INDONESIA'S COAL POWER EMISSION NORMS

LESSONS FROM INDIA AND CHINA

Indonesian Centre for Environmental Law
JAKARTA, INDONESIA

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Abbreviations

AQI	Air quality index
BTH	Beijing–Tianjin–Hebei
CAGR	Compound annual growth rate
CCS	Carbon capture and storage
CEA	Central Electricity Authority, India
CEC	China Electricity Council
CEMS	Continuous emission monitoring systems
CERC	Central Electricity Regulatory Commission, India
CFB	Circulating fluidized bed
CPCB	Central Pollution Control Board, India
CREP	Corporate responsibility for environmental protection
EC	Environmental clearance
EIA	Environmental impact assessment
EP	Environmental permit
EPB	Environmental Protection Board
EPMA	Environmental Protection and Management, 2009
ESP	Electrostatic precipitator
FGD	Flue-gas desulphurization
FTP	Fast track programme
IEA	International Energy Agency
IGCC	Integrated gasification combined cycle
IO	Permit operation
IPP	Independent power producer
LEB	Local Environmental Board
LNB	Low NO_x burners
MEP	Ministry of Environmental Protection, China
MERM	Ministry of Energy and Mineral Resources, Indonesia
MoEF	Ministry of Environment and Forestry, Indonesia
MoEF&CC	Ministry of Environment, Forest & Climate Change, India
MoP	Ministry of Power, India
MT	Million tonnes
NAAQS	National Ambient Air Quality Standards
NDRC	National Development and Reform Commission, China
NEA	National Energy Administration, China
NO_x	Nitrogen oxides
O&M	Operation and maintenance
OFA	Over-fire air
OTC	Once-through cooling
PLN	Perusahaan Listrik Negara
PM	Particulate matter
PPU	Private power utility
PRD	Pearl River Delta
PROPER	Programme for Pollution Control, Evaluation, and Rating
RPC	Regional Power Committee
RUKN	Rencana Umum Ketenagalistrikan Nasional
RUPTL	Rencana Usaha Penyediaan Tenaga Listrik
SC	Supercritical
SCR	Selective catalytic reduction
SNCR	Selective non-catalytic reduction
SO_2	Sulphur dioxide
TPP	Thermal power plant
UKL	Environmental Management Efforts
UPL	Environmental Monitoring Efforts
USC	Ultra-supercritical
YRD	Yangtze River Delta

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Part 1: The state of coal-based power sector—Indonesia

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Introduction

Coal is the mainstay of the global electricity supply, accounting for nearly 40 per cent of the world's total. Despite recent growth of renewable energy in major economies, coal continues to be the leading contributor due to its wide availability and the competitive price of coal-based electricity generation.

However, coal has also contributed significantly to increase in pollution. The International Energy Agency (IEA) estimates that in 2015 electricity generation contributed nearly one-third of the global sulphur dioxide (SO_2), 14 per cent of the nitrogen oxides (NO_x) and 5 per cent of the fine particulate matter ($PM_{2.5}$) emissions. Coal-based plants alone are estimated to account for three-fourths of the power sector's SO_2, 70 per cent of its NO_x, and over 90 per cent of its $PM_{2.5}$ emissions. But the last decade has seen some positive developments. IEA estimates that during 2005–15, global SO_2, NO_x and $PM_{2.5}$ emissions from the coal-based sector decreased by 55 per cent, 34 per cent and 32 per cent respectively, even while the power generation increased by 34 per cent. Introduction of stringent pollutant emission norms across major countries was responsible for this change.[1]

Coal is the mainstay of global electricity supply, but it has also contributed significantly to increase in pollution

Developed countries like the US, Japan and in Europe introduced emission control standards during the 1970s, which were made more stringent in recent years. The objective was to balance the need for development of the power sector with the goal of maintaining environmental sustainability. Initially, these regulations focused on PM emissions control and were later expanded to include SO_2 and NO_x emissions controls. These standards acted as the prime driver for installation of pollution control technologies across existing and upcoming power plants along with the use of low-sulphur coal.

In recent decades, emerging economies have significantly increased their coal-based power capacity. Several emerging economies are also facing significant deterioration in their air and water quality. As a result, some countries have begun to take serious policy steps to control emissions from power plants.

China, which has the world's largest coal-based power capacity, introduced some of the tightest standards for emissions in 2011. It is also among one of the first countries to notify special and ultra-low emission standards for highly polluted and densely populated regions. Enforcement of the national standards has been a remarkable success—compared to the 1990 levels, the PM, NO_x and SO_2 emissions from coal-based power sector in the country have decreased significantly, despite a sharp growth in the generation of power.

India, which has the world's fourth highest coal-based capacity, revised its standards in 2015. This notification was long overdue, given the massive rise in coal-based capacity in the past 10–15 years. Various key decision makers and influencers, including Ministry of Environment, Forest and Climate Change (MoEF&CC), pollution regulators and the civil society, were in agreement that India's emissions regulations for PM, SO_2 and NO_x needed to be in line with the global standards. Ministry of Power and the thermal power industry is also on board with the new norms. Moreover, regulators have kept a very tight deadline to comply with the new norms, given the scale of environmental damage from sharp increase in power generation.

Indonesia appears to be on a similar trajectory as China and India on a number of fronts. Rapid economic growth leading to increased use of fossil fuels in industry and transport sectors, rising urbanization, and continued use of biomass in the household sector has lead to deterioration of Indonesia's air quality.

Indonesia's Electricity Supply Business Plan (RUPTL) 2016–25 estimates that the country's electricity demand will more than double over the coming decade, in response to economic growth and electrification expansion. This is planned to be met through an unprecedented increase in the installed generation capacity. While the government has decided to cap the share of coal in the capacity mix at 50 per cent by 2025, new power plants with a combined capacity of 34.8 GW are planned to be added.

Pollutant emissions from coal-based power plants contribute significantly to poor air quality levels in immediate surrounding areas. The environmental impact of power plants in Indonesia is exacerbated by the fact that a majority of the coal used in the country is of poor quality.

Indonesia has the opportunity to avoid the mistake of 'pollution first, abatement later' made by most industrialized countries

The *Burden of Disease from Rising Coal-fired Power Plant Emissions in Southeast Asia* research paper estimates 0.03 million tonnes (MT) of $PM_{2.5}$ and 0.29 MT both of SO_2 and NO_x were released from coal-fired power plants in Indonesia in 2011.[2] If the standards remain unchanged, the planned coal-based capacity addition is expected to lead to a three-fold increase in the SO_2 and NO_x emissions, and a doubling of $PM_{2.5}$ emissions by 2030, compared to the 2011 levels (see *Graph 1: Projected growth in national inventory of emissions from coal-based plants in Indonesia*).

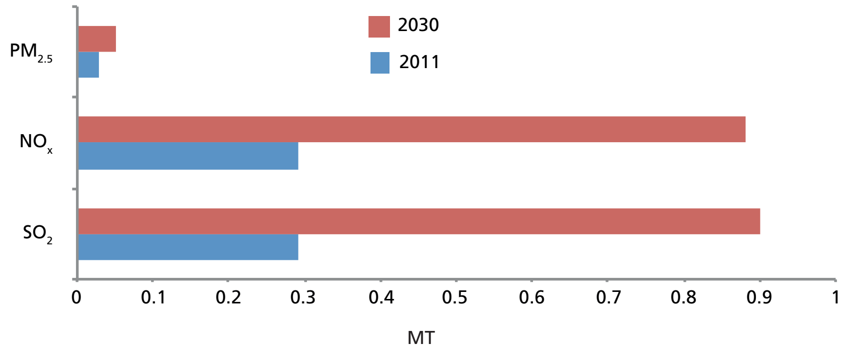
In general, tracking the exact impact of the coal-based power plants in Indonesia is tricky due to lack of air quality monitoring. However, self-monitored data reported by some of the coal-based power plants point to poor ambient air quality; yet additional capacity development is being planned in those areas.

The increase in emissions and the resulting negative health impact will be highest in the Java region, given the high concentrations of existing and upcoming coal-based plants there. Overall, IEA estimated that air pollution-related issues were the cause of around 70,000 premature deaths in Indonesia during 2015.

The government last updated the emission standards for coal-based power plants in 2008. They are fairly loose compared to the norms in developed and major emerging economies. While the government has put in place standards to maintain air quality, it may now be time to tighten emissions norms for power plants.

Graph 1: Projected growth in national inventory of emissions from coal-based plants in Indonesia

Under a business as usual (BAU) scenario, pollutant emissions from coal-based plants in Indonesia are expected to increase two to three times by 2030



Note: Data reflects estimated annual emissions for 2011 and projections for 2030

Source: Koplitz, S. N., Jacob, D. J., Sulprizio, M. P., Myllyvirta, L., & Reid, C. (2017). Burden of Disease from Rising Coal-Fired Power Plant Emissions in Southeast Asia. Environmental Science and Technology.

Adoption of stringent emission norms is crucial for ensuing reliable and affordable supply, while addressing environmental protection concerns. In this, Indonesia has the opportunity to avoid the mistake of 'pollution first, abatement later' made by most industrialized countries. While there may be multiple and varied sources of pollution but, when feasible, regulating major sources such as coal-based power plants can lead to a significant impact, nationally and locally.

The present study examines the role of coal in Indonesian power sector and its impact on future emissions. It provides suggestions for Indonesia to adopt new air emissions standards for coal-based power generation sector based on the experience of two major emerging economies—India and China—and an analysis of Indonesia's fleet profile and emissions performance.

PART I

The state of coal-based power sector—INDONESIA

Emission of pollutants from coal-based power plants is a rising challenge in Indonesia. The country's dependence on coal for meeting its electricity demand is steadily increasing due to its cheap and abundant local availability. Over the past decade, generation from coal-based plants increased at a compound annual growth rate of 9.3 per cent, which is projected to continue growing at 7.3 per cent over the next ten years. At the same time, the country has adopted some of the weakest emissions standards for thermal power plants in the world, especially for SO_2 and NO_x.

An analysis of the country's fleet profile and pollution performance data indicates that these standards can easily be tightened for a significant majority of the installed capacity. At present, large-sized units of 300 MW and above capacity account for nearly three-fourths of the existing installed capacity. Further, 66 per cent of the capacity was installed over the past decade (since 2006). In addition, the pollution performance of large units is also within acceptable limits, as indicated by data provided by MoEF for 23 large generation units of 300 MW and above capacity.

Emissions norms can be easily tightened for such units, given that larger-sized newer units have techno-economic flexibility to invest in pollution control devices.

1. Coal-based power sector —Overview

INDONESIA

Electrification rate
2006: 63 per cent
2015: 88 per cent

Annual per capita electricity consumption
2006: 505 kWh
2015: 910 kWh

Improving access to electricity

Access to electricity in Indonesia has been improving steadily over the past decade in response to the government's focus on adding generation capacity and expanding the electricity grid. The electrification rate in the country has increased from 63 per cent in 2006 to over 88 per cent in 2015, while the annual per capita consumption has nearly doubled from 505 to 910 kWh[1] (see *Graph 2: Steady improvement in electrification*). Some of the western provinces such as Bangka Belitung, Jakarta Special Capital Region, Banten, East Kalimantan and Aceh have achieved an electrification rate of over 95 per cent. However, eastern provinces such as South East Sulawesi, East Nusa Tenggara and West Papua lag behind, reporting electrification rates between 45 per cent and 70 per cent.

Indonesia is yet to catch up with the progress achieved by some other emerging economies in the Southeast Asia region such as Vietnam, Thailand and Malaysia, which report electrification rates between 97–100 per cent.[2] The per capita consumption of electricity in these countries is also higher than that of Indonesia.

During the past decade (2006–15), the electricity generation in the country increased at a compound annual growth rate (CAGR) of 6.2 per cent (see *Graph 3: Growth in electricity generation*). However, this is slower than 'actual demand' growth (somewhat difficult to assess given that sizable population doesn't have access to electricity). The shortfall in supply has resulted in deficits and frequent power cuts.

