximately 1,100 million tonnes (see *Table 6: Baseline $CO_2$ emissions for India's coal fleet*).

Two possible scenarios for the projected $CO_2$ emissions by 2030 emerge. First, the assumption for calculating BAU emissions are explained in *Table 7: Projected $CO_2$ emissions under BAU scenario by 2030*. Then, assumptions for best-case reduction scenario are discussed. BAU scenario primarily make assumptions based on past trends of policy implementation, analysis of recent trends of policy based on MoP and CEA notifications and inputs from experts on future trajectories. The scenario of implementing the best-case reduction policies is envisaged based on expediting implementation of existing policies, and bringing in global best practices and systems to achieve ambitious decarbonization of the coal fleet.

**Table 6 : Baseline $CO_2$ emissions for India's coal fleet**

*Small and subcritical capacity has a large share in the country's $CO_2$ emissions*

| Capacity | Vintage (years) | | | | | Capacity (GW) | Plant load factor (per cent) | Specific $CO_2$ emissions (kg/kWh) | Annual $CO_2$ emissions (million tonnes) |
|---|---|---|---|---|---|---|---|---|---|
| | > 35 | 26–35 | 16–25 | 3–15 | 0–2 | | | | |
| Up to 250 | 9 | 16.15 | 12.95 | 20.78 | 1.95 | 60.83 | 50 | 1.19 | 317.06 |
| > 250 and < 500 MW | 0 | 0 | 0.6 | 14.71 | 2.67 | 17.98 | 50 | 1.05 | 82.69 |
| 500 MW and < 650 MW | 0.5 | 7 | 7 | 55.29 | 1.7 | 71.49 | 65 | 1 | 407.06 |
| 650 MW and above (supercritical) | 0 | 0 | 0 | 38.39 | 16.16 | 54.55 | 70 | 0.85 | 284.33 |
| 650 MW and above (ultra-supercritical) | | | | | 1.3 | 1.3 | 70 | 0.75 | 5.98 |
| Advance ultra-supercritical | | | | | | | 0 | | |
| Total | 9.5 | 23.15 | 20.55 | 129.17 | 22.48 | 206 | | | 1,097.11 |

*Source: CSE, 2020*

### Table 7 : Projected $CO_2$ emissions under BAU scenario by 2030

*Overall emissions from coal-power plants will increase in a BAU scenario*

Present capacity : 205 GW
Expected capacity: 266 GW (CEA)
Expected generation: 1,250 BU (CEA)
Expected overall PLF: 54 per cent (rough estimate)
Total $CO_2$ emissions : 1,120 million tonnes

Assumptions for calculation:

| Parameter | Actions and their impacts |
|---|---|
| Retiring old and inefficient plants | Retiring 25 GW*<br>Included in new capacity addition |
| Installing new technology (supercritical, ultra-supercritical and advanced ultra-supercritical) | 266 GW = 205 - 25 + 60 (supercritical) + 26 (ultra-supercritical)** |
| Renovation and modernization | 1–2 per cent reduction in overall $CO_2$ emissions. However, this reduction will be neutralized by frequent ramping and cycling of plants due to increased renewable generation |
| Biomass co-firing | 10 per cent biomass co-firing in 20 per cent of the capacity*** |
| BEE's PAT (cycles 7 and 8) | 1–2 per cent reduction in overall $CO_2$ emissions |
| Merit Order based on national availability | 1–2 per cent reduction in overall $CO_2$ emissions |
| Carbon capture and storage | Not feasible till 2030 |
| Heat rate tracking through CEMS | Not feasible |
| Carbon tax and carbon trading | Not included |
| Coal beneficiation | Not included |

*Retiring only small old and inefficient units (based on 2–3 GW of annual retirement)
** Based on the current trend of technology adoption in India
*** Considering only states with agro-residue burning issues adopt co-firing
*Source: CSE analysis*

