

India's Energy Transition:

The cost of meeting
air pollution standards
in the coal-fired
electricity sector

ISSUE BRIEF



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List of Abbreviations

CEA	Central Electricity Authority
CEEW	Council on Energy, Environment and Water
CEMS	continuous emission monitoring system
CFBC	circulating fluidized bed combustion
CNY	China Yuan Renminbi
ESP	electrostatic precipitator
ERC	Electricity Regulatory Commission
FGD	flue gas desulfurization
FY	fiscal year
GoI	Government of India
GW	gigawatt
Hg	mercury
IISD	International Institute for Sustainable Development
INR	Indian rupee
kWh	kilowatt hour
LCOE	levelized cost of energy
LNB + OFA	low-NO _x over fire air burners
MoEFCC	Ministry of Environment, Forest and Climate Change
MoP	Ministry of Power
MW	megawatt
NO_x	nitrogen oxides
O&M	operation and maintenance
OECD	Organisation for Economic Co-operation and Development
PCT	pollution-control technology
PM	particulate matter
SCR	selective catalytic reduction
SERC	State Electricity Regulatory Commission
SNCR	selective non-catalytic reduction
SO₂	sulphur dioxide
USD	US dollar
WFGD	wet flue gas desulfurization



1.0 Introduction

In *India's Energy Transition, 2018 Update*, the International Institute for Sustainable Development (IISD) and the Council on Energy, Environment and Water (CEEW) published updated estimates of energy subsidies in India for financial year (FY) 2017 and partial data for FY 2018 (Soman et al., 2018). According to the report, quantifiable subsidies for coal in India totalled INR 15,992 crore (USD 2.4 billion) in FY 2017. Non-compliance with environmental standards was identified as an important subset of coal subsidies.¹ Non-compliance with coal-washing requirements was identified as the largest in this category (INR 981 crore, USD 146 million in FY 2017).²

In 2015, the Ministry of Environment, Forest and Climate Change (MoEFCC) legislated new standards to limit the concentration of sulphur dioxide (SO₂), nitrogen oxides (NO_x), particulate matter (PM) and mercury (Hg) in stack emissions for coal-fired power plants. The Ministry amended the standards in 2018; however, there was no material change in air pollution norms (Central Pollution Control Board, 2018). Existing thermal generators were expected to comply by December 2017. For new plants, compliance was required at the point of commissioning from January 2017. However, by December 2017, almost no coal plants had installed the equipment and the deadline was extended to 2022.

This brief extends the analysis in the IISD and CEEW report by detailing the cost of compliance with regulations on air pollution and implicit subsidies associated with extensions and non-compliance. This issue brief examines: the reasons for slow progress by coal power plants; the cost of installing pollution-control equipment for the sector and implications for the electricity price; the cost of externalities related to human health; and a comparison of the cost of installing pollution-control equipment with phasing out non-complying coal plants.

KEY FINDINGS AND RECOMMENDATIONS

- The total capital expenditure required to install SO₂, NO_x and PM pollution-control technology is estimated to be INR 86,135 crore (USD 12 billion),³ or INR 73,176 crore (USD 10 billion) if plants to be retired by 2027 are excluded.
- This will add between INR 0.32 per kWh to INR 0.72 per kWh for coal power plants (or around 9 to 21 per cent to average generation tariffs) depending on the size of the unit and other factors. On account of remaining useful life and more stringent requirements, the average 500 MW units face the steepest tariff increases. In most cases, more than 80 per cent of the tariff increase will be in the form of a fixed cost. The variable component in all cases adds less than INR 0.1 per kWh.
- Distribution companies need to be able to pass on these higher costs to end-consumers. Electricity subsidies should be targeted only to the poorest, while other consumers will need to pay tariffs that reflect the cost of supply, including technologies or levies (such as the coal cess) that mitigate externalities.

¹ The conservative approach used in the IISD and CEEW report only defines non-compliance as a “subsidy” if a law exists, and special exemptions have been granted, or good data exist on non-compliance.

² Coal washing is the process of refining or removing contaminants to improve its emissions profile.

³ INR 1 = USD 0.014, Source: Average rate for 2018 (Federal Reserve, 2019).

- Incentives, penalties and seasonal shutdowns should also be used to control air pollution.
- Technical guidance aside, an independent assessment of retrofit costs at a plant level, by empanelled agencies would expedite the ability of private sector power plants to submit tariff increase petitions to the regulators. The back and forth between the Electricity Regulatory Commission (ERC) and Central Electricity Authority (CEA) and the resulting lack of clarity on cost increases is a key impediment to compliance. In the interest of public health we recommend that the exercise be funded by Government of India (GoI) to expedite the process.
- Most experts are of the view that the deadline will still see many plants not complying with the new standards. To avoid this situation, the Ministry of Power (MoP) must take a stricter position which precludes all non-compliant plants from generating, unless they exhibit a clear retirement or phase-out plan or have made material progress in awarding tenders and beginning the construction process.
- Finally, plants that do implement the technology need to be monitored to ensure that standards are being met. There is a financial burden of pollution-control technologies (PCTs) on end-consumers and transparency is key in ensuring that higher tariffs do indeed result in health benefits. The availability of data from the continuous emission monitoring system (CEMS) devices installed in the emission stacks of plants, to the electricity regulator and the broader public must be a first priority.



2.0 Context

Coal-fired power plants produce a range of externalities, and arguably the most pronounced is the impact of local and regional air pollution on human health. Air pollution occurs when there is a release of high concentrations of harmful particles, as identified through continuous emissions monitoring systems. Burning coal to produce electricity releases PM⁴, SO₂, NO_x and Hg. If the emission trends of thermal power plants remain unchanged, projections estimate that these pollutants will cause an estimated 1.3 million deaths in India per year by 2050 (Health Effects Institute, 2018).

To address the issue, the central government set emissions standards in 2015 for all four pollutants (Ministry of Environment Forest and Climate Change, 2015). The permitted emissions levels varied with the age of the generation unit: older units were allowed higher emissions than more modern ones (Annex 1). Compliance requires a retrofitting or upgrading of pollution-control equipment (Table 1).

Table 1. Air pollution-control equipment for coal-fired power plants commonly used in India

Pollutant	Control equipment
Sulphur oxides	flue gas desulphurization (FGD), limestone injection
Particulate Matter	electrostatic precipitators (ESP)
Nitrogen oxides	over fire air burners low-NO _x burners selective catalytic reduction (SCR) selective non-catalytic reduction (SNCR)

⁴ Particles less than 10 micrometers in diameter, that can pass through the nose and throat and enter the lungs, with serious health impacts on the heart and lungs. PM is generally defined as fine (<2.5 micrometers) and coarse (2.5–10 micrometers).