Dominant role of coal

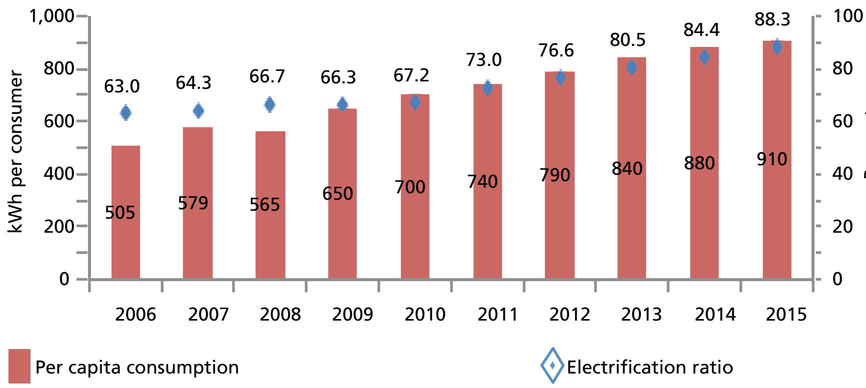
Indonesia is heavily dependent on coal for power generation, given its abundant and cheap domestic availability. It is estimated that the country has an aggregate coal reserve of 32 giga tonne (GT), which includes 8.3 GT of proven reserves. Almost 64 per cent of the reserves are of medium rank with a calorific value of 4,700–5,700 KCal per kg, while the remaining is of low rank. Generally, Indonesian coal has low ash (5–7 per cent) and sulphur (less than 1 per cent) content, but a high moisture content of (20–30 per cent).

Of the country's total installed capacity of 55.5 GW at the end of 2015, coal accounted for 24.7 GW, or about 44 per cent share (see *Graph 4: Fuel-wise share in installed capacity, 2015*). The share has been increasing steadily from 38 per cent in 2006.

Coal-based installed capacity in Indonesia has witnessed strong growth over the past decade. During 2006–15, while the total installed capacity expanded

Graph 2: Steady improvement in electrification

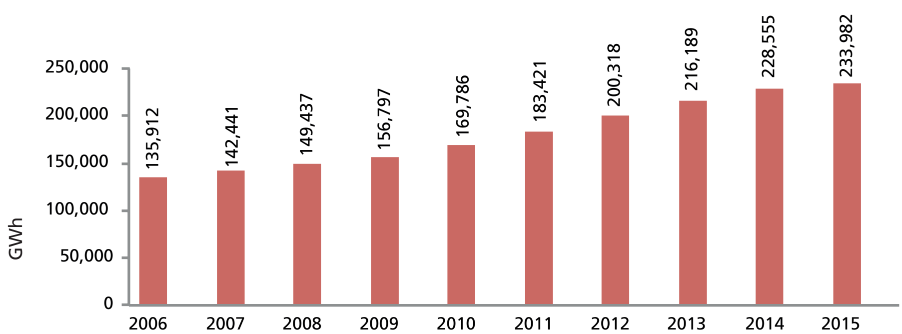
Per capita electricity consumption has almost doubled in Indonesia during the past decade



Source: MEMR

Graph 3: Growth in electricity generation

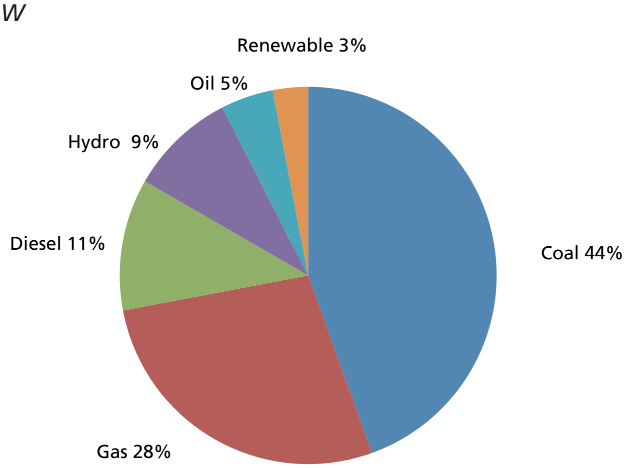
Electricity generation in Indonesia has nearly doubled over the past decade



Source: MEMR

Graph 4: Fuel-wise share in installed capacity, 2015

Coal accounts for the largest share in Indonesia's installed generation capacity of 55.5 GW



Source: MEMR

at a CAGR of 7.2 per cent, steam-based installed capacity increased at a rate of 10.4 per cent. The growth was especially strong in the recent five years (2011–15), when the steam-based capacity increased at a CAGR of 13.7 per cent, while the total capacity increased at a CAGR of 8.6 per cent (see *Graph 5: Growth in installed capacity).*

The consumption of coal by the power sector has increased in line with the growth in the installed capacity. During the past decade, coal consumption for power generation has more than doubled from 19 million tonnes (MT) to 49 MT, registering a CAGR of 11 per cent (see *Graph 6: Consumption of coal for power generation*).

Significant growth in demand

The General National Electricity Plan (Rencana Umum Ketenagalistrikan Nasional, or RUKN), prepared by the Ministry of Energy and Mineral Resources (MEMR), outlines the broad guiding principles for the development of the electricity sector in Indonesia. Perusahaan Listrik Negara (PLN), the government-owned vertically-integrated dominant electricity utility, makes use of the framework provided by the RUKN to draft the Electricity Supply Business Plan (Rencana Usaha Penyediaan Tenaga Listrik, or RUPTL), which details province-wise electricity business plans. The business plan is for a period of ten years, updated every year in line with policy changes and other developments.

Coal will continue to remain a key contributor in the projected generation growth in Indonesia

Electricity demand will be driven by the projected economic growth (at rate of 4.7 to 8 per cent per annum), population expansion (nearly 30 million addition), and the national target of providing 99.4 per cent electrification by 2024.

To meet this increase in demand, RUPTL has planned for rapid capacity addition. Generation is projected to increase to 528 TWh by 2025, at a CAGR of 8.8 per cent. Coal will continue to dominate generation, increasing from 141 TWh in 2016 to 266 TWh in 2025. (PLN recently released RUPTL 2017–26 with updated data, however the changes in projections are not major.)

Growth in capacity—coal dominant

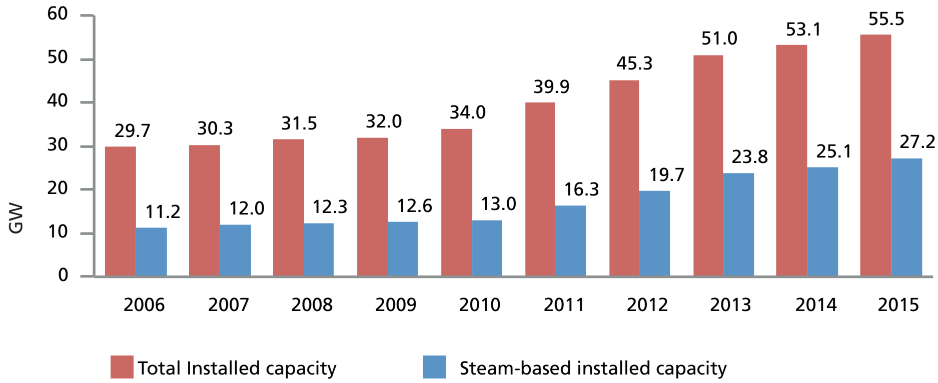
The optimal generation mix indicated in the draft RUKN 2015-34 targets a 50 per cent share of coal, 25 per cent of renewable energy, 24 per cent of gas, and 1 per cent of oil by 2025.

The projected coal-based capacity addition target has been lowered from 42.1 GW under RUPTL 2015–24 to 34.8 GW under RUPTL 2016–25.[3] Some coal-based power projects have been dropped while others have been replaced by gas-based power plants. Going forward, the government may even consider shutting down some of the old and inefficient coal-based generation plants in order to meet the targets set under the RUKN.

Meanwhile, despite the downward revision under the recent RUPTL, coal will continue to remain the dominant source of electricity generation in Indonesia, accounting for a 43 per cent share of the total installed capacity in 2025 (see *Graph 7: Projected growth in electricity generation*). The country faces an uphill

Graph 5: Growth in installed capacity

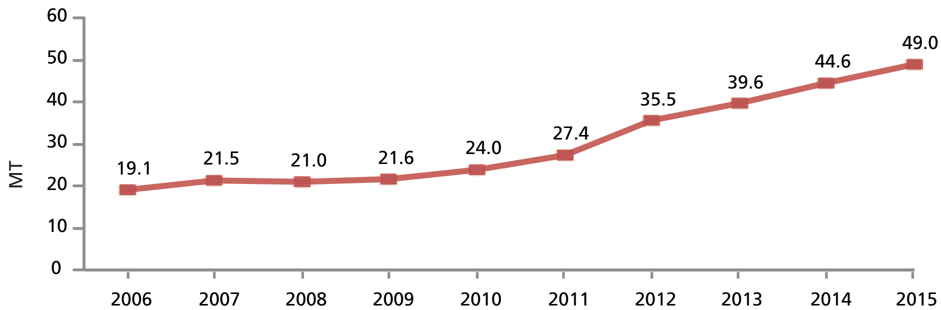
Steam-based capacity in Indonesia has expanded at faster rate than total capacity in the past decade



Source: MERM

Graph 6: Consumption of coal for power generation

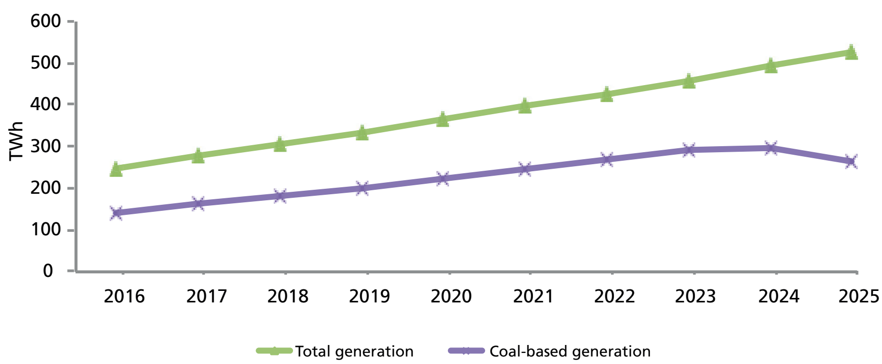
Use of coal for power generation has more than doubled over the past decade in Indonesia



Note: MT: million tonnes
Source: MERM

Graph 7: Projected growth in electricity generation

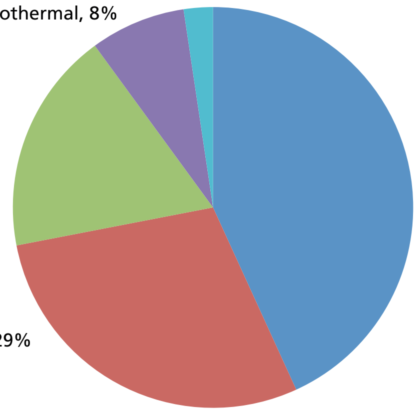
Electricity generation is projected to grow steadily over the coming decade in Indonesia



Source: PLN

Graph 8: Break-up of additions in installed capacity

Coal-based power projects dominate capacity additions of 80.5 GW to be made during 2016–25 in Indonesia



Source: PLN

task of expanding the reach of the electricity grid to millions of new consumers, while meeting the rising demand. Coal, which is abundantly available locally, provides the cheapest source of generation in the country. Gas and oil are estimated to be twice and four-times as expensive as coal respectively.[4]

Over the past few years, the Indonesia government has made several attempts to accelerate generation capacity addition in the country, specifically focusing on coal-based capacity. Indonesia first launched the Fast Track Programme (FTP)-I in 2006 with the objective of adding 10 GW of new coal-based generation capacity by 2010. It later launched FTP-II in 2009 with a target of adding 17.5 GW of generation capacity, including 10.5 GW of coal-based capacity, by 2014. With a majority of projects under these two programmes facing delays, the actual capacity addition by 2016 was about 85 per cent and 5 per cent under FTP-I and FTP-II, respectively. The government launched its third accelerated programme in 2015—the 35 GW capacity addition plan by 2019—which includes about 20 GW of coal-based generation capacity.

2. Coal-based fleet—An analysis

Efficiency performance

The aggregate efficiency of power plants in Indonesia is low and has been deteriorating. The data of PLN's thermal plants (which includes diesel and gas-based plants) shows that the efficiency levels have steadily declined from 33.5 per cent in 2006 to 23.7 per cent in 2015 (see *Table 1: Operational performance of PLN's plants*). Data from CoalSwarm suggests that the efficiency of utility-owned coal-based power stations in Indonesia ranges from 37.6 to 39.6 per cent, which appears to be very high.

Similarly, the capacity factor and load factor of PLN's thermal plants are low, despite some improvements over the past decade. In 2015, the capacity factor was only 50.5 per cent; the load factor (indicating use of plant during peak load conditions) was a little better at 80 per cent. Further, there are wide variations in load factor of power plants across regions.