### Table 8: $CO_2$ emissions under the best-case reduction scenario by 2030

*This scenario will roughly translate into reduced $CO_2$ emissions to the tune of 250 million tonnes from a BAU scenario*

Expected capacity: 266 GW (CEA)
Expected generation: 1,250 BU (CEA)
Expected overall plant load factor: 54 per cent (rough estimate)
Projected $CO_2$ emissions: 850 million tonnes

Assumptions:

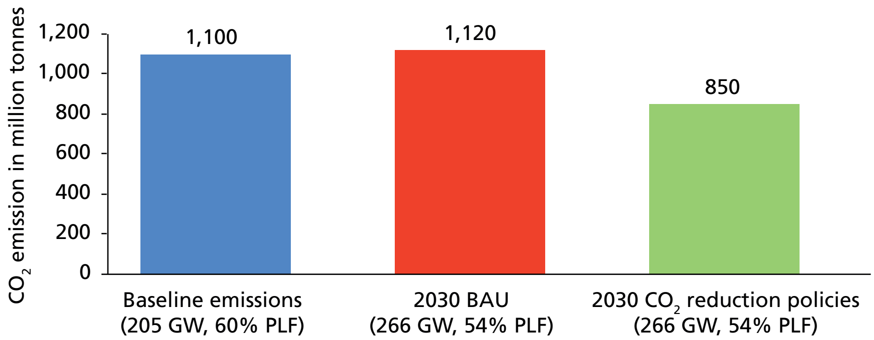
| | **Actions and their impacts** |
|---|---|
| Retiring old and inefficient plants | Retiring 48 GW*<br>Adding 10 GW of biomass capacity (impact will be covered in new capacity addition) |
| Installing new technology (ultra-supercritical and advanced ultra-supercritical) | 266 GW = 205 - 45 +50 (supercritical) + 30 (ultra-supercritical) + 16 advance ultra-supercritical + 10 GW biomass |
| Renovation and modernization | 1–2 per cent reduction in overall $CO_2$ emissions. However, this reduction will be neutralized by frequent ramping and cycling of plants due to excessive renewable generation |
| Biomass co-firing | 10 per cent biomass co-firing in 100 per cent of the capacity |
| Carbon capture and storage | Not feasible till 2030 |
| Heat rate tracking | Impact dependant on other policies |
| BEE's PAT (cycles 7 and 8) | 2–3 per cent reduction in overall $CO_2$ emissions when targets are based on deeper analysis, aligning with CERC normative heat rate targets |
| Merit Order based on national availability | Impact clubbed with other policies |
| Carbon tax and carbon trading | 8 per cent reduction |
| Coal beneficiation | 2–3 per cent reduction in overall $CO_2$ emissions |

*As per the National Electricity Plan, 2018
*Source: CSE analysis*

Under the BAU scenario, annual $CO_2$ emissions from the coal fleet will actually slightly increase, while under the GHG reduction scenario, around 22 per cent $CO_2$ emissions reduction is possible if strict adherence to technological and regulatory policies happens.

### Graph 12 : Projected trend of $CO_2$ emissions, comparing BAU scenario and the best-case scenario

*$CO_2$ emissions will increase in a BAU scenario but can decrease by as much as 22 per cent in the best-case scenario*