A two-year compliance window was allowed for units installed before January 1, 2017. All plants under construction and those commissioned after January 1, 2017 were expected to comply from their date of commissioning. The December 2017 deadline was not met. An IISD and CEEW consultation with a range of sectoral experts (see Annex 4) found that, in retrospect, experts have concluded that the two-year timeline set initially was perhaps unrealistic given the processes involved and the lack of experience in installing these systems on a large scale. Further, the Central Electricity Authority (CEA) published technical guidelines on flue gas desulphurization only in December 2017. Before these guidelines were established, developers could not be confident that investments would meet the new requirements

The deadline was extended to December 2022 (Central Pollution Control Board, 2018), thereby providing a further 5-year period for complying with the new emission standards. For thermal plants located in proximity to the National Capital Region, the target date for environmental compliance is end of 2019.

In the process of compiling a list of power plants and their attributes, 177 GW of utility power plants based on coal was identified (excluding captive power plants). These plants were all commissioned on or before June 2017. For reference, the total capacity of coal-based power plants (as of March 2019) stands at 194 GW. In the CEA phasing plan, 166 GW of capacity requires retrofitting with flue gas desulphurization and 66 GW with modifications or enhancements to the electrostatic precipitators system in place (to achieve the new PM standards). While no clear directives were issued to plants for retrofits to meet the new NO_x standards, consultations with and assessments by other groups suggest that all plants require some modifications or additions (Pathania, Phadke, Hande, & Ramanathan, 2019; Srinivasan et al., 2018). In our assessment, nearly 172 GW required process modification or retrofitting with some technology to meet NO_x standards (Table 3). In arriving at this figure, we merely exclude those plants that use the circulating fluidized bed combustion (CFBC) boiler design and assume that all other plants need a retrofit.

Some progress is being made with the retrofits. In December 2017, Central Electricity Authority (CEA) published technical guidelines on flue gas desulphurization, removing a major impediment to installation. However, the in-principle approval for costs to be incurred in installing these systems, as sought by various generators (specifically state-owned NTPC which has a fleet of plants) have been repeatedly quashed by various regulators, including the Central Electricity Regulatory Commission (CERC). In-principle approvals are not found in the tariff regulations of the Central Electricity Regulatory Commission⁵ (Central Electricity Regulatory Commission, 2019b) and plants have been asked to approach the CEA with specific cases and arrive at projected expenses for approval by the regulators.⁶ However, CEA did not respond to the requests early on and belatedly came out with an assessment of normative impact on tariffs as a result of FGD installation for various kinds of plants in September 2018. Though limited, it also gave clarity to plants on how the additional costs would not affect merit order dispatch and suitable measures would be taken to ensure power plants aren't at a disadvantage as a result of retrofits (Ministry of Power, 2018). The CEA for its part has started monitoring implementation progress. As of March 2019, bids have been awarded or tenders have been issued for installation of flue gas desulphurization for around 96 GW of capacity, more than half of the capacity requiring this retrofit (Table A2.1). Flue gas desulphurization is the most important equipment because it represents around 80 per cent of the costs of the retrofits (Central Electricity Authority, 2019).

⁵ The 2019 Tariff regulations contain a provision for in-principle approvals and will hopefully resolve some uncertainty on the process.

⁶ The state of Maharashtra has in-principle approvals defined in tariff regulations, and plants may approach the regulator for a tariff increase using this in tandem with the change in law notification issued by MoP



In the National Capital Region, flue gas desulphurization has been planned for 12.7 GW of thermal capacity, out of which it has been installed for only 1.3 GW capacity as of March 2019. Bids have been awarded or tenders have been issued for the remaining capacity (see Annex 2 for details on the status of implementation of flue gas desulphurization installation) (Central Electricity Authority, 2019).

Consultations with power sector experts suggest that retrofitting flue gas desulphurization equipment typically requires 18–30 months for construction (Centre for Science and Environment, 2016). Given that 42 per cent of non-compliant power plants have not even issued notifications inviting tenders, some plants are likely to miss the 2022 deadline for SO₂ compliance.

Many of the existing plants will be able to meet NO_x emission standard compliance by 2022. The standard equipment, over fire air (OFA) burners or low-NO_x Burners (LNB), are relatively inexpensive and fast to install. A number of NTPC plants (more than 10) have awarded contracts in the last year for installation of low-NO_x burners to bring emissions within the thresholds. However, for newer plants and those of a recent vintage, NO_x limits are tighter and more efficient removal technologies such as selective catalytic reduction (SCR) or selective non-catalytic reduction (SNCR) are required to meet the standards. Pilot studies at eight units are underway for SCR and two units for SNCR technology (Power Line, 2019). While there are many mentions of bids being awarded for SCR technology to state-run engineering firm Bharat Heavy Electricals Limited (BHEL) (Mint, 2019), no specific details of which plants have chosen SCR technology to meet the norms was available

The poor history of enforcement and compliance monitoring of regulations and notifications pertaining to pollution standards has meant that the industry continues to drag its feet, despite clear timelines being specified for each plant. This is further exacerbated by the fact that upfront costs are high and the cost recovery process is not clear.

The Change in Law notification, issued in March 2018, allows for installation and operating costs of emission-control equipment to be passed on to utilities and from there to retail consumers by way of increased tariffs (Ministry of Power, 2018; Varadhan, 2019). The notification was issued to provide regulators and plant operators with clarity on who is eligible to pass on incremental costs of compliance to end-consumers. Notwithstanding this legal backing, it is politically challenging to pass on higher power costs to consumers, and many efforts to do so have been rolled back or postponed. Electricity distribution utilities in India are already under serious financial stress on account of the historic and continuing burden of subsidizing retail tariffs (Soman et al., 2018). In order to reduce possible pressure on distribution utilities, the Ministry of Power has submitted a proposal to the Finance Ministry for INR 83,500 crore (USD 12 billion) to help power plants install pollution-control equipment (Varadhan, 2019). This way, little or none of the cost gets passed on to consumers. However, at the time of writing it is not clear that the subsidy will be approved and, given that many bids and tenders are underway, such a proposal will not be seen favourably by those who have already incurred the costs.

BOX 1. CHINA'S SUCCESS IN CLEANING UP ITS THERMAL FLEET

China, with the world's largest thermal fleet of 981 GW capacity (about 55 per cent of its total electricity generation mix), revolutionized its highly polluting coal power sector to tackle the problem of air pollution. Emissions from coal plants contributed to around 40 per cent of PM_{2.5} emissions in China (China Power Team, 2016). One study estimated that the ambient PM_{2.5} pollution from coal plants accounted to 3,66,000 premature deaths in 2013 (China Power Team, 2016). In 2006, the Chinese government decided to reduce national SO₂ emissions by 10 per cent under the 11th Five Year Plan (2006–

2010). In 2011, China set a target of reducing national NO_x emissions by 10 per cent under the 12th Five Year Plan (2011–2015) with the use of two prominent NO_x-control technologies: selective catalytic reduction (SCR) and selective non-catalytic reduction.

In 2011, China brought in stringent emission standards for coal power plants by reducing the NO_x and SO₂ limits to 100–200 mg/m³ limits and 100–400 mg/m³, respectively, based on the age and location of the plants. In highly polluting regions, SO₂ standards were 50 per cent lower than the rest of the nation. In addition, it is reported that certain regions, including Beijing, have voluntarily adopted stricter norms than the national ones (Singh, 2017).