Size distribution

At present, Indonesia's coal-based power generation capacity of 24.7 GW comprises over 142 generation units, ranging in size from 5 MW to 815 MW. The analysis of the data received from MEMR indicates that:

Table 1: Operational performance of PLN's plants

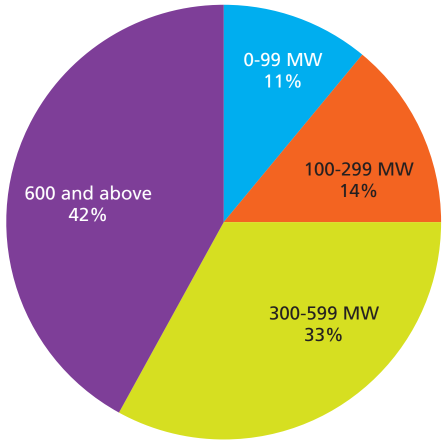
There has been a steady decline in the aggregate efficiency levels of thermal plants

Year	Thermal efficiency (per cent)	Capacity factor (per cent)	Load factor (per cent)
2006	33.51	48.00	64.15
2007	32.04	64.47	59.60
2008	31.96	52.62	80.77
2009	29.95	53.71	76.37
2010	29.46	55.90	77.78
2011	29.23	55.67	78.53
2012	26.87	51.96	79.18
2013	27.18	54.72	80.04
2014	26.60	50.97	78.30
2015	23.66	50.53	80.02

Source: EDSM Energy and Economy 2015

Graph 9: Size distribution of existing coal-based power capacity, 2015

Units of 300 MW and above account for nearly three-forth of the coal-based capacity in Indonesia



Note: Total existing coal-based capacity in 2015 was 24.7 GW
Source: Analysis based on MEMR data

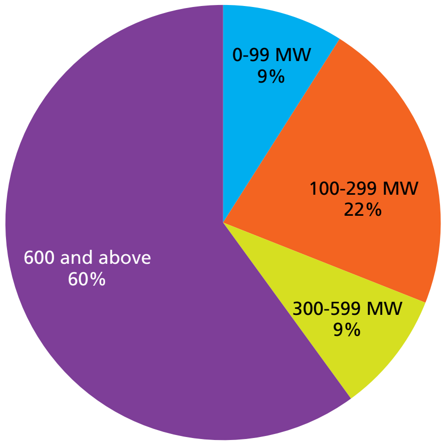
- Very small units of less than 100 MW (average size of around 30 MW) account for nearly half of the total number of installed units; however, they add up to only 9 per cent of the aggregate generation capacity. Most of these units were installed prior to 2006.
- Small units with capacity ranging from 100 MW to 299 MW also account for a small share of only 14 per cent of the installed coal-based capacity. Most of these units were installed over the past decade (since 2006).
- Large sized units account for nearly three-fourths of the installed capacity—24 units of 300 MW to 599 MW hold 33 per cent share, while 16 units of 600 MW and above hold 42 per cent share. 65 per cent of larger units are newer plants, installed after 2006.

Size distribution has important implication for pollution control norms—larger and newer units are able to meet tight standards for both economical and technical reasons.

The upcoming generation capacity has a similar distribution (see *Graph 10: Size distribution of upcoming coal-based power capacity, 2016–25*). Analysis based on the upcoming plants included in the RUPTL indicates that 124 units (or 59 per cent of total) of less than 100 MW size are currently under various stages of construction and development, which aggregate to only 2.9 GW of capacity (or 9 per cent). Meanwhile, 23 upcoming units of 600 MW and above size aggregate to 19.2 GW of capacity (60 per cent of total).

Graph 10: Size distribution of upcoming coal-based power capacity

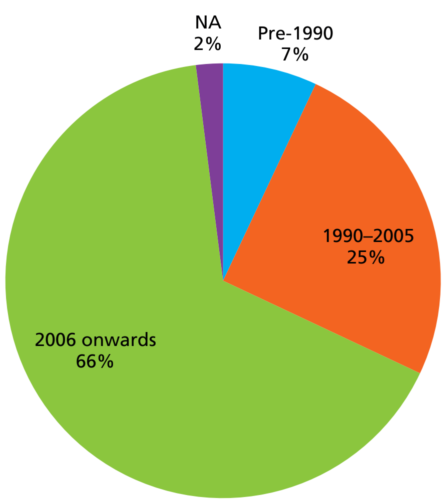
Units of 600 MW and above capacity hold the majority share in coal-based capacity to be installed between 2016 and 2025



Note: Based on 32.2 GW of steam-based capacity for which unit-wise data was available.
Source: Analysis based on MEMR data

Graph 11: Age distribution of coal-based power capacity, 2015

Majority of the coal-based capacity in Indonesia has been installed since 2006



Note: Total existing coal-based capacity in 2015 was 24.7 GW
Source: Analysis based on MEMR data

Age distribution

Coal-based power plants in Indonesia have been installed since the mid-1980s. However, significant majority of coal-based plants (or 66 per cent share) were commissioned after 2006, following the government's focus to promote coal-based generation through FTP-I. Of the total capacity of 16.2 GW commissioned since 2006, 11.4 GW comprises large units of 300 MW and above. Very old units (commissioned prior to 1990) aggregate to only 1.7 GW or 7 per cent share.

Regional distribution

Nearly 78 per cent of the installed capacity, as well as 57 per cent of the upcoming capacity is located in the Java island (see *Graph 12: Regional distribution of coal-based capacity*). Most of the upcoming and installed units in the region are of large size (300 MW and above).

Provincially, Central Java and Banten will lead coal-based generation capacity in Indonesia, with nearly 11.5 GW and 11.2 GW of capacity expected to be operational in the provinces by 2025. While East Java currently accounts for maximum installed coal-based capacity (5.8 GW), very few projects (0.75 GW) are planned in the province going forward.

Ownership pattern

Nearly 78 per cent of the installed capacity, as well as 57 per cent of the upcoming capacity is located in the Java island

Following the semi-liberalization of the electricity market in Indonesia, PLN no longer holds monopoly over the generation segment. However, it continues to dominate the sector, operating 69 per cent of the country's aggregate installed capacity including 55 per cent of the coal-based capacity (see *Graph 13: Ownership-wise coal-based installed capacity*).

The remaining installed generation capacity is shared between independent power producers (IPPs) (primarily selling power to PLN), private power utilities (PPUs) and permit operations (IOs). IPPs account for 40 per cent of the total installed coal-based capacity, about 5 per cent is accounted by IOs, while the share of PPUs is marginal.

The share of private sector has been steadily increasing in coal-based power generation since 2006, in response to liberalization of policies, and is set to rise further in the coming decade. Under the RUPTL 2016–25, private sector accounts for 22.1 GW of upcoming steam-based capacity (69 per cent share), PLN accounts for only 7.8 GW (24 per cent), while 2.2 GW remains unallocated.

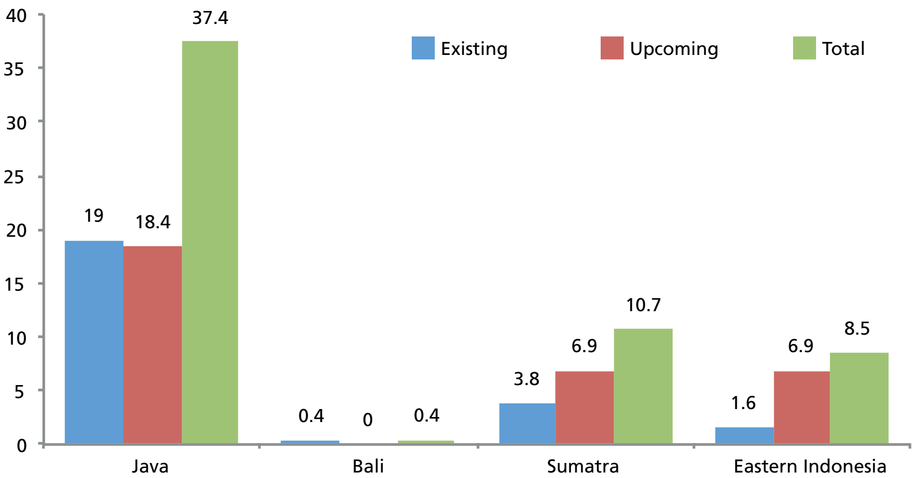
Technology matrix

Indonesian coal-based power generation fleet depends primarily on subcritical generation technology. The first supercritical (SC) units were commissioned in the country during 2011-12 in the form of the 660 MW Cirebon and 815 MW Paiton-3 thermal power plants. So far, four SC units aggregating 2.8 GW have been commissioned in the country, which add to only 11 per cent of the total coal-based capacity.

Indonesia's SC capacity base is set to expand significantly in the near future. Of the total planned capacity addition of 34 GW over the next decade, 21.9 GW is planned to be based on super- and ultra-super critical capacity. Share

Graph 12: Regional distribution of coal-based capacity

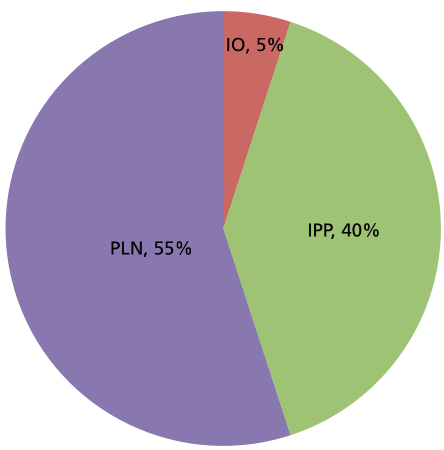
Java accounts for a significant majority of the existing and upcoming coal-based capacity



Note: Existing capacity is of 2015; upcoming capacity during 2016–25; and total capacity is as projected for 2025.
Source: Analysis based on MEMR data

Graph 13: Ownership-wise coal-based installed capacity

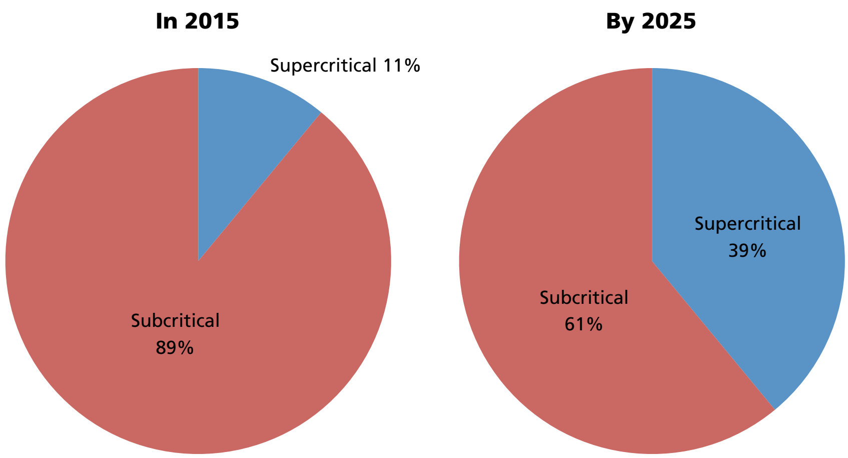
PLN owns and operates majority of the existing coal-based capacity



Source: MEMR

Graph 14: Share of super-critical units in coal-based capacity

Share of super-critical technology in Indonesia is set to expand substantially in the coming decade



Source: CSE analysis

of SC capacity in total installed capacity will thus increase to 39 per cent by 2025 (see *Graph 14: Share of super-critical units in coal-based capacity*). This includes 11 ultra-supercritical (USC) units of 1,000 MW each, the first of which is proposed to come up in 2019 as the Central Java IPP.

At present, there are no projects planned with integrated gasification combined cycle (IGCC) and carbon capture and storage (CCS) technologies under the RUPTL 2016-25. However, PLN has undertaken a study along with the World Bank on the construction of CCS-ready power plants. IGCC is also expected to be introduced by 2025.

3. Emission standards and performance

New statute

The legal framework for environmental management in Indonesia is defined by Environmental Protection and Management (EPMA), 2009. Enacted in October 2009, it replaced the 1997 Law Regarding Environmental Management, which in turn had replaced a 1982 statute. EPMA, 2009 seeks to integrate environmental protection and management across economic activities to ensure sustainable development. Among other things, the law recognizes the government's responsibility towards controlling environmental pollution and damage by setting out requirements and procedures for obtaining an environmental permit (EP) and by specifying quality and emission standards.[1]

Regulatory framework for air pollution control

The general framework for controlling air pollution from mobile and stationary sources is provided by the Government Regulations No. 41 of 1999 (PP 41/1999) on Air Pollution Control, issued under the Law No. 23 of 1997. These regulations set out the National Ambient Air Quality Standards (NAAQS) covering thirteen pollutants.[2] The provisions of the PP 41/1999 continue to remain in force under the 2009 EPMA, as long as they are not contrary to its contents. While the new law called for notification of a new set of regulations within a year of its enactment, these are still being drafted and notification could take another year.