*Source: CSE, 2020*

# 5. Conclusion and recommendations

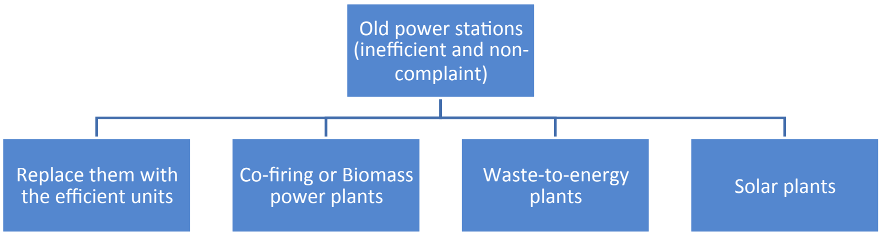
India's reliance on coal will continue for its energy security. Coal capacity is scheduled to increase to 266 GW by 2030 from 205 GW in 2020 and will contribute 50 per cent to the generation mix by 2030. Global pressure is already building up to phase out coal. Many developed countries have vowed to phase out coal plants and have already set deadlines in this regard. Nineteen countries have planned to stop coal power use by 2030, and some by 2040. Under such circumstances, even for developing countries, a BAU approach will not work. Thus, if developing countries want to continue to use coal for their energy security, the onus is on them to ensure it is burnt in a highly efficient and clean manner. Based on the various technological, regulatory and financial interventions discussed in this report, it can be said that India has the opportunity to eliminate more than 250 million tonnes of $CO_2$ emissions annually by 2030 in comparison with a BAU approach. To achieve this, the country will require a robust, concrete and comprehensive plan. The following recommendations highlight key policy steps to rapidly decarbonize our coal fleet:

1. **Roadmap for new technology:** MoP does not have a clear roadmap for the inclusion of advanced coal technology in the upcoming coal fleet. While CEA states that all new plants will be supercritical, it does not underline the inclusion of ultra-supercritical, advanced ultra-supercritical or IGCC technologies in the next decade, all of which are much more efficient than supercritical technology. Plants installed in 2020–30 will operate till 2050, so the installation of state-of-the-art technology is crucial to ensure significant $CO_2$ emissions mitigation in this period.

   CSE recommends that MoP should come out with a coal technology roadmap for the country, clearly mentioning the technology type and respective break up for the capacity to be installed during 2020–30.

2. **Renovating old plants:** Based on plant efficiency and new environmental norms, CEA, in the National Electricity Plan of 2018, has already identified plants that need to be retired. However, it is well known fact that on the ground India is very slow in deciding the fate of old power stations. A merry-go-round approach vis-à-vis stakeholders in deciding the retirement of old, inefficient plants is the culprit. It is essential to prudently utilize the resources of old power plants—coal linkages, land resources, manpower and local employment in the area—by replacing them with efficient units, or converting them into biomass or waste-to-energy plants based on location.

**Figure 2: Pathways to renovate old plants**




*Source: CSE, 2020*

CSE recommends that MoP, CEA and MoEF&CC conduct an analysis based on key parameters—coal linkages, pithead plants, and availability of biomass municipal waste and barren land—to take informed decisions regarding the shifting, shutting or conversion of old power stations.

3. **Renovation and modernization, and life extension:** Renovation and modernization will play a crucial role in improving the efficiency of existing power plants. On an average, renovation and modernization improve efficiency by 1–2 per cent, equivalent to 2–4 per cent $CO_2$ emissions reduction. However, experts believe that due to rapid increase in the share of renewable energy in the power generation mix, thermal power plants will face frequent cycling and ramping. It will affect their efficiency, increase $CO_2$ emissions, and offset the benefits of renovation and modernization. The inclusion of biomass conversion in new renovation and modernization, and life extension policy is a welcome step and has great potential to reduce $CO_2$ footprints of India's coal plants.

   CSE recommends that the renovation and modernization policy should be prudently used by maintaining efficiency of power plants with increasing share of renewable energy and promoting biomass co-firing.

4. **Biomass co-firing:** Biomass co-firing of up to 10 per cent has been accepted as a practical, less capital-intensive and implementable solution to reduce carbon footprints of coal-based power plants. However, actual implementation of biomass co-firing at plants still needs a significant push. Except NTPC, no other generating company has provided information regarding initiatives for biomass co-firing.

   CSE recommends that biomass co-firing should be made compulsory , in a phase-wise manner, at India's thermal power plants. Initially, 5 per cent biomass co-firing can be made compulsory in regions where crop burning is prominent. Later, it can be implemented across India. Biomass co-firing has immense employment potential in rural areas. Moreover, it can help deal with other serious issues facing the country like stubble burning and the waste mountains popping up on the outskirts of cities.