The government initiatives were successful. The Chinese Ministry of Environmental Protection reported that since 2012, SO₂ emissions from coal-based plants decreased by 38 per cent and NO_x emissions declined by 42 per cent. By 2015, more than 50 per cent of the plants had installed the devices (Singh, 2017).

China's success in cleaning up its thermal fleet can be attributed not only to the adoption of stringent norms but the comprehensiveness of the action plan.

- Power generators were encouraged to install pollution-control equipment through the introduction of a differential tariff system in 2004 that granted a higher tariff to low-emission-generating assets.
- A premium payment is assured for generators that meet an “ultra-low” emission standard (CNY 0.01 per kilowatt hour [kWh]) for those connected to grid systems before January 1, 2016 and CNY 0.005 per kWh connected after; USD 0.0015 and USD 0.00075, respectively).⁷ The cost of the ultra-low emissions subsidy is estimated to be CNY 3.6 billion (USD 545 million) for already-installed capacity and another CNY 1.8 billion (USD 272 million) for newly installed capacity in 2016 (Denjean et al., 2016).
- In addition to premium payments, the government also guarantees purchase by the grid of an additional 200 hours from ultra-low emissions generators in the annual electricity generation plan. The value of the purchase guarantee is estimated at CNY 3.3 billion (USD 499 million) in 2015 (Denjean et al., 2016).
- The government provided subsidized grants and loans through various environmental funds to support investments in pollution-control technology.
- In some provinces around 10–30 per cent of pollution-control technology investment costs could be covered by government funding (Denjean et al., 2016).
- The Chinese government assisted the power plants to choose the required pollution-control technology by issuing technical guidelines.
- A strict cumulative penalty system is placed for plants not complying with the standards. Such plants are periodically monitored and penalized until complete compliance is achieved.
- China follows a preferential dispatch mechanism in certain regions, under which power procurement is prioritized from the plants that have low emissions and high efficiency levels.

The aforementioned policy changes have encouraged the power generators of China to reduce their emissions in order to stay ahead in the market and escape penalties.

⁷ Exchange rate 1 USD = CNY 6.609 (average for 2018) (Federal Reserve, 2019).



3.0 Methodology

3.1 Economic Impact Analysis

This report assesses the costs of compliance of the identified list of power plants. This is a fairly exhaustive—though not comprehensive—list. Pollution-control technologies were assigned at a plant level, and the total investments required was calculated. Then the incremental cost of electricity generated from retrofitted plants was calculated. The analysis considers only capacity that was online as of June 2017 in order to keep the data requirements manageable and to understand the state of implementation of the old and existing plants. Plants that would have been commissioned since then are in any case expected to comply with the new standards.

3.1.1 Capacity and Scenario Analysis

In the National Electricity Plan 2018 (Central Electricity Authority, 2018), a capacity of 9,399 MW⁸ has been considered for retirement by 2022, and a further 25,253 MW is planned for retirement from 2022 to 2027. In some of these plants, a lack of availability of space for the installation of pollution-control technologies also means that they are candidates for prompt retirement, as opposed to sustained use even after end of useful life (normally 25 years). Installation of pollution-control technology on these plants would likely be financially inefficient, as they have a brief remaining use period. Also, plants with circulated fluidized bed combustion-type boilers are not required to install additional pollution-control technology, as the emissions from such plants are very low due to the firing process and materials used. For the purpose of analysis in this study, two cases have been considered.

⁸ The retirement plan by 2022 in the NEP refers to a capacity of 16,789 MW. However, nearly 7,400 MW of this has already been retired and this leaves only 9,399 MW for further retirement by 2022.

- Case 1: Retrofitting all “eligible”⁹ plants, including those identified for retirement in the National Electricity Plan
- Case 2: Retrofitting “eligible” plants from among those that are not identified for retirement

3.1.2 Technology

Specific pollution-control technologies were assigned to individual coal-fired generators for each pollutant category based on the capacity of the unit, date of commissioning, age of the unit, existing infrastructure and the emission standards. Table 2 describes the criteria that determined the allocation of technologies to power plants. Table 3 provides the total installed capacity requiring each of the technologies. Further details about the various technologies and their applications are summarized in Annex 2.

Table 2. Emission Criterion for pollution-control technology installation based on different studies

Pollution-control technology	Criterion
SO ₂	Wet flue gas desulphurization (WFGD) is used for capacities greater than 400 MW and dry flue gas desulphurization (DFGD) for units less than 400 MW (Srinivasan et al., 2018). Also, for units with capacity less than 500 MW commissioned before December 31, 2003, the norms are relatively loose and attained through alternative means. Hence, limestone injection (LI) which has a removal efficiency of around 50 per cent is sufficient to meet the norms.
NO _x	This study assumes that the NO _x -control technologies have to be retrofitted across the entire capacity, as the number of those already complying is negligible. According to technology suppliers, the latest low-NO _x burners (LNBS) and overfire air systems (OFA) technology are capable of reducing NO _x emissions well below the 300 mg/Nm ³ limit, and only plants commissioned after January 1, 2017 have to meet the stringent NO _x guideline of 100 mg/Nm ³ (Centre for Science and Environment, 2018). Hence, selective catalytic reduction technology, whose removal efficiency is higher (~90 per cent), was chosen for the plants commissioned after January 1, 2017.
PM	Plants requiring electrostatic precipitator retrofits have been identified based on the five Regional Power Committee notifications that provide a plan for implementation of emission norms. The electrostatic precipitator retrofits primarily target particulate matter emissions.

Sources: Srinivasan et al., 2018; Centre for Science and Environment, 2018.

⁹ Eligible if plants were explicitly identified by the CEA in their phased retrofit plan or if it was deemed that a plant should be retrofitted and there is no evidence to suggest that it meets the environmental norms at the time of the analysis.

Table 3. Capacity of coal-fired power plants requiring retrofitting of pollution-control technology (capacity, GW)

Pollutant	Pollution-control technology	Case 1: All plants commissioned pre-June 2017	Case 2: Excluding plants scheduled for retirement
SO ₂	Total capacity	165.2	130.6
	Wet flue gas desulphurization	105	96
	Dry flue gas desulphurization	29.4	29.2
	Limestone injection	30.8	5.3
NO _x	Total capacity	172.6	138
	Low-NO _x burners and overfire air systems	167.2	132.6
	Selective catalytic reduction	5.4	5.4
PM	Total capacity	65.8	38.2
	Electrostatic Precipitator	65.8	38.2

Source: IISD & CEEW analysis.

3.1.3 Cost of Pollution-Control Technologies

Srinivasan et al. (2018) and Ramanathan (2017) identify costs of the various pollution-control technology on a normalized basis per MW of installed plant capacity. These costs are subject to change, based on improvements in technology, the economies of scale achieved over large number of installations and most importantly, plant- or unit-level constraints. For example, the cost of a wet flue gas desulphurization system was as low as INR 19 lakhs per MW (USD 27,426) in a recent bid. However, this was an outlier, and the average cost (as suggested by technology providers and the literature they reviewed) is INR 50 lakh (USD 72,175) per MW.