The prescribed norms for emissions control in Indonesia are very loose compared to the standards set in developed and major developing countries, especially in case of SO_2 and NO_x

Regulatory framework for emissions control from power plants

For the stationary sources of pollution, which include factories, refineries, boilers and power plants, air pollution standards were first introduced by the Ministry of Environment in 1988, and were updated in 1995. The most recent revision in the standards was in May 2007 (for industrial boilers) through Decree No. 7 (PermenLH 7/2007) and in December 2008 (for thermal power plants) through Decree No. 21 (PermenLH 21/2008).

In the 2008 revision the government decided to retain the 1995 standards for old power plants, either operational or under advanced stages of development at the time the decree came into force (1 December 2008). New power plants, specifically the ones planned before but commissioned after the decree became operational, were required to maintain the 1995 standards while in transition and fully comply with the new standards from 1 January 2015. All thermal power plants planned and commissioned after the enactment of the decree have to comply with the new standards.[3] See *Table 2: Air emissions standards for coal-based power plants*.

Table 2: Air emissions standards for coal-based power plants, 2008

Emission standards remain considerably weak, especially for NO_x and SO_2

Parameter	Unit	Old plants	New plants
SO_2	mg/m^3	750	750
NO_X	mg/m^3	850	750
PM	mg/m^3	150	100
Opacity	per cent	20	20

Note: Reference conditions for testing are 25°C at an atmospheric pressure of 1 atm (or 101 kPa) on a dry flue gas basis with 7 per cent O_2 in the flue gas (except for opacity).
Source: Ministry of Environment and Forestry, Indonesia

The prescribed norms for emissions control in Indonesia are very loose compared to the standards set in developed and major developing countries, especially in case of SO_2 and NO_x (which ranges between 100 to 200 mg/m^3 globally).

Regulations mandate installation of CEMS for all coal power generation plants with an installed capacity equal to or above 25 MW

Provision for regional emission norms

The 2008 regulations allow provincial governments to stipulate emission standards for their respective regions as long as these are more stringent than the national standards. Additional parameters can also be added by the provincial government after obtaining approval from the Ministry of Environment and Forestry (MoEF). Stricter emission standards can also be determined for power plants if the requirement is established during the Environmental Impact Assessment (EIA) for plants with capacity greater than 100 MW, or Environment Management (UKL) and Environmental Monitoring Effort (UPL) for plants with capacity less than 100 MW.

In practice, however, plant- or region-specific standards for air emissions have not been put in place in Indonesia so far.

CEMS implementation

The 2008 regulations also mandated installation of continuous emission monitoring systems (CEMS) for all old and new coal-based power generation plants with an installed capacity of 25 MW and above; as well as for new generation plants with a capacity of less than 25 MW but with sulphur content of over 2 per cent in the coal. In case of plants with over 25 MW of capacity, old plants are required to install CEMS at the stack that emits the highest emission load (as calculated during early stages of planning), while CEMS is required to be installed at all stacks in new power plants. For CEMS operation, plants are required to have a quality assurance and quality control system. For all other power plants that do not require compulsory CEMS installation, emission levels are to be tested at least once every six months by accredited laboratories.

The monitored result has to be reported to the regent or mayor, with copies being sent to the respective governor and MoEF every three months in case of CEMS-based monitoring, and every six months in case of manual monitoring. In addition, coal-based power plants are also required to calculate their emission load for SO_2, NO_x, PM and CO_2 for each unit of electricity produced, and report it annually.

In case of power plants installed with CEMS, the daily average levels of emissions for three months are allowed to exceed the standards less than 5 per cent of the time. However, plants with manual monitoring systems are not allowed to exceed the notified emission limits under normal conditions. But, abnormal or emergency conditions must be reported to the MoEF and respective Local Environmental Board (LEB) within a week. Such situations call for contingency plan to be implemented.

Compliance monitoring

The regency or city governments through LEBs are responsible for supervising compliance of power plants to the air emission standards (as stated in their EIA). While monitoring should primarily be conducted through CEMS, there is no reliable information on how many of the CEMS are connected to the LEBs or MoEF networks. For instance, at the 380 MW Celukan Bawang coal-based power plant, the LEB neither has a system to connect with the CEMS, nor does it receive the CEMS self-monitoring report from the plant.

Information on how many CEMS devices are connected to the LEBs or MoEF networks in Indonesia is not reliable

In most cases, the LEBs receive the CEMS report from the plants every three months, as mandated by the MoEF Regulation No. 21 of 2008. A self-monitoring report on ambient air quality is usually submitted along with the CEMS report. The report is also copied to the provincial government and the MoEF.

In addition to self-reporting, LEBs can also undertake direct monitoring depending on the locality's budget. Such inspections are usually triggered by community complaints. Further, the rate and frequency of direct monitoring is not known.

Penalties for violations

As per the law, the penalties for violations of air pollution regulations or of the terms and conditions of the EP by a power plant vary depending on the degree and seriousness of the violation (which is not clearly defined). The punishments can vary from the LEB sending out a reprimand letter to the plant asking it to take corrective action, to suspension and revocation of the EP of the plant. Repetitive violations can further lead to criminal enforcement.

However, in practice, there have been no instances of stricter punishments being imposed for violations of emission norms (because of lax monitoring and enforcement practices and also because shutting power plants in an electricity-deficit country is a difficult decision). Even the reprimand letters send out by LEBs are rarely followed up in a timely manner.

Emissions from power plants

Data on emissions performance of power generation units is not publicly disclosed in Indonesia. In this report, the analysis of the PM, SO_2 and NO_2 emissions performance of coal-based power plants is based on the data received from the MoEF for 23 units aggregating 12,080 MW in capacity.

The data shared by the MoEF accounts for nearly half of the country's total installed generation capacity, however, this may not be a representative data set given that the sample covers larger units ranging from 300 to 815 MW in size. A significant number of the installed units in Indonesia are small in size (lower than 300 MW capacity), whose emissions may be higher than the units in the sample. Since large units contribute around 75 per cent of the capacity, analysis of their emissions is critical to understanding overall sector performance and to suggest norms. In terms of age, the sample can be considered representative—around 65 per cent of the units were installed after 2006, a similar share as the total fleet.

The data provided by MoEF gave maximum and minimum emission levels for each units but not the distribution of the emissions. The following analysis focuses on the maximum reported emissions levels because it gives an idea about the potential violation and the possible pollution control measures that may be required. Moreover, the minimum reported levels are extremely low and inconsistent with the installed pollution control equipment for several plants, suggesting the minimum data may not be fully reliable.

For large units, PM emissions seem to be at acceptable levels but SO_2 and NO_x emissions are high

PM emissions: Overall, the emissions seemed to be at an acceptable level, most likely reflecting the fact that the sample was overrepresented by larger, newer units (see *Table 3: PM emissions performance of Indonesian coal-based power plants*). A quarter of the plants reported emissions of less than 50 mg per m^3; another third reported emissions of less than 100 mg per m^3. These plants can either upgrade or increase the size of their electrostatic precipitators (ESPs) to meet tighter norms.

SO_2 emissions: SO_2 emissions reported by power plants range from 502 to 716 mg/m^3 (with the exception of one 815 MW unit where the reported emission is possibly wrong; see *Graph 15: SO_2 emissions by coal-based power plants*). These numbers look broadly correct, assuming coal with sulphur content in the range of 0.1 to 0.2 per cent and calorific value of 5,500 kCal per kg. Minimum levels for SO_2 emissions seemed to be wrong given that very few plants have installed flue gas desulphurization (FGD) to control SO_2.

NO_x emissions: The reported NO_x emissions levels were high but the data seems reasonably correct (see *Table 4: NO_x emissions performance of Indonesian coal-based power plants*). Almost 56 per cent of the capacity reported emissions of higher than 400 mg per m^3 (with the highest being 812.4 mg per m^3) while the remaining reported emission levels of under 400 mg per m^3.

Even in case of NO_x emissions, the minimum emissions levels reported by several power plants (lowest being 46 mg per m^3) are unlikely to have been achieved without the use of advanced technologies such as selective non-catalytic reduction (SNCR) and selective catalytic reduction (SCR).

Low penetration of pollution control devices

In absence of tight pollution standards for power plants in Indonesia, especially for SO_2 and NO_x, the penetration of advanced pollution control devices is low. In general, EIAs of power plants do not consider and discuss pollution control devices in detail. While some of the recent EIAs have started providing information on the planned installation of air-pollution control devices, they continue to lack performance details.

Table 3: PM emissions performance of coal-based power plants

PM emission from sizable capacity remains at an acceptable level of under 100 mg/m³

PM emissions (mg/m^3)	Aggregate capacity (MW)
Less than 50	2,895
50-99	4,160
100-150	5,025

Note: Analysis of maximum emission levels reported by 12,080 MW capacity
Source: MoEF

Table 4: NO_2 emissions performance of coal-based power plants

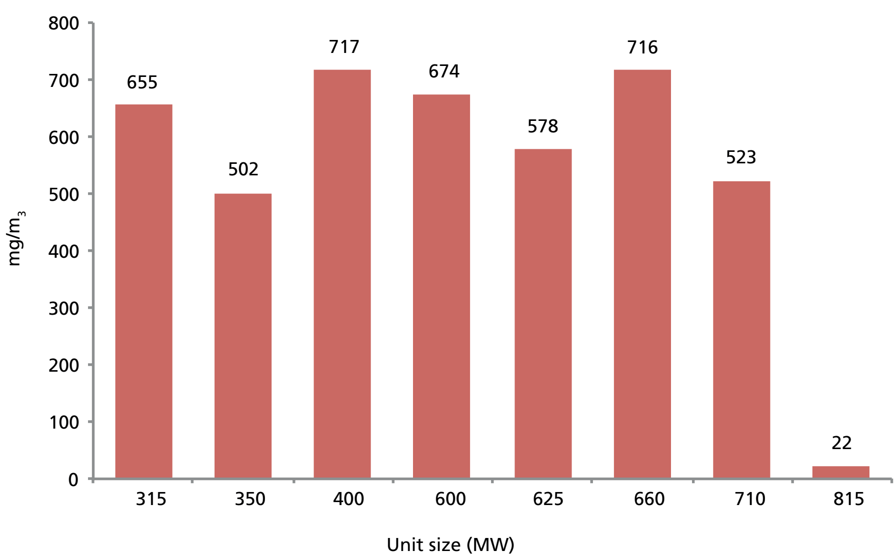
For 44 per cent of the capacity, NO_x emissions are less than 400 mg/m^3

NO_2 emissions (mg/m^3)	Aggregate capacity (MW)
100-199	2,160
200-399	3,165
400-699	5,330
500 and above	1,425

Note: Analysis of maximum emission levels reported by 12,080 MW capacity
Source: MoEF

Graph 15: SO_2 emissions by coal-based power plants

Data shows the highest emitter unit in each size category. Indonesian power plants report high levels of SO_2 emissions



Note: Analysis of maximum emission levels reported by 12,080 MW capacity
Source: MoEF

A 'PROPER' INITIATIVE

Indonesia has adopted the Programme for Pollution Control, Evaluation, and Rating (PROPER) as the key regulatory tool to promote compliance with pollution control regulations by industries. It is a national-level environmental reporting initiative based on the principles of voluntary disclosure and accountability, transparency in operations, and community participation, aimed at empowering local communities to achieve effective and sustained pollution control.

The programme was introduced in the mid-1990s. Initially, it was a pilot scheme under which industries were to self-report water pollution levels. In 2001, the scope of the programme was expanded under PROPER-II to include more industries and air pollution reporting. In 2016, PROPER tracked about 1,930 companies across 111 industries. This included 22 coal-based power generation plants.

Under PROPER, the environmental performance of companies is analyzed and rated on a five-tier colour-coded ranking system, varying from Gold (best performance), to Green, Blue, Red and Black (worst performance). The rating is based on a number of parameters, including environmental management, energy efficiency, pollution prevention (air, water, hazardous waste, sea water etc.), and community development. Varying weights are attached to each of the selected parameters.

Factories are required to gather and report monthly data on air, water, and toxic wastes. The LEB then analyses and verifies the reported information using historical data and modeling techniques. The analysis of the pollution data generated during January–February is also shared with the factories, for them to improve performance. The ratings are finalized by an advisory board which includes representatives from health department, business groups and NGOs.