   Finally, biomass briquettes pellets might need their own supply chains, and cost a little more to the consumer than coal, but not only will the country be eliminating the negative impact of coal burning, but it will also be generating additional income and employment in rural areas.

5. **Carbon capture and Storage (CCS):** Global progress on CCS has been lackadaisical, even dismal, if we only consider coal-based thermal power plants. No experts and research studies are hopeful for introduction of CCS in India before 2030.

   CCS will be crucial in drastically reducing carbon footprints of fossil fuels, but it is prohibitively expensive. India has the capability and technological availability to introduce CCS. CSE recommends that pilot testing based on indigenous research and development, in-house technology development and installation be initiated to find the means to reduce capital and operational cost of CCS significantly.

6. **Carbon tax and emissions trading mechanisms:** Carbon pricing will play a crucial role in decarbonization. ETS schemes incentivize the efforts made for reducing carbon footprints and funds raised through carbon taxes can be utilized for cleaner energy pathways. Countries have realized the role of carbon tax and ETS in mitigating the challenges of climate change. A number of schemes have been implemented worldwide.

   CSE recommends that MoEF&CC initiate ETS at the earliest. It is a well-established fact that the design of ETS is critical for its acceptance by various sectors. Significant pilot testing and improvements over the years are needed to ensure robustness and sustainability of an ETS. We are already late, unless ETS is implemented immediately, it will be difficult to push the thermal sector down the path of decarbonization.

   The carbon tax on coal (of Rs 400 per tonne) has already been subsumed in the GST. The tax used to be collected in the NCEEF, now there is no clarity on funds for clean energy. A clear carbon tax will set the roadmap for decarbonization of the sector and generating funds for investment in cleaner technologies.

7. **Coal washing:** India's power plants get the poorest quality of coal in the world. It affects their efficiency, emissions and maintenance cost. Coal washing, besides reducing fly ash, and operation and maintenance cost, has the ability to reduce $CO_2$ emissions by 2–3 per cent.

   CSE recommends that the government should rethink its decision on 'removing the ash content restriction in power plants and allowing use of unwashed coal'.

8. **Merit Order:** Currently, many efficient power plants do not get proper scheduling. Largely, because of lack of coordination on load dispatch at the state and Central levels, especially in interstate transfers. Implementation of Merit Order at the national level for interstate power transfer will ensure that efficient power plants are scheduled more than inefficient ones.

   CSE recommends that MoP should try to improve the efficacy of the Merit Order system so that clean and efficient plants get maximum scheduling. Government should remove the lacunae in Merit Order Dispatch system through better information management and transparency among generation companies, discoms and regulatory authorities.

9. **BEE's PAT scheme** has a key role to play in improving the efficiency of India's young coal fleet. BEE's PAT cycle I (2012–14) was criticized for laying down easily achievable target for power plants at a time when India was the poorest in efficiency. As per a CSE analysis, in the PAT cycle 2 (2016–19), heat rate reduction targets, on an average, are in the range of 1–2 per cent, i.e., not stringent enough. Results of PAT cycle 2 are still awaited.

   CSE recommends that BEE's PAT scheme be made more transparent in setting targets and disclosing results. CSE also recommends a deeper analysis of the coal sector for setting a better rationale and ambitious target during the 2020–30 cycles. BEE's PAT targets should be at par with or more stringent than heat rate norms of CEA.