The analysis presented in Srinivasan et al. (2018) is more recent and within the range of the latest tenders approved for pollution-control technology installation. The capital and operations and maintenance (O&M) costs of different pollution-control technologies chosen in this study are listed in Table 4.

Table 4. Average cost of pollution-control technologies per plant in India

Pollution-control technology	Capital Cost (per MW)	O&M Cost (per MW per annum)
Wet flue gas desulphurization	INR 50,00,000 (USD 72,175)	INR 6,00,000 (USD 8,661)
Dry flue gas desulphurization	INR 35,00,000 (USD 50,522)	INR 6,00,000 (USD 8,661)
Limestone injection	INR 15,00,000 (USD 21,000)	INR 6,00,000 (USD 8,661)
Low-NO _x burner + open fire air	INR 8,00,000 (USD 11,548)	0
Selective catalytic reduction	INR 30,00,000 (USD 43,305)	INR 50,000 (USD 722)
Electrostatic precipitator	INR 5,00,000 (USD 7,217)	INR 50,000 (USD 722)

Source: Srinivasan et al., 2018.

As mentioned earlier, the change in law allows for pass-through of the additional costs and petitions for revision in tariff will have to be evaluated and approved by the regulatory commissions. The financial impact of the installation of pollution-control technology on tariffs is calculated based on Central Electricity Regulatory Commission guidelines for tariff determination. The change in tariff varies for plants based on compliance requirements and operational characteristics.

3.1.4 Sensitivity Analysis

Since incremental costs are represented on a per-kWh basis, it is important to capture the variability in this as it depends on various physical and operational characteristics of plants. To enable this, a sensitivity analysis was carried out for the change-in-tariff calculation with respect to three parameters:

- Capacity of the unit being retrofitted
- Plant load factor (the average level of utilization of the plant, expressed as a per cent of total capacity)
- The remaining useful life of the plant.

Eight plant capacities (125, 200, 250, 300, 500, 600, 660 and 800 MW) representing the prominent plant sizes in India were examined. At the same time, we evaluated the variation with their respective expected residual life (see Annex 5): three plant load factors (35 per cent, 60 per cent and 85 per cent) were considered. The three plant load factors represent, respectively: a low range; the national average; and the standard value that is specified by the Central Electricity Regulatory Commission for change-in-tariff calculations.

3.2 Stakeholder Consultation

IISD and CEEW conducted a stakeholder consultation in parallel with the quantitative analysis. An open questionnaire was designed (refer to Annex 4). The questions centred on:

- Reasons behind the failure to enforce the air pollution standards
- Expectations on compliance levels
- Financial challenges and ways forward
- Role of subsidies in pollution-control technology upgrades
- Cross linkages to other industry challenges such as retrofits and maintenance, flexibility of generation, distribution company financial struggles and stranded assets
- Expert opinions on assumptions used in the quantitative analysis.

The stakeholders interviewed included a wide range of experts at the central government, private sector and policy researchers. The organizations represented by the stakeholders include independent power producers (Jindal Group), technology solutions providers, electricity regulators (Central Electricity Regulatory Commission), government research and development groups (NITI Aayog and Central Electricity Authority) and think tanks working on this issue. The open nature of questions allowed for interviewees to share their opinions based on their experience and the sensitive data that they have reviewed.



4.0 Results

The outcomes of the quantitative analysis and stakeholder consultations are summarized below.

4.1 Economic Impact Analysis

The aggregated capital cost for pollution-control technology installation is presented here. The total capital investment required is approximately INR 86,135 crore (USD 12.6 billion) in Case 1 and INR 73,176 crore (USD 10.6 billion) in Case 2 (when plants scheduled for retirement before 2027 are excluded). This estimation does not include the variable O&M costs, namely reagent costs and any applicable energy penalty on the plant over the lifetime of the plants. Capital expenditure (capex) required for abatement of different pollutants is given in Table 5.

Table 5. Estimated capex for abatement of different pollutants

Pollutant	Case 1 Capital Cost		Case 2 Capital Cost	
	INR crore	USD million	INR crore	USD million
SO ₂	67,416	9,438	59,034	8,265
NO _x	15,430	2,231	12,233	1,769
PM	3,289	476	1,909	276
Total	86,135	12,059	73,176	10,245

Figure 1 shows that the SO₂ abatement costs constitute the lion's share (~81 per cent) of the total capex requirement, while NO_x-control technologies account for 16 per cent and the electrostatic precipitator retrofits costs around 3 per cent.

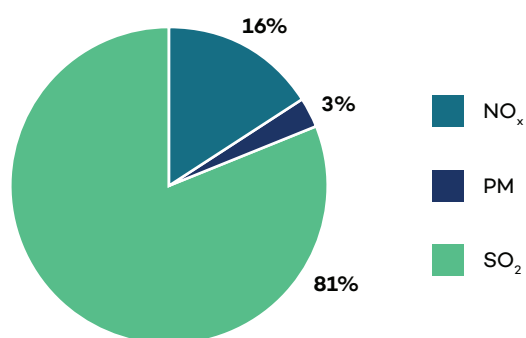


Figure 1. Percentage share of capex of different pollutants

It is equally important to understand the implications for end-consumers, by way of increased tariffs from this retrofitting. The impact of pollution-control technology installation on tariffs varied from INR 0.32 per kWh to INR 0.72 per kWh (or around 9 to 21 per cent increase to average total cost of power generation prevailing today) depending on the capacity of the plant and operating plant load factors. Units with a capacity of 500 MW exhibit a higher cost increase (INR 0.54 – 0.72 per kWh), as the norms are more stringent and the average plant also has a lower residual life (Table 6). Other factors determining the results within each plant capacity category are the pollution-control technologies needed and the load factors (see Annex 5 for details).

Table 6. Tariff increases arising from installation of pollution-control technology

Plant capacity (MW)	Average residual life (years)	Tariff increase	
		INR/kWh	US cents/kWh
125	8 ¹⁰ (8)	0.32–0.94	0.45–1.32
200	8 ¹¹ (7)	0.32–0.93	0.45–1.30
250	18 (6)	0.30–0.71	0.42–0.99
300	19	0.32–0.71	0.45–0.99
500	13	0.40–1.13	0.56–1.58
600	21	0.37– 0.80	0.52–1.12
660	22	0.36–0.96	0.50–1.34
800	20	0.36–0.80	0.52–1.12

Source: IISD & CEEW analysis.

¹⁰ The numbers within parentheses for 125, 200, & 250 MW indicate the average residual life of plants that would likely use the LI process to address SO₂ emissions. It varies from the average of other plants falling under same range because of the fact that we are suggesting LI installation for plants commissioned before 2003 (Refer Table 2).

¹¹ Plants below the 200 MW capacity range have already completed their useful life (25 years). Hence, the average residual life is considered as eight years assuming that the plants will be retired by 2027.