The annual rating performance is published by the Directorate General of Pollution and Environmental Damage Control, and shared with the general media. The information available in the report is then utilized by the regional representatives' councils to decide whether to ignore, admonish, or prosecute factories ranked black or red on the PROPER scale. Similarly, banks and investors can decide based on the report where to redirect loans and investments from under-performing units.

Overall, the information disclosure strategy adopted under PROPER has been successful in improving environmental governance practices in Indonesia.[4] It has helped raise environmental awareness among factory owners and employees; as well as generated greater community awareness. It has also helped improve compliance with environmental regulations. However, the impact of PROPER has been constrained by the limited coverage of the programme (in terms of number of factories) and the weakness of the environmental regulations itself.

The sample data for 12,080 MW capacity (which covers only the large coal-based units) shared by the MEMR provides the following information regarding installation of pollution control equipment:

- Almost all units have installed ESPs for PM control. However, there could be differences in terms of the size of the ESP (i.e. the number of fields installed) as the PM control performance varies across units.

- FGD system has been installed only at Units 3 and 4 of the Tanjung Jati B power station of 710 MW each, owned and operated by PT Bhumi Jati Power. It employs a wet FGD system using limestone.

- Only six units aggregating 3,180 MW of capacity reported having low-NO_x burners while one unit of 660 MW has adopted tangential burning for reducing NO_x emissions. However, this data seems inaccurate, given that most large boilers commissioned over the past decade are likely to have an in-built low NO_x burner for efficient operations.

- None of the units had installed SCR or SNCR for NO_x control.

Key challenges in emissions control in Indonesia

- **Weak policy framework:** The standards set for ensuring clean air are very loose compared to global levels and the penalties for non-compliance are also lacking.

- **Loose emission standards:** Indonesia has not tightened the emissions standards for coal-based power generation units, unlike other developed and developing countries, for a while. Even the existing norms for emissions control are not being monitored closely; so compliance levels of the sector are likely to be poor.

- **Underperformance of installed equipment:** LEBs have so far shied away from monitoring power plants under construction; which is a serious gap since plants often don't comply with the technical requirements (related to stack height and monitoring point on stack etc.). There have been cases where the operation appropriateness certificate has been issued without proper inspection of the environmental controls.

- **Inadequate capacity of regulators:** LEBs in Indonesia responsible for effective monitoring and enforcement of emission standards are generally short staffed. Employees some times lack the required technical capability and expertise.

- **Inadequate penalty mechanisms:** The existing policy framework for emissions control lacks the backing of a powerful penalty mechanism. Not only are the provisions for sanctions weak, the regulators often shy away from severe punishments due to lack of wide public and political support. Also, under the existing power deficits scenario, imposing strict punishments like suspension of environmental license is not feasible.

- **Inadequate monitoring practices and issues with CEMS:** There exists an ad hoc and largely voluntary approach to monitoring of emissions performance, despite the law providing for development of an environmental information system. MoEF does not have all CEMS connected to their system; nor does it have information on how many LEBs are receiving real-time data from power plants. CEMS does not seem to be working at most of the

LEBs in Indonesia responsible for effective monitoring and enforcement of emission standards are generally short staffed

power plants. Local governments are not enforcing any sanction for this non-compliance with the CEMS requirement, other than once in a while reminding the power plants to report CEMS data as soon as possible. The quality of reported emissions data is poor, with some power plants reporting unrealistically low levels of emissions.

- **Limited awareness on pollution control:** Public awareness on the issue of air pollution is minimal, especially outside major cities. The feedback mechanism from the non-governmental parties such as impacted communities, civil societies and think tanks is also generally weak.

  Further, power generators indicate limited willingness to invest in appropriate environmental safeguards devices, making them less likely to support and comply with tight norms and standards. This could be partly due to limited financial capability, and concerns over the limited ability to raise tariff to cover increased investment

- **Access and cost trade off:** Last but not the least, the fundamental issue of access to electricity is important. Indonesia must recognize the significant health impact associated with air pollution and accordingly invest in pollution control technologies. Government can build public support for investing in pollution control since the costs are manageable. Investments in pollution control will provide overall economic benefit, as it will ensure long-term sustainability and viability of the sector.

PART 2

Addressing the emission challenge—INDIA AND CHINA

India and China have devoted considerable attention to controlling pollutant emissions from coal-based thermal power plants, given that it is a significant source of industrial pollution. China took a lead in the area by notifying some of the most stringent standards in the world for pollutants emitted from coal-based TPPs in 2011. The country also adopted ultra-low emission limits for critically polluted regions in light of the severity of the situation. India, too, has followed suit, notifying very tight emission standards for coal-based TPPs in 2015.

As Indonesia treads along the path of rapid coal-based generation expansion to meet its rising electricity demand, it may gain from studying the experience of China and India in adoption, implementation and monitoring of emission norms for the coal-based power sector.

4. Common challenges

China and India have had somewhat similar experiences in increasing their electricity supply and facing pollution growth, though both the scale and timelines vary. Both countries have experienced sharp increase in electricity demand since the 1990s, triggered by rapid economic growth. In response, both countries focused on adding electricity generation capacity and expanding grids. At present, China has the world's largest generation capacity of over 1,645 GW (2016), while India has the fourth largest capacity of 315 GW (2016). Coal has occupied a key position in the generation capacity expansion plan in both countries. At present, it accounts for nearly three-fourths of the total electricity generated in both countries.

Both China and India have been grappling with serious air pollution issues, which have gathered wide coverage on national and global platforms in recent years. Both countries have been trying to mitigate the issue by adopting and implementing policy instruments across major polluting sectors, including power, transport and industry.

China and India have been grappling with serious air pollution issues, which have gathered wide coverage on national and global platforms in recent years

Rising electricity demand

The transformation of China and India into fast-growing economies in the past 25 year has been phenomenal. Economic growth in China picked up with the introduction of market-oriented reforms in 1979, with the country experiencing double-digit growth rates throughout the 1990s and 2000s. In India's case, the growth accelerated after the introduction reforms in the early 1990s. Since then, the country has been registering an average annual growth rate of 7–8 per cent.

Massive growth of economies in the two countries has driven electricity demand. Governments have made concerted efforts to expand electricity infrastructure, not only to meet the increasing demand but also to connect the non-electrified regions. Since 1990, China has successfully provided electricity to all its citizens; its per capita consumption increasing nearly eight folds (see *Table 5: Progress in the electrification scenario in China and India since 1990s*).

India, on the other hand, is yet to achieve 100 per cent electrification; however, progress made since 1990 has been commendable. The electrification ratio in the country has increased from 45 per cent to almost 80 per cent, while per capita consumption has increased nearly three times.

Role of coal

Since the 1990s, electricity generation in China and India increased at a high CAGR of 9.8 per cent and 6.6 per cent, respectively. Coal-based power generation accounted for a lion's share in this expansion and continues to dominate generation.

In China, coal-based installed generation capacity was 943 GW at the end

Table 5: Progress in the electrification scenario in China and India since 1990s

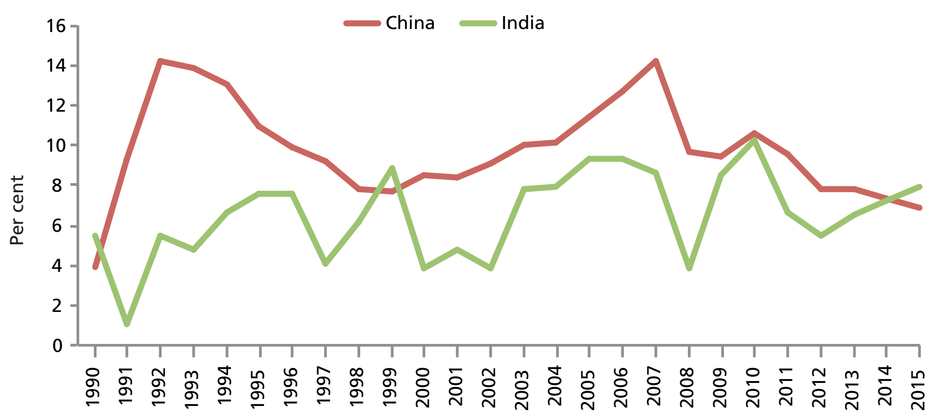
Electricity consumption and generation increased several folds over the past two decades

Year	Access to electricity (per cent of population)		Per capita electricity consumption (kWh per capita)		Electricity generation (TWh)	
	China	India	China	India	China	India
1990	89.4	45.1	511	273	621	284
2000	94.8	59.6	993	395	1,356	555
2010	99.7	76.3	2,944	642	4,207	951
2014	100	79.2	3,927	805	5,794	1,253

Source: World Bank and BP Energy Statistics

Graph 16: Economic growth in China and India since 1990

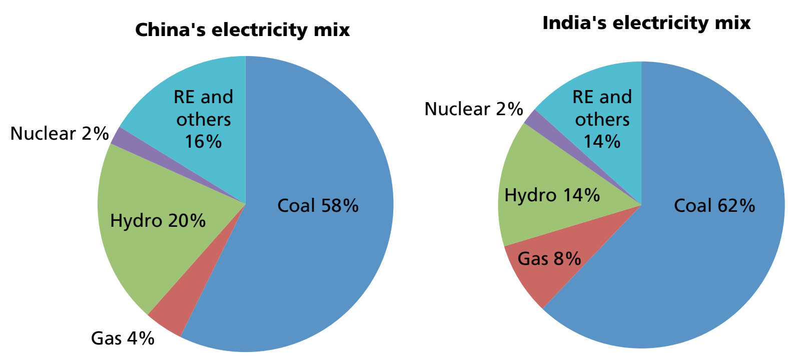
China and India have reported rapid economic growth in the past two decades



Note: Annual growth rate corresponds to GDP at market prices on constant local currency
Source: World Bank

Graph 17: Share of coal in the installed capacity of China and India in 2016

Coal accounts for more than half of the installed capacity in the two countries



Note: Data for China is as of December 2016 and for India in March 2017
Source: CEC and CEA

of December 2016, accounting for 57 per cent of the country's total installed generation capacity.[1] Its share in total generation during 2016 was even higher at 65 per cent. Similarly, in India, coal-based generation capacity of 185 GW as of March 2017 accounted for 62 per cent share in the country's total installed capacity, and 74 per cent share in generation (in 2016–17).[2]

Coal's contribution to power generation in both the countries will continue to remain high in the foreseeable future, even as both countries have ambitious plans to grow renewable energy and shut down some old and inefficient coal-based power plants. Under the Thirteenth Five Year Plan, released in November 2015, the Chinese government has set a target of increasing the coal-based generation capacity to 1,100 GW by 2020.[3] Even though a significant number of China's currently approved projects would be shelved, this would still imply a net capacity addition of over 150 GW.

India's draft National Electricity Plan, released by the Central Electricity Authority (CEA) in December 2016, estimates that no additional coal-based capacity is required during the 2017–22 period, based on projected electricity demand and growth of renewable capacity.[4] However, over 50 GW of coal-based power projects, which are expected to come online by 2022, are currently under different stages of construction.

Coal accounts for 57 per cent of the installed capacity in China and 62 per cent in India

Rising pollution and role of coal

Air pollution in China

China's extraordinary economic achievements over the past couple of decades have been accompanied by some of the highest rates of air and water pollution experienced in the world. Air pollution has become one of the more visible of China's environmental challenges.

According to a Ministry of Environmental Protection (MEP) report in 2014, 71 of the 74 cities monitored by the Central government failed to meet minimum air quality standards. In China's capital, Beijing, for instance, air pollution reached extremely high levels with air quality index (AQI) measuring 755 in 2013; anything above 500 is considered very hazardous. According to a report published by US-based Berkeley Earth, 38 per cent of the country's population is breathing unhealthy air.[5]

The sources of China's air quality problems are many—rapid industrialization and urbanization, growth in the number of automobiles, expansion in the construction sector etc. But, the country's overwhelming reliance on coal for meeting its energy needs is a key factor contributing to this. In 2015, China's national coal consumption was 3.74 billion tonnes, almost half of the global consumption of 7.86 billion tonnes.

A 2013 study led by the Tsinghua University in Beijing indicated that industrial coal burning alone was responsible for 40 per cent of the $PM_{2.5}$ emissions in China. The study attributed 86,500 deaths to emissions from coal-based power plants. The second consultation draft released by the MEP in 2011 for defining the new emission standards for thermal plants estimated annual emissions of

SO_2, NO_x and PM by coal-based power plants of 12.59 MT, 8.4 MT and 2.97 MT, respectively.[6]

In light of this, China's air pollution control efforts, both at the national and regional levels, have focused on controlling emissions from coal-based power plants. The country has affirmed its commitment by notifying the tightest standards for air emissions control in the world. It has also become the first country to prescribe ultra-low emission standards for its heavily polluted regions. This has been accompanied by shutting down some of the old and inefficient plants as well as plants located in highly polluted regions.