# References


1. Mengpin Ge and Johannes Friedrich 2020. *4 Charts Explain Greenhouse Gas Emissions by Countries and Sectors*, World Resources Institute. Available at https://www.wri.org/blog/2020/02/greenhouse-gas-emissions-by-country-sector, as accessed on 5 May 2020

2. Anon 2020. *Emissions–Global Energy & $CO_2$ Status Report 2019–Analysis*, International Energy Agency. Available at https://www.iea.org/reports/global-energy-$CO_2$-status-report-2019/emissions, as accessed on 2 June 2020

3. Mengpin Ge and Johannes Friedrich 2020. *4 Charts Explain Greenhouse Gas Emissions by Countries and Sectors*, World Resources Institute. Available at https://www.wri.org/blog/2020/02/greenhouse-gas-emissions-by-country-sector, as accessed on 5 May 2020

4. Ibid

5. Anon 2019. *Draft Report on Optimal Generation Mix for 2029–30*, Central Electricity Authority, 2019. Available at https://doi.org/http://cea.nic.in/reports/others/planning/irp/Optimal_generation_mix_report.pdf, as accessed on 5 May 2020

6. *India's Intended Nationally Determined Contribution to UNFCC*. Available at https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/India%20First/INDIA%20INDC%20TO%20UNFCCC.pdf, as accessed on 5 May 2020

7. Chikkatur, Ananth P., Ambuj D. Sagar, Nikit Abhyankar, and N. Sreekumar 2007. "Tariff-based incentives for improving coal-power-plant efficiencies in India", *Energy Policy* ٣٥, no. ٣,٧٤٤ :٧–3,758

8. Chandra Bhushan, Priyavrat Bhati, Sanjeev Kumar Kanchan, Angeline Sangeetha, Sai Siddhartha, Soundaram Ramanathan and Abhishek Rudra 2015. *Heat on Power: Green Rating of Coal-based Power Plants,* Centre for Science and Environment, New Delhi

9. Qian Zhu 2020. *Historic Efficiency Improvement of the Coal Power Fleet*, International Energy Agency CCC/300 978–92–9029–623-2

10. Sam Nierop and Simon Humperdinck 2018. *International comparison of fossil power efficiency and $CO_2$ intensity—update 2018*, Ecofys. Project number: 205329

11. Anon 2017. *Energizing India*, Joint project report of NITI Aayog and IEEJ

12. Anon 2015. "Critically Acclaimed", *Power Today*, September 2015

13. Ibid

14. Anon 2017. *Energizing India*, Joint project report of NITI Aayog and IEEJ

15. Ibid

16. Priyavrat Bhati 2016. *Shutting Old Capacity: The 34-GW Question*, Centre for Science and Environment, New Delhi

17. Anon 2020. *Impact of part-load power operation on efficiency*, Central Electricity Authority

18. María V. Gil and Fernando Rubiera 2019. "Coal and biomass co-firing: Fundamentals and future trends", *New Trends in Coal Conversion*, pp. 117–140. Woodhead Publishing

19. Anon 2013. *Technology: Policy Brief E21*, IEA-ETSAP and IRENA 2013

20. Available at https://www.ieabioenergy.com/wp-content/uploads/2019/11/IEA-Bioenergy_Task-32-Triennium-2016-2018-1.pdf, as accessed on 5 May 2020

21. Anon 2017. *Biomass Utilization for Power Generation through Co-Firing in Pulverized Coal Fired Boiler*, Ministry of Power

22. Anon 2019. *Biomass Utilization at Coal-Fired Power Plant: A Choice for Environment and Economy* (Presentation), CEA-JCoal. Available at http://cea.nic.in/reports/cea-jcoal/presentation/JCOAL_presentation.pdf, as accessed on 5 May 2020

23. Tabbi Wilberforce, Ahmad Baroutaji, Bassel Soudan, Abdul Hai Al-Alami and Abdul Ghani Olabi 2019. "Outlook of carbon capture technology and challenges", *Science of the Total Environment* ٦٥٧: 56–72

24. Anon 2020. "LET Hydrocarbon Engineering Signs Pact with NTPC for $CO_2$-to-Methanol Plants-ET Energy World." *ETEnergyworld.com*, 20 August 2020. Available at https://energy.economictimes.indiatimes.com/news/power/let-hydrocarbon-engineering-signs-pact-with-ntpc-for-co2-to-methanol-plants/77649687, as accessed on 20 August 2020

25. Greg Kelsall 2020. *Carbon Capture Utilization and Storage (CCUS)-Status, Barriers and Potential*, IEA Clean Coal Centre, April 2020

26. Peter Viebahn, Daniel Vallentin and Samuel Höller 2014. "Prospects of carbon capture and storage (CCS) in India's power sector–An integrated assessment", *Applied Energy* ٧٥-٦٢ :١١٧.