Table 7. Contribution of different pollutants to tariff increase

Plant capacity (MW)	Tariff increase INR/kWh		
	SO ₂	NO _x	PM
125	0.23–0.74	0.04–0.10	0.05–0.10
200	0.24–0.74	0.04–0.10	0.04–0.09
250	0.25–0.60	0.02–0.05	0.03–0.06
300	0.27–0.60	0.02–0.05	0.03–0.06
500	0.34–0.76	0.03–0.30	0.03–0.07
600	0.31–0.68	0.02–0.05	0.04–0.07
660	0.31–0.68	0.02–0.22	0.03–0.06
800	0.31–0.69	0.02–0.05	0.03–0.06

Source: IISD & CEEW analysis.

The sensitivity analysis shows that flue gas desulphurization contributes significantly to the increase in tariff due to its high fixed costs. Plants running at lower load factors also see a much larger increase in costs compared to those running at higher loads. The residual life of the plant is another important factor in determining the amount of tariff increase. Plants having a lower residual life have to recover their capex in a short span of time and, consequently, the tariff increases. It is important to note that the variable cost increase is in all cases less than INR 0.1 per kWh. This includes the cost of reagents and consumables used in the pollution-control process and also account for nominal increases in auxiliary consumption by the power plant. However, we have not considered the cost of handling waste.

The total cost of electricity generated from coal-fired power plants, as measured by the levelized cost of electricity (LCOE) metric, is in the range of INR 1.86–INR 7.5 per kWh. This includes the impact of pollution-control technology installation. The base costs of a power plant are determined by various factors such as imported coal usage and load factors. When PCTs are considered, residual life and the choice of PCT (depending on the applicable emissions limit) determine the extent of increase in costs. At a time when the costs of renewable energy-based electricity are decreasing and newly discovered tariffs are in the range of INR 2.5 to INR 3, the increasing cost of coal makes it less competitive, albeit providing different services compared to a renewable energy plant.

4.2 Stakeholder Consultation

The stakeholder opinions identified in this study can be loosely grouped into three categories: issues related to meeting the deadlines; who should pay for the pollution-control equipment; and technical and regulatory barriers.

4.2.1 Barriers to Meeting the Deadlines

There was consensus among stakeholders that the initial deadline (December 2017) was unrealistic. Various opinions were expressed on whether the new target will be met. No interviewees were entirely confident that the new deadline will be met by all plants.

High upfront investment was agreed by all to be the biggest hurdle to plants implementing the new deadline. The level of compliance with the new deadline (2022) is likely to be determined by whether producers have access to additional resources or commercial finance. The centrally owned NTPC and state-owned generators are likely to meet the deadline because they are large, have high cash flow and can either borrow funds or receive financing from government. Private power producers, many of which are already financially stressed, are less able to obtain finance and are least likely to meet the targets.

4.2.2 Paying for the Pollution-Control Upgrades

Stakeholders agreed that the financial health of electricity distribution companies is a key issue. Distribution companies are already under financial pressure due to high technical and commercial losses and regulated consumer tariffs. Therefore, while the law states in principle that the cost of pollution-control equipment can be passed on from power producers to distribution companies, there is considerable uncertainty surrounding their ability to recover this increased tariff in the regulated environment. State governments are required by law to scrutinize price increases on a case-by-case basis and these legal and regulatory approvals take time. In some cases, distribution companies have appealed against higher prices (Pathania, 2019).

Some state regulators have also contended that space provisioning for flue gas desulphurization—mandated in environmental approvals granted at the time of construction of the plants—also implies that operators must make financial provisioning for such retrofits and that this cannot be interpreted as a change in law for such plants.

There was general agreement that generating companies must bear the initial costs, and it is unlikely that the government will offer subsidies. While the power generators expect grants from the government, environmental experts interviewed insisted that power producers should bear the expenses based on the “polluter pays” principle.

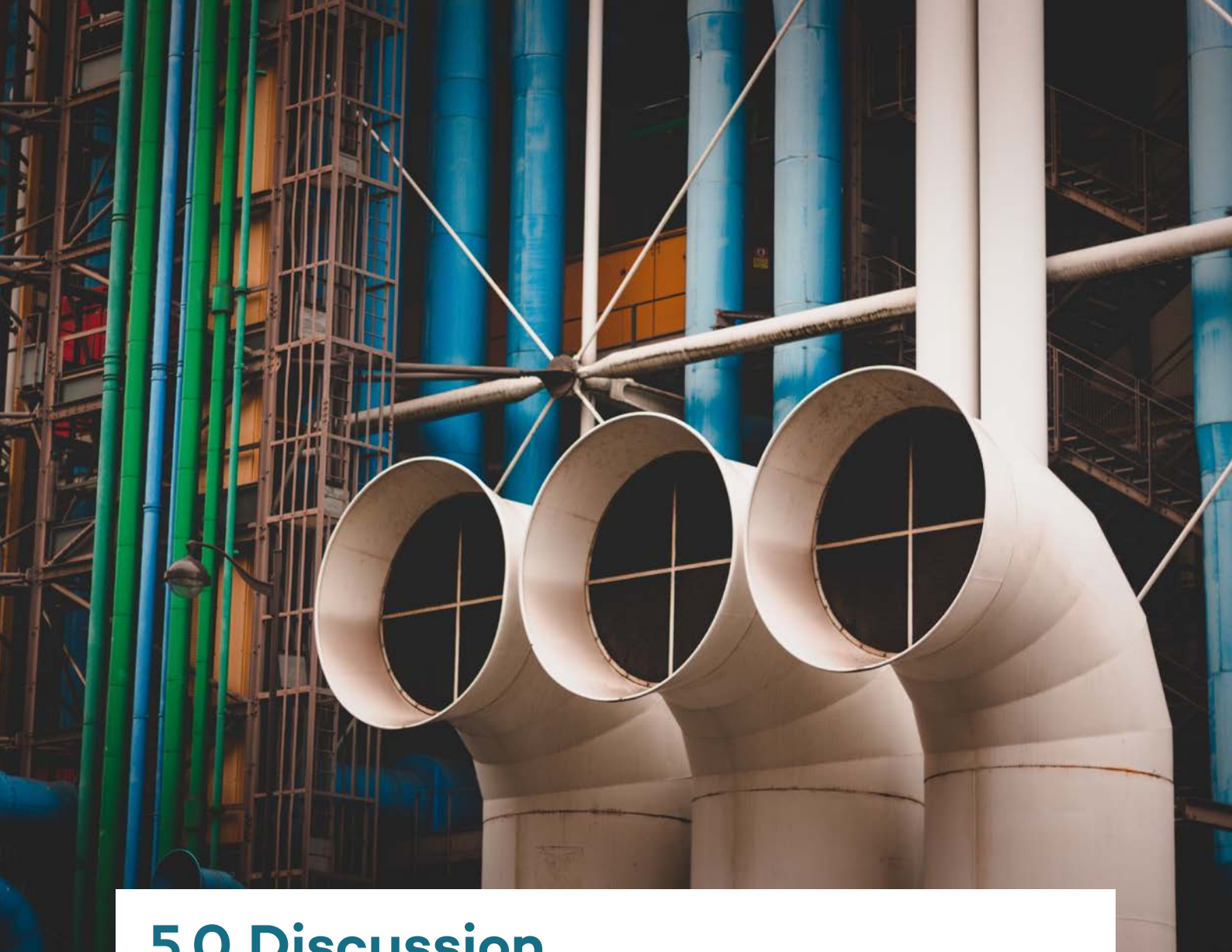
4.2.3 Technical Barriers

Another major barrier identified was the inadequate practical experience among Indian power producers on choosing, installing, commissioning and operating pollution-control technologies (the only pollution-control technology widely installed in India is the electrostatic precipitator to control PM emissions). This is compounded by a lack of technical guidelines for some pollution-control technologies.