Collectively, these efforts have yielded positive results. As per the recent *China Environmental Statistics Bulletin*, the share of coal-based power plants in the national SO_2 emissions has declined from 40 per cent to 28 per cent between 2012 and 2015, NO_x from 40 per cent to 30 per cent and PM from 12 per cent to 11 per cent.[7]

Indian scenario

Economic progress and industrialization experienced by India over the past two decades has also been accompanied by increase in pollution with the situation deteriorating in the last five years. While bad air quality in major cities like New Delhi has garnered wide media coverage, it is a national phenomenon. WHO's Global Urban Ambient Air Pollution Database lists 10 Indian cities among the 20 most polluted in the world, including several smaller towns. Recent reports also indicate that the number of air pollution-related deaths in India is approaching that in China.

Many factors have resulted in the high levels of air pollution in India including rapid industrialization, growing vehicular traffic, use of biomass for cooking in rural areas and expansion in the number of construction projects. In the industrial segment coal-based power sector is the largest contributor.

CSE estimates that the thermal power industry accounts for nearly 60 per cent of the PM, 45 per cent of SO_2, 30 per cent of NO_x and 80 per cent of mercury emissions from the industrial sector[8] (see *Graph 18: Contribution of coal-based power sector to industrial emissions*). This is partly because Indian power plants use some of the poorest quality coal in the world, with ash content as high as 40–50 per cent. Although the sulphur content of Indian coal is low, SO_2 emissions tend to be high due to the relatively large quantity of coal utilized per unit of electricity generated because of the low calorific value.

Lack of adequate standards was another key factor responsible for high emissions. Power plants in India have not installed advanced technologies to control SO_2 and NO_x in absence of these standards.

Until recently, the standards for pollutant control were defined only for PM, that too at very lenient levels of 50–350 mg/Nm^3. Many power plants were not even meeting these loose emission standards due to poor monitoring and enforcement mechanisms.

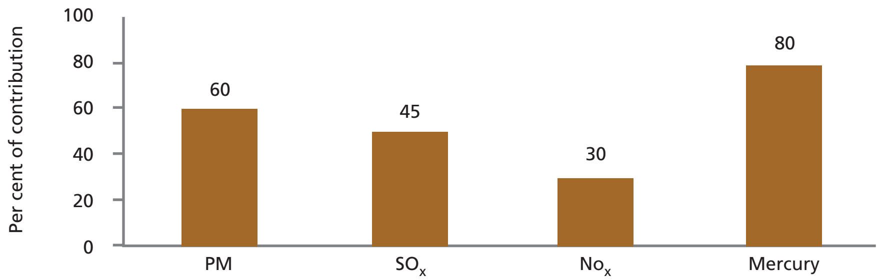
Coal power emissions as a share of:

Total (China)
SO_2: 28 per cent
NO_x: 30 per cent
PM: 11 per cent

Industrial sector (India)
SO_2: 45 per cent
NO_x: 30 per cent
PM: 60 per cent

Graph 18: Contribution of coal-based power sector to industrial emissions in India

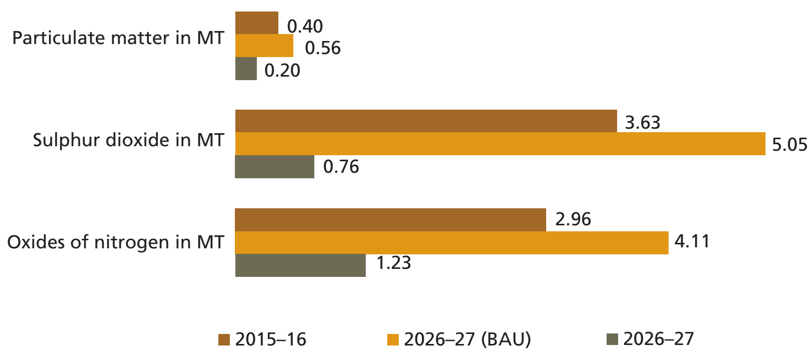
Coal-based sector is a major contributor to industrial emissions



Source: Heat on Power, 2015, Centre for Science and Environment (CSE)

Graph 19: Expected benefits from India's new emission norms

Implementation of new standards will result in 65–85 per cent lower emissions by 2026-27, compared with a BAU scenario



Assumptions: a) Generation data from CEA report b) 34 GW installed prior to 1990 to be shuttered by 2026–27
Source: Centre for Science and Environment, 2016

Recognizing the coal-based power sector's role in growing air pollution, Indian government recently revised emission norms, bringing them at par with global standards. CSE expects implementation of new standards will result in 65–85 per cent lower emissions by 2026-27, compared with a BAU scenario (see *Graph 19: Expected benefits from India's new emission norms*).

5. Regulatory evolution

India's emission standards and experiences

Old and new standards

India's Ministry of Environment, Forest & Climate Change (MoEF&CC) announced tighter emission standards for coal-based TPPs in December 2015, the first such revision after almost two decades (see *Table 6: Pollution standards for coal-based power sector of India*).

Previously, power plants were required to meet only PM emissions norms, which were fairly loose. Furthermore, two-thirds of the power plants in the country failed to comply with even these lenient standards, revealed CSE's 2015 study, *Heat on Power*. There were no national regulations for SO_2, NO_x and mercury emissions from power plants. The regulations required chimney height based on a certain formula to ensure flue gas is dispersed so as to limit incremental ambient concentration of SO_x and NO_x. However, increasing levels of pollution from other sources, clubbed with sharp growth in thermal power generation, rendered this emission control methodology inadequate.

Age and size profile of a unit are two of the most important parameters that help in determining the most appropriate pollution control options

Key considerations behind establishment of new norms

India's new emission standards evolved from extensive consultations organized by the MoEF&CC and the Central Pollution Control Board (CPCB) and independent studies.[1] Key considerations were age and size of the coal-based generation units, and performance of available pollution control technologies. CPCB also analyzed reported data emissions for PM, SO_x and NO_x to assess achievable emission levels. Finally, emission regulations enacted in countries with sizable coal-based power capacity served as indicative data points.

1. **Fleet profile:** Age and size profile of a unit drive levels of emissions. They also help in determining the most appropriate pollution-control options. The age–size distribution of India's coal-based generation capacity indicates that bulk of the fleet comprises relatively large and new units (see *Table 7: Age–size distribution of coal-based power generation units in India*).

   Newer units in India are generally large in size and have adopted better technology, given that private sector investments expanded after enactment of the Electricity Act, 2003. Several of these units have better boiler combustion design for low-NO_x emissions and ESPs designed for low PM emissions. Also, a newer, larger unit can afford to invest more in cutting pollution since it has longer remaining life to recover costs. Finally, older units frequently face technical constraints that limit emission cuts they can achieve.

   Thus, India's new emission norms categorized power plants into three groups—units installed prior to 2004, between 2004 and 2016, and to be commissioned after 2016—and specified different standards for each category.

2. **Peer benchmark:** In deciding the new standards, emission norms notified in countries like China, US and the EU provided a peer benchmark (see *Table 8: Emission standards for thermal power plants in major countries*). For newer units, India adopted similarly tight emission standards (even tighter in certain cases). However, for old units, the standards were kept relatively liberal, given their limited ability to invest and lower expected cuts.

3. **Gradual evolution of requirements:** Over the last 15 years or so, regulators in India have gradually introduced provisions to push plants to improve their environmental performance. Some of these measures were in expectation of future changes in law, while others were project-specific. The major initiatives are listed as follows:

    - Environmental clearance (EC) given after 2004 require units larger than 500 MW to keep space for future FGD installation (which will allow such units to meet a stringent SO_2 standard).

    - ECs issued after 2008 require plants to meet PM of 50 mg per Nm^3. Occasionally, this standard was imposed on specific plants located in heavily polluted or densely populated area. For instance, NTPC Limited's Badarpur TPP located in Delhi was required to meet the PM standard of 50 mg per Nm^3 to check the rising pollution levels in the capital city.

Over the last 15 years, regulators in India have gradually introduced provisions to push plants to improve their environmental performance

4. **Failure of voluntary reductions:** MoEF&CC had launched the Charter on Corporate Responsibility for Environmental Protection (CREP) in 2003 to reduce pollution levels across the industrial sectors beyond defined regulatory norms. Under this, the power sector had committed to improve environmental performance by meeting tighter PM standards (of 100 mg per Nm^3) and implementing SO_x/NO_x standards by 2005-06. Not only did the coal-based power plants fail to act on the voluntary commitment, two-thirds of them were not even meeting the prevailing loose standards. Notification of tight emissions standards thus became necessary.

5. **Technology availability:** The decision on new emission standards reflected a realistic evaluation of the emission levels achievable by the existing power plants, given their present emissions and the improvement that can be registered through application of available pollution control technologies. Discussions with experts had established that technologies to control PM, SO_2 and NO_x were mature and had been widely used for the past two-three decades for a range of coal quality and operating conditions.[2] Further, equipment availability was not a concern, given that many large-scale manufacturers, domestic and global, were supplying technologies to meet the new standards.

Table 6: Pollution standards for coal-based power sector of India

In 2015, standards were notified for the first time for NO_x and SO_2 emission restrictions in plants

	Old standards	New standards		
		Units installed till 2003	Units installed between 2004 and 2016	Units installed after 1 January 2017
PM	150–350	100	50	30
SO_2	None	600 (for units < 500 MW) 200 (for units ≥ 500 MW)	600 (for units <500 MW) 200 (for units ≥ 500 MW)	100
NO_X	None	600	300	100
Mercury	None	0.03 (for units >= 500 MW)	0.03	0.03

Note: Existing plants are to comply with the new norms by December 2017; while plants commissioned after 1 January 2017 are to comply with the new standards from the start of their operations.
Figures in mg/Nm^3
Source: MoEF&CC

Table 7: Age–size distribution of coal power generation units in India

Large newer units account for a majority share in the aggregate capacity

Unit size	Capacity in MW				Total
	25 years	1990–2003	2004-08	2009-16*	
Up to 250 MW	28,610	16,292	2,070	5,816	52,788
> 250 MW–500 MW	-	5,350	3,850	20,810	30,010
500 MW and above	5,500	9,500	5,980	82,814	103,794
Total	34,110	31,142	11,900	109,440	186,592

Note: *As on 31 August 2016
Source: Centre for Science and Environment (CSE)

Table 8: Emission standards for thermal power plants in major countries

Major countries have adopted very tight emission standards for new generation capacity

Pollutant	Category	China	EU	US
NO_x	New plants	100	200 (built after December 2015); 500 (built till December 2015)	117
	Existing plants	100 (built during April 2004–December 2011); 200 (build before April 2004)		117 (built after February 2005); 160 (built during 1997–2005); 640 (built during 1978–96)
SO_2	New plants	100	200	160 (built after 2005)
	Existing plants	200 (for 28 provinces); 400 (four provinces with high sulphur coal)	400	160 (built during 1997–2005); 640 (built during 1978–96)
PM	All plants	30	50; 100 (for low quality coal e.g. lignite)	22.5
Mercury	All plants	0.03	0.03 (only in Germany)	0.001- 0.006

Note: China has prescribed stricter standards for highly polluted regions.
Source: World Resources Institute

Table 9: Basis of pollutant limits set under the new emission standards in India

Rational considerations back formulation of emissions control standards in India

Pollutant	Basis of determination and formulation
PM	• Relatively lenient standards of 100 mg per Nm^3 were adopted for plants installed prior to 2003 in consideration of the existing capability of installed ESP systems, and the limited investment recovery period. • Existing units installed since 2004 were notified to meet a PM standard of 50 mg per Nm^3 as a sizable majority of these units, especially those installed since 2008 were already required to meet this norm under their ECs. The remaining units, currently subjected to a requirement of 100 mg per Nm^3, can easily achieve the new standard by upgrading their ESPs. • CEA estimated that 115 GW of capacity, almost two-thirds of the total, is already complying with the new PM norms. • Most stringent norms were established for upcoming plants, in line with global standards, as these are easily achievable through a combination of ESP and FGD.
SO_2	• Most smaller units (of less than 500 MW size) in India do not have sufficient space available for installation of FGDs. Their pollution load is also lower. Thus, such units were subjected to lenient SO_2 norm of 600 mg per Nm^3. They could consider economical solutions such as partial FGD or sorbent injection. • A tight standard of 200 mg per Nm^3 was selected for existing large plants (similar to the Chinese standards) as a vast majority of these units had space available for FGD installation. Further, most of these units were installed after 2008 so they can recover investment costs. • Upcoming plants were required to meet the most stringent standards of 100 mg/Nm^3. These units can install state of the art pollution control technology and an economically efficient multi-pollutant design (for e.g., a smaller ESP when FGD is being installed).
NO_X	• Lenient standards of 600 mg per Nm^3 were prescribed for older units. Lot of these units have boilers with inefficient design and sub-optimal combustion and may find it difficult to cut emissions. The new norms require plants to make only minimal interventions. • A standard of 300 mg per Nm^3 was prescribed for units installed after 2003, as majority of the large units have already installed low NO_x burners and can achieve the new standards by optimizing boiler operations. Other units can also achieve these emission levels through basic interventions as burner modification, over fire air supply (OFA) etc. • Upcoming units were subject to strictest standards of 100 mg per Nm^3, in line with global best standards. These units will need to install advanced NO_x control technologies like SCR and SNCR.