27. Manish Ram, Michael Child, Arman Aghahosseini, Dmitrii Bogdanov, Alena Lohrmann, and Christian Breyer 2018. "A comparative analysis of electricity generation costs from renewable, fossil fuel and nuclear sources in G20 countries for the period 2015–30", *Journal of Cleaner Production* ٧٠٤-٦٨٧ :١٩٩.

28. Greg Kelsall 2020. *Carbon Capture Utilization and Storage (CCUS)-Status, Barriers and Potential*, IEA Clean Coal Centre, April 2020

29. Ibid

30. S. Bam, L. Powell and A. Sati 2017, *Coal Beneficiation in India*, Observer Research Foundation

31. Ibid

32. Anon 2020. *Notification on Coal Beneficiation, 21 May 2020*, MoEF&CC

33. Shuanzhu Sun *et al* 2020. "The extension of continuous carbon emission monitoring system in China's thermal power plants under the carbon market." *Earth Environment Science* 467 012165

34. Chikkatur, Ananth P., Ambuj D. Sagar, Nikit Abhyankar, and N. Sreekumar 2007. "Tariff-based incentives for improving coal-power-plant efficiencies in India", *Energy Policy* ٣٥, no. ٣,٧٤٤ :٧–3,758

35. Anon 2020. *Summary of the comments and suggestions received on Approach Paper on Terms and Conditions of Tariff Regulations for the tariff period 1 April 2014 to 31 March 2019*. Available at http://www.cercind.gov.in/2013/regulation/Comments/MC.pdf, as accessed on 5 May 2020

36. Nihar R. Sahoo, Pratap K.J. Mohapatra, Biresh K. Sahoo and Biswajit Mahanty 2017. "Rationality of Energy Efficiency Improvement Targets under the PAT Scheme in India—A Case of Thermal Power Plants, *Energy Economics*. Available at doi:10.1016/j.eneco.2017.06.004, as accessed on 5 May 2020

37. Anon 2020. *What Does It Mean to Put a Price on Carbon?* World Bank. Available at https://www.worldbank.org/en/news/feature/2014/06/11/what-does-it-mean-to-put-a-price-on-carbon, as accessed on 14 July 2020

38. Jieqiong Yang and Panzhu Luo 2020. "Review on international comparison of carbon financial market", *Green Finance* 2, no. 1: 55.

39. Ibid

40. Anon 2020. *India 2020, Energy Policy Review*, International Energy Agency

41. Anon 2020. "Government Proposes Waiving Carbon Tax on Coal," *Business Today*, 31 December 2019. Available at https://www.businesstoday.in/current/economy-politics/big-win-coal-industry-pmo-proposes-waiving-carbon-tax/story/392877.html., as accessed on 5 May 2020

42. Anon 2019. *Discussion Paper on Carbon Tax Structure for India*, Ernest & Young

43. Anon 2020. *India 2020, Energy Policy Review*, International Energy Agency

Despite the growth in renewable power, India continues to be heavily reliant on coal to meet its energy needs. This is unlikely to change in the near future. India's coal power sector contributes nearly 50 per cent of India's fuel-related $CO_2$ emissions.

Beset with all kinds of problems, from poor quality coal to slow progress on technical and institutional reforms, India's coal power sector is one of the most inefficient in the world. But there is immense scope of reducing the sector's $CO_2$ emissions footprints and, in turn, augment its climate change mitigation potential. In this report, we delve deeper into the possible interventions and the impact they can have.

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