To handle grid stability issues arising from widespread and uncoordinated outages of plants, it is important that a clear implementation plan for each plant is put in place. A large majority of plants will have their capacity tied up through power purchase agreement (PPAs) with different states. For grid stability and security, any issues from implementation of pollution-control technologies must be resolved at a regional level to ensure that regional imbalances do not spill over to the national grid.

In terms of which plants should be retrofitted first, stakeholders supported the CEA's current methodology of prioritizing the worst polluters and the most polluted regions. Funds should be invested for plants to first comply with pollution-control technology, then flexible operations¹² and lastly on improving efficiency through renovation and maintenance. Flexibility is seen as the next update required for coal plants to be remain relevant.

¹² The ability to operate reliably with significant shares of variable renewable electricity



5.0 Discussion

The total capex required for pollution-control technology installation is estimated to be significant. The costs range between INR 73,176 crore (USD 10.2 billion if plants marked for retirement are not retrofitted) and INR 86,135 crore (USD 12 billion if the retrofits were to happen across all eligible plants). This will add between INR 0.32 per kWh to INR 0.72 per kWh (or around 9 to 21 per cent to average tariffs) of electricity generated from these plants, depending on the load factor, the size of the unit and the remaining useful life. In extreme cases, the tariff increases could be as high as INR 0.9 per kWh to INR 1.2 per kWh, but these are for a handful of plants when operated at very low PLFs consistently, and it would be far more economical to retire these. The broader question of whether to retire or retrofit will need a more nuanced analysis that considers the load dispatch constraints and overall demand for electricity in the years to come.

In the absence of any further details or in the event there is uncertainty on the use of plants, it is better to be cautious—all plants must be retrofitted if they are to operate in 2023. The delays are essentially a benefit provided to plant operators and the coal sector as a whole at the cost of public health. The incremental variable cost of operating the PCTs is small and will in any case not affect the merit order and potential revenues a plant stands to make. However, the operationalization of this separation of charges and accounting could prove to be tricky.

Government support to coal mining and coal-fired power was INR 15,992 crore (USD 2.4 billion) in FY2017. In recent auctions by the Solar Energy Corporation of India Ltd. (SECI), solar tariffs fell to their lowest level—roughly INR 2.44 (USD 3.7 cents) per kWh and wind tariffs at INR 2.77–2.83

(USD 4.1–4.3 cents) per kWh. At these rates, renewables compare very favourably relative with coal power tariffs, which average INR 3–5 (USD 4.7–7.7 cents) per kWh for domestic coal and INR 5–6 (USD 7.7–9.3 cents) per kWh for imported coal (Soman et al., 2018). Government should not redirect any additional financial resources to a polluting technology over a clean energy source that is now cheaper on a per-kWh basis.

The public health costs of air pollution arising from power plants far outweigh the cost of retrofitting. Gunatilake, Ganesan, & Bacani (2014) find that by merely spending USD 0.28 cents per kWh, health impacts attributable to pollution from thermal power plants can be reduced from USD 0.125 per kWh to USD 0.0105 per kWh. Nkambule & Blignaut (2017) modelled the external costs of a supercritical power station and calculated it to be between INR 32.7 (USD 0.47) to INR 71.3 (USD 1.03) per kWh. The externalities considered were biodiversity losses, greenhouse gas emissions, damage to roads, noise, water pollution and air pollution. Air pollution accounted for 21 per cent of the external costs. However, the assessment was made for a coal power plant fitted with flue gas desulphurization.

The current coal cess of INR 400 (~ USD 6) per tonne of coal does not fully reflect the external costs of coal-fired power. Inclusion of the cost of pollution-control equipment (both fixed and operating), in the price of coal-fired electricity is appropriate because it ensures the internalization of much of the costs that are currently socialized.

A forward-looking model-based assessment for the period 2015–2030 found that non-compliance with emission norms would result in around 3–3.2 lakh (300,000–320,000) premature deaths and 5.1 crore (51 million) hospital admission cases due to respiratory disorders between 2019 and 2030. The mortality and morbidity costs attributing to PM_{2.5} alone were estimated to be INR 8,88,038 crore (USD 128 billion) and INR 74,184 crore (USD 11 billion) respectively during 2015–2030 (Srinivasan et al., 2018).

Interestingly, Srinivasan et al. (2018) found that the reduction in ambient PM_{2.5} concentrations will yield greater benefits in cleaner areas than more polluted areas. The underlying logic is that any abatement in highly polluted regions will have minimal impact on health improvement. However, this is against the Supreme Court's approach of prioritizing compliance in critically polluted areas (Supreme Court of India, 2016). Compliance with the emission norms would result in benefits that outweigh the investment in pollution-control technology installation (Srinivasan et al., 2018).

An important follow-up to the installation of the pollution-control devices is the monitoring of their performance and ensuring standards are indeed being met. Much of the costs of pollution control are fixed in nature and, given the full pass through, it is possible that plants do not deploy the pollution-control technology (PCT) devices continuously in the absence of monitoring. Given that end-consumers are paying higher tariffs for the installation, they must be privy to the monitoring and must have full confidence that the emissions have indeed been brought under control and the health impact has been reduced. To enable this, the data from continuous emissions monitoring system (CEMS) devices must be made available publicly, just as the ambient air quality information is being made available by the environment regulators in all states. This is the ultimate proof that the PCTs are functioning and effective. Without this, any decision to pay incremental tariffs cannot be approved by the electricity regulator.



6.0 Conclusions and Recommendations

Almost four years have passed since the first notification from the central government regarding air pollution standards for India's coal-fired power fleet. Progress with retrofitting pollution-control technology has been slow. For SO₂ and NO_x emissions, a negligible amount of capacity has installed the equipment as of June 2019. Only around 58 per cent of the total installed capacity has issued a notice inviting tenders, though in some cases bids have been received and contracts awarded. Given that retrofitting flue gas desulphurization equipment requires 18–30 months for construction (Centre for Science and Environment, 2016), many plants are unlikely to meet the 2022 deadline. The PM retrofits are more likely to happen within the timelines specified.