Source: CSE compilation

Implementation status

Progress in implementation

With only a few months remaining till the deadline for the existing power plants to achieve new emission norms, the progress reported in implementation has been unsatisfactory. Despite the notification of the final order in December 2015, a number of companies remained in a wait-and-watch mode, hoping that MoEF&CC will eventually extend the deadline or loosen standards. Meanwhile, most plants in the pipeline are continuing construction without any changes to their plans.

But, on a positive note, the Central government-owned NTPC, the country's largest generator, has made good progress. It has said that all its existing plants will be able to meet PM standards by 2017. NTPC has also initiated five pilot projects to confirm if SCR/SNCR technology would be suitable for power plants using high-ash Indian coal for NO_x control in upcoming plants. As for SO_x, two existing power plants have launched tenders for procuring FGD and others are in the process of acquiring them.

In order to push implementation, the Ministry of Power (MoP) established a high powered committee in September 2016, under the chairmanship of CEA. The committee obtained emissions data, identified key parameters to help plants decide what pollution control equipment upgrade or installation was required, and estimated cost.[3] It also instructed the four regional power committees (RPCs) to prepare a unit-wise plan for installation of pollution control devices. The RPCs released the phasing plans in the first quarter of 2017.

According to the timelines mentioned in these plans, existing power plants will begin to report compliance with the new norms from 2019 onwards, and the process will be completed by March 2023 (a delay of over six years). The plans will have to be updated and reworked by the MoP, given MoEF&CC's recent statement in the Parliament that there will be no relaxation of timelines.

Key challenges—overestimated requirement, cost and timelines

The power generation industry in India has delayed implementation claiming, initially, that the pollution control technology is not suitable for Indian coal and will not be able to cut emissions to a level enabling compliance. The industry also exaggerated the equipment upgrade or installation costs and time taken for installation.

Over the past several months, CSE has worked with the MoEF&CC and CPCB to address these concerns and push the implementation of revised standards. CSE felt it was important to engage with all key stakeholders to identify issues and propose solutions and organized a conference on 'New Environmental Norms: The Way Forward' on 7 September 2016. The conference was attended by executives from major government- and private-owned generators and leading global equipment manufacturers. Top tariff regulators, researchers and sector experts also participated in the deliberations.

A consensus has developed among policy makers and the industry in India that available pollution control technology can enable plants to comply with the new emission norms

1. **Technology is not an impediment**
   CSE's work helped build consensus among policy makers and the industry that available pollution control technology can enable plants to comply with the new emission norms—ESPs can be augmented to achieve PM norms; FGD, to control SO_2, is a mature technology, which has been widely used across the world; existing plants can meet NO_x norms by optimizing boiler combustion or installing low-NO_x burners, a relatively simple upgradation; and suppliers are confident that SCR technology, which will be required by upcoming plants to meet tighter NO_x norms, will work for Indian coal.

2. **Manageable installation and upgrade requirements**
   CSE analyzed the data presented in the CEA–RPC reports and concluded that the timelines given by the industry were long. CSE research suggested that a far tighter timeline was achievable; CSE prepared a unit-wise schedule of implementation that was shared with both the environment and power ministries. Following is a summary of the findings:

   - **ESP upgrade needed only for 25 per cent capacity:** New PM emission norms are already being met by nearly 115 GW of capacity (65 per cent of the total coal-based capacity), as per the CEA–RPC data. CSE estimates that only 25 per cent of the capacity would require ESP upgrades, as the remaining 10 per cent are over 25 years old and can be gradually shuttered. Upgrading ESP for 25 per cent of the national capacity can easily be completed within a maximum period of two years.

- **NO_x emissions control requires minimum interventions:** Majority of the new power plants in India have already installed low-NO_x burners. Significant reductions in emissions levels can further be achieved by merely optimizing boiler operations. This does not require major interventions and can be easily executed for the entire fleet during the planned annual overhauls over the next two years.

- **FGD installation limited to 45 per cent of capacity:** Given the data on availability of space, it emerges that only 45 per cent of India's existing coal-based capacity (or 78 GW) can install FGD. This accounts for a significant majority (88 per cent) of the capacity that has to meet tighter SO_2 norms of 200 mg per Nm^3. Given that FGD installation takes 18–24 months, CSE estimates that compliance to new SO_2 norms can be ensured by December 2019.

Indian coal power industry feared that the new norms would result in higher tariff (IDR 80–100 per kWh). CSE research indicated that the impact would be far lower (IDR 40–70 per kWh)

3. **Manageable tariffs increase:** The initial expectation from the industry was that the implementation of the new norms would result in substantially high tariff impact of Rs 0.40–0.90 per kWh (Indonesian Rupiah or IDR 80–100 per kWh). However, CSE research on the cost of pollution control equipment (see *Table 10: Cost of pollution control equipment in India*) indicated that the impact of these investments on the cost of generation would be in the range of Rs 0.20–0.35 per kWh (IDR 40–70 per kWh). CEA's estimates of cost of pollution control devices would result in similar impact on generation cost.

   Tariff impact will be little higher for retail consumers given transmission losses and discom costs. However, CSE estimated the retail tariff to increase by less than 10 per cent. The increase in costs appears manageable given that for the past three years the average retail tariff growth has been 7–9 per cent.

4. **Achievable timelines:** Since the draft for the new norms was released in May 2015, existing plants had almost two and a half years to comply (by December 2017) with the new standards.

   While the power producers raised concerns about the timelines being too tight, CSE research indicated that the deadline indicated for meeting the norms was manageable (see *Table 11: Time required for installing different pollution-control equipment in India*). In fact, for a vast majority of the power plants the PM emissions norms have remained unchanged. Similarly, several of the power plants had already installed low-NO_x boilers and were reporting low emissions levels.

Table 10: Cost of pollution control equipment in India

Cost of investments in emissions control devices is manageable

Technology required	Approximate cost (Rs million/MW)
ESP upgradation	0.5–1.5
FGD	4.0–5.0
Partial FGD	2.5–3.0
De-NOx burners	1.0–1.5
SCR/ SNCR	2.0–2.5

Note: Rs 1 = IDR 207.7
Source: Centre for Science and Environment (CSE), 2016

Table 11: Time required for installing different pollution-control equipment in India

The transition to low emissions can be completed by a power plant in about two years

Technology	Construction time	Downtime
Electrostatic precipitator (ESP)	~ 3–6 months	~ 20–30 days
Flue gas desulphurization (FGD)	~ 18–24 months	~ 30–90 days
Selective catalyst reduction (SCR)	~ 5 months	~ 30 days
Selective non-catalyst reduction (SNCR)	~ 4 months	~ 7 days
Low NO_x burner, OFA etc.	~ 1 month	~ 15–20 days

Source: Centre for Science and Environment (CSE), 2016

Inadequate monitoring by regulators

The environment and power ministries have not made a serious effort to track implementation progress or to pro-actively address concerns of the industry regarding financing and cost recovery, which has added to the industry stalling investments in pollution control devices. CSE has recommended that MoEF establish close monitoring processes to minimize delays:

- **Directive to submit project plans:** The CPCB and SPCBs must obtain plants' detailed 'action plans', which should be evaluated to ensure that best possible efforts are being made. Progress should be monitored against the timelines indicated in these plans.

- **Penalty for deviations from plan:** The ministry must set up a mechanism of penalties if there is a delay in meeting the deadlines set under the committed action plan.

Lack of baseline emissions data

Unavailability of reliable emissions data is another factor affecting implementation of emissions control standards in India. The quality of data generated by CEMS and provided to CPCB is not reliable; several generation units are not reporting data on SO_2 and NO_x. Accurate emissions data is crucial to figure out the appropriate technology and to measure the effort required by both individual plants and the sector.

China's emission standards and experience

Old and new standards

China has introduced regional variations, wherein stricter emission limits have been prescribed for densely-populated economically-developed regions

Emission standards for air pollutants for thermal power plants in China were initially introduced in 1991 and later amended in 1996, 2003 and 2011. The standards introduced in 1991 only covered PM emissions, while SO_2 emissions were being managed through stack height requirements. In the 1996 revision, standards for SO_2 and NO_x were included for the first time. Emission limits for all the three pollutants were significantly tightened in the 2003 revision, and varied standards were introduced based on the age of the units.

Introduction of stringent norms in 2011: China introduced a new set of standards in 2011 (GB-13223-2011) which tightened the emission limits for PM, SO_2 and NO_x, to the point that they are stricter than comparable laws in the US, EU, and Canada. The emission limit for SO_2 was reduced by almost 50 per cent compared to the previous levels, while the limit for NO_x was decreased by nearly 78 per cent.

- Regional variations were introduced, wherein stricter emission limits were prescribed for densely-populated economically-developed regions.
- Acknowledging the difference between new and existing boilers (given the age and technology), stricter emission limits were specified for new capacity considering technological progress.

Table 12: Emissions standard of air pollutants for coal-fired power plants in China

New standards introduced in 2011 are stricter than those in developed countries

Category	PM	SO_2	NO_x	Mercury
New plants	30	100 (200[a])	100	0.03
Existing plants	30	200 (400[a])	100 (200[b])	0.03
Special emission limit[c]	20	50	100	0.03

In mg/m^3
[a] For plants located in the Guangxi Zhuang Autonomous Region, Chongqing Municipality, Sichuan Province and Guizhou Province;
[b] For existing circulating fluidized bed, operating or getting environmental impact report approval before 31 December 2003;
[c] The geographical scope and time for the implementation is prescribed by the MEP under the guidance from the state council.

Existing units were required to comply with the standards for PM, SO_2 and NOx from 1 July 2014, while the new units had to implement these from 1 January 2012. For mercury emissions, all units were to ensure compliance from 1 January 2015.

REGIONAL POLLUTION STANDARDS

China established a joint air pollution prevention and control system under its Twelfth Five Year Plan for three of its highly polluted metropolitan regions—the Beijing-Tianjin-Hebei region (BTH), Yangtze River Delta region (YRD) and the Southern Guangdong Pearl River Delta region (PRD)—with the objective of improving their air quality at least to the Grade-II level under the National Ambient Air Quality Standard.[1] In order to achieve this, the regional authorities have notified very stringent air pollution control policies, which include adoption of special emission standards for coal-based boilers or power plants, significantly tighter than the 2011 national standards.

- BTH region: The regional standards for industrial coal-based boilers in the region are generally stricter than the special emission limits prescribed in the national standards.
- In 2015, Beijing announced some of the tightest emission norms for coal-based boilers in the world, and eventually decided to shut down all four of its coal-based power plants.
- The new standards set in Tianjin in 2016 are generally less strict than in Beijing, however their limit for NO_x emission from new coal-based boilers is tighter than the national standard. The port city has also set a target of shutting all coal-based TPPs located within specific high-polluted areas after 1 January 2018.
- The Hebei province, which is highly dependent on heavy industries, also adopted very stringent standards for certain boiler types in 2014. Later, the province decided to convert all its existing coal-based plants into ultra-low emission plants by 2015. This has not been achieved yet, with plants still complying with earlier standards.
- YRD region: The municipality of Shanghai adopted ultra-low emissions standards for coal-based TPPs in January 2016. The schedule of implementing these standards varies as per the ownership and installed capacity of units. Similarly, Zhejiang and Jiangsu provinces have also adopted ultra-low emission standards. While the target is to achieve this by the end of 2017, Zhejiang is expected to complete the transition by mid-2017 and Jiangsu by end-2018.
- PRD region: All coal-based TPPs in the region are required to comply with the special emission limits set under the national standard since 1 July 2014.