Upfront cost is the main barrier to installation of these retrofits, and uncertainty around the approvals for investment for each plant is delaying compliance. While state-owned generators can access finance or financial support from government, private producers are unwilling to fund the retrofits without certainty that they can pass on costs to distribution companies. As a result, private sector petitions to regulators are in various stages of scrutiny, and without explicit approval from the regulator, no physical labour on retrofits will happen. State and central sector generators are relying less on explicit approval and are proceeding with tenders and physical construction with the expectation that the change in law clause will be honoured and all costs allowed to pass through. The legal process is clear, but each tariff



increase petition must be scrutinized on a case-by-case basis, adding to the delays and uncertainty in the recovery of the costs. With the in-principle approval finding place in the 2019 Tariff Regulations, it is possible for those petitioning CERC (plants supplying to multiple distribution companies across states), to use this route and enable the process to move forward. In any case, the CEA letter from September 2018 also establishes clear cost benchmarks for a variety of on-the-ground conditions. There is now less leeway for privately owned plants to cite these as bottlenecks in implementing PCTs.

Subsidies for pollution-control equipment from the government are problematic for two reasons. First, the expense is high and would divert a large amount of public resources to private companies. Second, the cost of pollution-control equipment should be incorporated in the price of coal-fired power to ensure it reflects externalities. The higher price for coal-based power makes renewable technologies more competitive in comparison.

At the other end, distribution companies are financially stressed and unable to pay the higher prices. In some cases, they have appealed against the price increases arising from these retrofits. Distribution companies are caught between higher potential costs from producers and artificially subsidized consumer tariffs that prevent them passing on these costs. They must be allowed to recover the additional costs involved in power purchase and not become an additional burden on the process. India's significant levels of energy poverty require that the poorest consumers (including those in the agricultural sector) continue to be protected. Reform of India's electricity subsidies (for example, a targeted direct cash benefit) is needed to better target the poorest while other consumer groups should pay tariffs that reflect the price of supply and externalities. Needless to say, this issue requires a review of the independence of the regulator and their ability to ensure prudence, quality of service and the financial viability of the sector.

For assets that are to be retired by 2027, investment in pollution-control technology may not be economically viable, under certain circumstances. The sensitivity analysis found that for plants with less remaining useful life or low plant load factor (utilization), retrofits will result in higher increases in electricity generation cost because the fixed costs need to be recovered over a shorter operating time. For these plants, alternatives to reducing their air pollution impact need to be considered, including: early retirement; shutdowns during critical pollution seasons (as relevant locally or in the region); or a grid prioritization system that incorporates their externalities so as to ensure reduced usage year-round.

Utilization levels have not been considered as a lever in national regulation or compliance, nor has the relationship between meteorological conditions and the dispersal of pollutants. A detailed air pollution dispersal model—examining how and when plants impact local and regional air quality the most—could allow plants to have a useful remaining life while reducing air pollution impacts.



To further facilitate installation of pollution-control technology, the CEA and Central Pollution Control Board should develop technology guidelines and specifications for lenders to extend financing to power generating companies and plant operators on a commercial basis.

6.1 Policy Recommendations

- Prices of electricity from coal-fired power plants should reflect the cost of installing pollution-control technology. These costs should ultimately be passed on to end-consumers, which will facilitate installation of the equipment while also ensuring that the price of coal-based electricity reflects more of its external costs. Increments to tariffs on account of pollution abatement are minimal at the national level and can be recovered from retail tariffs. Subsidies at the retail level must be targeted only to the poor who truly need it.
- Plants that do implement the pollution-control technology need to be monitored to ensure that standards are being met. There is a financial burden of pollution-control technologies (PCTs) on end-consumers, and transparency is key in ensuring that higher tariffs do indeed result in health benefits. The provision of data from the continuous emission monitoring system (CEMS) devices installed in the emission stacks of plants, to the electricity regulator and the broader public must be a first priority.
- To avoid any potential non-compliance by the 2022 deadline, the government should determine a prioritization plan based on environmental (regional air quality and local pollution) and financial considerations (useful generator life and load factors).
- In the interim, rules detailing temporary shutdowns of polluting plants and incentives for higher utilization of less-polluting plants must also be spelled out.
- Given the rising air pollution problem and its damaging and permanent impact on health, the government must have a zero-tolerance policy and impose strict penalties for power plants not adhering to emission standards within the timelines prescribed.
- Further technical guidelines that provide clarity on site-specific costing and capacity building for regulators and stakeholders is needed to hasten the process. In order to break the back and forth between ERCs and CEA on appropriate costs and tariff increase, we recommend that the MoP create a fund to independently carry out an assessment of feasibility and retrofit costs for all non-compliant plants. The reports from such a study can be used by the respective ERCs to approve tariff increases, subject to a reconciliation and determination of actual realized costs.

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Annex 1

Table A1.1. Revised standards for coal-based thermal power plants, 2015.

Thermal Power Plants (units) installed before December 31, 2003	
Particulate Matter	100 mg/Nm ³
Sulphur dioxide (SO ₂)	600 mg/Nm ³ (units smaller than 500 MW capacity) 200 mg/Nm ³ (for units having capacity of 500 MW and above)
Nitrogen oxides (NO _x)	600 mg/Nm ³
Mercury (Hg)	0.03 mg/Nm ³ (for units having capacity of 500 MW and above)
Thermal power plants (units) installed after January 1, 2003, up to December 31, 2016	
Particulate matter	50 mg/Nm ³
Sulphur dioxide (SO ₂)	600 mg/Nm ³ (units smaller than 500 MW capacity) 200 mg/Nm ³ (for units having capacity of 500 MW and above)
Nitrogen oxides (NO _x)	300 mg/Nm ³
Mercury (Hg)	0.03 mg/Nm ³
Thermal power plants (units) to be installed from January 1, 2017	
Particulate matter	30 mg/Nm ³
Sulphur dioxide (SO ₂)	100 mg/Nm ³
Nitrogen oxides (NO _x)	100 mg/Nm ³
Mercury (Hg)	0.03 mg/Nm ³

Source: Ministry of Environment Forest and Climate Change, 2015.

Annex 2

Table A2.1 Summary of current status of implementation of phasing plan for flue gas desulphurization (FGD) Installation

GENERAL SUMMARY

S. No.	Sector (capacity in MW)	FGD planned	Feasibility study started	Feasibility study completed	Tender specifications made	Tenders issued	Bids awarded	FGD commissioned ¹³
1	Central	53,350	53,350	51,510	50,510	47,960	12,040	500
2	State	51,885	49,025	38,195	17,475	11,315	0	0
3	Private	61,737	59,107	42,080	33,720	21,150	1,820	3,800
	Total	1,66,972	1,61,482	1,31,785	1,01,705	80,425	13,860	4,300

S. No.	Sector (No. of units)	FGD planned	Feasibility study started	Feasibility study completed	Tender specifications made	Tenders issued	Bids awarded	FGD commissioned
1	Central	143	143	135	133	123	24	1
2	State	164	152	126	60	44	0	0
3	Private	134	128	82	62	37	3	6
	Total	441	423	343	255	204	27	3

Source: Central Electricity Authority, 2019.

¹³ The FGD-commissioned numbers includes units which have been publicly reported but not captured in the CEA report. This includes the NTPC's 500 MW Vidhyanchal Unit 13 and Adani's 1,980 MW Units 7, 8 and 9 in Mundra (Press Trust of India, 2019; Central Regulatory Commission, 2019a).

UNITS > 500 MW & LOCATED IN AREAS EITHER CRITICALLY POLLUTED OR HAVING POPULATION DENSITY > 400/KM²

S. No.	Sector (capacity in MW)	FGD planned	Feasibility study started	Feasibility study completed	Tender specifications made	Tenders issued	Bids awarded	FGD commissioned
1	Central	29,320	29,320	29,320	29,320	29,320	6,620	0
2	State	13,980	13,980	10,680	3,200	2,000	0	0
3	Private	13,510	13,510	9,610	7,370	4,970	1,320	1,320
	Total	56,810	56,810	49,610	39,890	36,290	7,940	1,320

S. No.	Sector (No. of units)	FGD planned	Feasibility study started	Feasibility study completed	Tender specifications made	Tenders issued	Bids awarded	FGD commissioned
1	Central	57	57	57	57	57	12	0
2	State	25	25	20	6	4	0	0
3	Private	22	22	16	12	8	2	2
	Total	104	104	93	75	69	14	2

Source: Central Electricity Authority, 2019.

UNITS LOCATED IN AND AROUND NCR

S. No.	Sector (capacity in MW)	FGD planned	Feasibility study started	Feasibility study completed	Tender specifications made	Tenders issued	Bids awarded	FGD commissioned
1	Central	3,320	3,320	3,320	3,320	3,320	1,820	0
2	State	4,770	4,560	2,800	2,800	500	0	0
3	Private	4,700	4,700	4,700	4,700	4,700	1,320	1,320
	Total	12,790	12,580	10,820	10,820	8520	3,140	1,320

S. No.	Sector (No. of units)	FGD planned	Feasibility study started	Feasibility study completed	Tender specifications made	Tenders issued	Bids awarded	FGD commissioned
1	Central	9	9	9	9	9	6	0
2	State	17	16	8	8	2	0	0
3	Private	7	7	7	7	7	2	2
	Total	33	32	24	24	18	8	2

Source: Central Electricity Authority, 2019.

Annex 3

Table A3.1. Technical description of pollution-control technologies.

Abbreviations	Pollution-control technologies	Removal efficiency (%)	Auxiliary power consumption (%)
ESP upgradation	Electrostatic Precipitator	99.60	0.1
SCR	Selective catalytic reduction (NO _x control)	90	0.6
SNCR	Selective non-catalytic reduction (NO _x control)	57.50	0.6
WFGD	Wet (freshwater) FGD	95	0.7
SWFGD	Sea water FGD	92	1.1
Dry FGD (SDA and CDS)	Spray dry absorber Circulating dry scrubbers	92–98	0.65–1
LI	Limestone injection	57	0.7
LI + washed coal		69	0.7
LNB	Low-NO _x burners	50	0
LNB + OFA	Over fire air	53	0
ESP + washed coal		99.80	0.1

Based on analysis by: (Srinivasan et al., 2018)



Annex 4

QUESTIONNAIRE FOR STAKEHOLDER CONSULTATION

1. Why do you think plants did not meet the original deadline of December 2017 for the retrofit? Barely any plants actually retrofitted in those two years. Are the reasons to do with cost, poor enforcement, regulatory hurdles or any others?
2. Do you think the deadlines issued this time around will be met by the plants? If Yes, what has changed in the way this is being enforced?
3. Despite the change in law clause being invoked and provide recourse for increased, the process is still not moving. What, in your view is the major challenge?
4. Would you categorise this situation as one of insufficient regulatory capacity to clear each plant's proposal, insufficient technical capacity within the Central Electricity Authority or other technical agencies to offer clear directives on costs of retrofit, specific to each plant?
5. What is it that we should target? Is there a priority-based approach to ensure a set of plants (that we prioritise) get retrofitted at all cost? Some approaches are based on population density around a plant, the size of the plant, or their utilisation levels?
6. In your view, what is the trade-off between pursuit of efficiency in operations and pollution-control? For plants that with a lesser useful life, should we pursue efficiency retrofits and renovation and maintenance over pollution-control technology installation?
7. What is the cost involved for such retrofitting? Who should bear such costs?
8. Given the state of the sector, do you believe that financing the investment required for the retrofits will be a challenge? Do you envision any new source of funding that could/must be tapped to enable this?
9. Do you think government subsidies will be required to support the active pursuit of retrofits and to make up for shortfalls in financing? If so, what type of subsidies?
10. In your view, would the downtime associated with the retrofits be a significant challenge for the Indian grid to handle? Alternatively, will the downtime allow for stressed assets which are currently not generating electricity to be used more?
11. Do you prefer to be named as an interviewee in the Acknowledgement section in case of this report's publication?

Annex 5

Table A5.1. Sensitivity of tariff increase due to pollution-control technology upgradation to plant load factor and capacity

PLF (%)	Capacity (MW)	Residual life	Total Increase in costs - INR/ kWh						Total
			ESP	WFGD	Dry FGD	LI	LNB + OFA	SCR	
35	125	8(8)	0.1	-	0.74	0.5	0.1	-	0.94
35	200	8(7)	0.09	-	0.74	0.52	0.1	-	0.93
35	250	18(6)	0.06	-	0.6	0.55	0.05	-	0.71
35	300	19	0.06	-	0.6	-	0.05	-	0.71
35	500	13	0.07	0.76	-	-	0.07	0.3	1.13
35	600	21	0.07	0.68	-	-	0.05	-	0.8
35	660	22	0.06	0.68	-	-	0.05	0.22	0.96
35	800	20	0.06	0.69	-	-	0.05	-	0.8
60	125	8(8)	0.06	-	0.45	0.31	0.06	-	0.57
60	200	8(7)	0.05	-	0.45	0.32	0.06	-	0.56
60	250	18(6)	0.04	-	0.37	0.34	0.03	-	0.44
60	300	19	0.04	-	0.37	-	0.03	-	0.44
60	500	13	0.04	0.46	-	-	0.04	0.19	0.69
60	600	21	0.05	0.42	-	-	0.03	-	0.5
60	660	22	0.04	0.42	-	-	0.03	0.14	0.6
60	800	20	0.04	0.42	-	-	0.03	-	0.49
85	125	8(8)	0.05	-	0.33	0.23	0.04	-	0.42
85	200	8(7)	0.04	-	0.33	0.24	0.04	-	0.41
85	250	18(6)	0.03	-	0.28	0.25	0.02	-	0.33
85	300	19	0.03	-	0.27	-	0.02	-	0.32
85	500	13	0.03	0.34	-	-	0.03	0.14	0.51
85	600	21	0.04	0.31	-	-	0.02	-	0.37
85	660	22	0.03	0.31	-	-	0.02	0.11	0.45
85	800	20	0.03	0.31	-	-	0.02	-	0.36

Source: IISD & CEEW analysis.