Table 13: Regional emissions standard of air pollutants for coal-based TPPs in China (mg per m^3)

Highly polluted metropolitan regions in China impose very stringent standards

Region	City or province	PM	SO_2	NO_x	Mercury
Beijing-Tianjin-Hebei Region	Beijing	5/10	10/20	30/80/100/150	0.0005/0.03
	Tianjin	20/30	50/100/200	150/200/400	0.0005
	Hebei	10/20/30	35/50/200	50/100/200	0.03/0.05
Yangtze River Delta Region	Shanghai	10	35	50	0.03
	Zhejiang	10	35	50	0.03
	Jiangsu	10	35	50	0.03
Pearl River Delta Region	-	20	50	100	0.03

Note: Emission limit in the BTH region vary depending on age, type and location of boilers.

1 Grade-II level of air quality requires annual average SO_2 emissions of 60 µg/m^3, NO_2 of 40 µg/m^3, NO_x of 50 µg/m^3, PM10 of 70 µg/m^3, PM 2.5 of 35 µg/m^3, etc.

- Emission limits for mercury and its compounds from coal-fired power plants were set for the first time, taking into account its harmful health impacts.

- Very tight timelines were prescribed for achievement of the new standards, especially for new boilers.

Ultra-low pollution standards: Recently, the Chinese government has started promoting ultra-low-emission retrofitting of coal-based plants through the use of multi-pollutant and efficient collaborative control technology, requiring emissions to be as low as that of natural gas-based power plants.[4] Under this, PM emissions are restricted to 5–10 mg per m^3, SO_2 to 35 mg per m^3 and NO_x to 50 mg per m^3. These ultra-low limits have been adopted by several municipalities and provinces including Shanghai, Jiangsu, Zhejiang, Shanxi, and Guangzhou.

Key considerations behind establishing new norms

New emission norms were defined in China after extensive study of the current emissions and projected increase in emissions from power plants, against the overall national goals for air pollution control. The new norms also considered technological development in emission control devices and the standards set in other major countries. The technical inputs for defining the new norms were provided by government-affiliated think tanks like the Environmental Protection Research Institute, the Guodian Science and Technology Research Institute, and the China Academy of Environmental Sciences.

Chinese government has started promoting ultra-low-emission through the use of multi-pollutant control technology

- **Benchmark set by national goals for air pollution control:** In deciding new emission norms, the government took into account the binding target set under the country's Eleventh Five Year Plan of reducing SO_2 emissions by 10 per cent, as well as the commitment of promoting desulphurization and denitrification of coal-based power plants. The Plan emphasized the urgent need for acid rain control by focusing on elevated sources of SO_2 and NO_x emissions, and on improvement of ambient air quality through control of PM emissions, especially $PM_{2.5}$. It further recognized that highly populated and polluted regions required special measures for air pollution control.

- **Projected growth in emissions from coal-based plants under 2003 standards:** The consultation paper released for defining the new emission standards indicated that in absence of tighter emissions standards the pollution from TPPs will continue to increase with severe impacts on environment and public health. It estimated if the 2003 emissions standards are not tightened, by 2015 there would be an addition of 1.34 MT, 2.51 MT and 0.27 MT to the 2007 (2.59 MT, 8.4 MT, 2.97 MT) emissions of SO_2, NO_x and PM, respectively from TPPs due to the projected increase in coal-based capacity to 1,000 GW.

- **Sustained performance of pollution control devices:** By 2008, desulphurization facilities were installed in 363 GW of thermal capacity (or 60 per cent) in China, providing managerial and operational confidence in the technology. Similarly, the 2003 standards pushed the development of low-nitrogen combustion technology for newly built large-scale coal-based units, helped in setting up of denitrification facilities in key regions and adoption of low-nitrogen burners at existing TPPs.

- **High pollution levels in key regions:** Special emission limits were prescribed for certain developed regions, where the carrying capacity of the environment was severely compromised. The limits prescribed for such regions were based on the most advanced and feasible pollution control technologies. Some of these industrialized regions were also able to afford the cost of advanced technology.

Implementation status and challenges

Penetration of pollution control devices

In response to the tightening emission standards, the penetration of pollution control devices in China increased sharply (see *Table 15: Penetration rates of air pollutant abatement technologies*). SO_2 emissions reduction was prioritized during the Eleventh Five Year Plan Period (2006–10) and NO_x became the focus during the Twelfth Five Year Plan Period (2011–15). Efforts for PM control have been ongoing since the mid-1990s and were intensified recently. The government regulations and premium tariffs have played a significant role promoting these reductions through technology.

In response to the tightening emission standards, the penetration of pollution control devices in China has increased sharply

- **PM control devices implemented across all units:** Controls for PM emissions have been installed in almost all generation units. By 2010, ESPs had been installed in 93 per cent of the pulverized coal boilers (88 per cent share), while the remaining utilized efficient bag filters.[5] All circulating fluidized bed (CFB) boilers (12 per cent share) utilized ESPs. By the end of 2014, ESPs, bag filters and electric bag composite dust collectors were installed in 77.3 per cent, 9 per cent and 13.7 per cent of the aggregate coal-based capacity.

- **FGD to control SO_2 installed across 93 per cent capacity:** Flue gas desulphurization (FGD) facilities had been installed across 820 GW of power plants (or 92.8 per cent of coal-based capacity) by the end of 2015, as per the China Electricity Council (CEC). The remaining capacity primarily comprises CFB boilers, which do not need to install FGD for desulphurization of flue gas.

  FGD installation picked up pace after enforcement of the 2003 standards, with its penetration increasing from 2.1 per cent in 2000 to 85.6 per cent in 2010 and to nearly 93 per cent in recent years. In fact, China has surpassed US in this area, where the penetration rate for FGD was around 75 per cent in 2013.[1]

- **Denitrification facilities installed across 95 per cent capacity:** By 2015, flue gas denitrification facilities (including low-NO_x burners—LNBs; SCR and

1 As per 'China's Electric Power Emission Reduction Policy Analysis and Outlook: China Electric Power Emissions Reduction Research 2015' by Wang Z X et al., and Wang S X and Hao J M, 2012.

SNCR) had been installed across 850 GW of power plants (95 per cent), as per the CEC. Installation of traditional LNBs were first to take off, however their penetration levels decreased after 2005 as the demand for advanced LNBs started picking up. As for SCR and SNCRs, MEP data for 2014 indicates that this equipment has been installed across 1,135 coal-based generation units aggregating 430 MW of capacity.

Estimated impact of emission norms

Increased penetration of pollution control devices in response to the tightening norms has resulted in reduction in emissions from thermal power plants. Compared to the 1990 levels, the $PM_{2.5}$, PM_{10} and SO_2 emissions from coal-based power generation units are estimated to have decreased significantly despite a massive growth in generation from this sector (see *Graph 20: Coal Consumption and Air Pollutants Emissions from CFPPs in China*).

Compared to the 1990 levels, the $PM_{2.5}$, PM_{10} and SO_2 emissions from coal-based power generation units in China are estimated to have decreased significantly despite a massive growth in generation

- PM emissions actually had two troughs in 1996 and 2005 due to changes in electricity demand and regulations. The first decline after 1996 is believed to be from slowdown in the Chinese economy and implementation of the 1996 standards. The second decrease after 2005 was due to the stricter emission standards introduced in 2003, leading to 40 per cent and 47 per cent decrease in $PM_{2.5}$ and PM_{10} emissions respectively between 2005 and 2010.

- The reduction in SO_2 emissions has been especially stark since 2005 as introduction of new norms in 2003 made FGD installation a key requirement. Thus, SO_2 emissions peaked in 2006 at 16.7 MT, and decreased by 54 per cent by 2010, as the FGD penetration rate increased to 85.6 per cent.

- As for NO_x, growth in the use of traditional LNB during 1990-2005 resulted in an average annual decrease in emissions by 1 per cent per unit of power generated. However, despite significant increase in the penetration rate of advanced LNB since 2005, total NO_x emissions are estimated to have increased on account of higher coal consumption.

  During 2011-15, NO_x emissions are estimated to have decreased due to increased focus on SCR and SNCR installations. It is estimated that in 2014, NO_x emissions from thermal power generation was 1.47 grams per kWh (fleet average), which represented 50 per cent reduction compared to the 2010 level.

Reported compliance to norms

There is limited information about compliance with emission norms by power plants in China. For existing power plants, the new norms came into effect from 1 July 2014. However compliance level can be estimated from the disclosure of the penalty notices on MEP website.

In 2014, as per the latest available information, there were 46 power plants owned and operated by 17 power corporations whose desulphurization and denitrification facilities did not fulfill requirements, primarily on account emissions exceeding prescribed standards, unreliable CEMS data and

Table 14: Basis of pollutant discharge limit under 2011 emission standards in China

Reasonable considerations back formulation of emissions control standards in China

Pollutant	Determination and formulation basis
SO_2	• Stringent standards were set for new units, which are required to be ≥ 300 MW in size and can adopt advanced SO_2 technologies. • The standards were kept more stringent for new plants to avoid reconstruction of existing plants. • For existing units, emission limits were set in line with the actual situation, environmental requirements and technology status.
NO_X	• For new units, stricter than EU standards for NO_X control were adopted. Units can adopt advanced low-nitrogen combustion technology and flue gas denitrification technology, justifying stricter standards. • Units commissioned after 2003 were required to set aside space for flue gas denitrification equipment. • For units installed before 31 December 2003, limits were set as per the actual situation, environmental requirements and technology status.
PM	• New unit have tightest norms for PM, as they can achieve high removal efficiency by installing ESP or bag filters along with FGD. • The achievability of stringent standards has been established in the US, EU and Japan. • Existing plants could also meet tighter standards as ESP had been deployed in most, with some large units using bag filters. • Electronic bag dust collector technology became technically mature to help meet the new standard for existing plants.
Mercury	• The emissions standard for mercury was determined after studying the standards in the US and Germany.

Adapted from 'Emission Standards of Air Pollutants for Thermal Power Plant' (GB-13223-2011) and 'Emission Standards of Air Pollutants for Thermal Power Plant' (Second consultation draft)

Table 15: Penetration rates of air pollutant abatement technologies

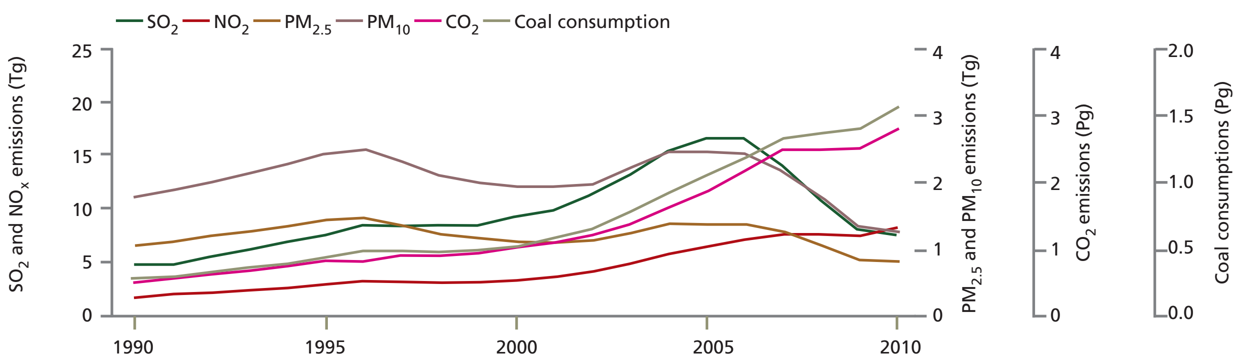
Tight emissions norms have led to significant rise in penetration of pollution control devices

Technologies	1990	1995	2000	2005	2006	2007	2008	2009	2010
Traditional LNB	12	22.1	38.7	53.7	51.8	46.6	44.2	42.1	39.4
Advanced LNB	0	0	0	0	7.4	19.8	29.2	35.9	42.0
FGD	0.1	1.0	2.1	12.2	29.5	49.9	70.2	81.9	85.6
Cyclones	7.6	7.4	5.2	3.6	3.0	2.3	1.6	0.7	0.3
Wet scrubbers	46.3	40.4	19	6.9	6.1	5.0	3.9	3.1	2.5
ESP	44.3	49.8	72.5	86.1	87.5	89.1	90.8	92.0	92.8
Bag filters	1.7	2.3	3.3	3.4	3.4	3.5	3.7	4.2	4.4

All figures in percentage.
Adapted from: High-resolution inventory of technologies, activities, and emissions of coal-fired power plants in China from 1990 to 2010. Link: www.atmos-chem-phys.net/15/13299/2015.

Graph 20: Coal consumption and pollutants emissions from CFPPs in China

Emissions from coal-based power generation units are estimated to have decreased significantly



Source: High-resolution inventory of technologies, activities, and emissions of coal-fired power plants in China from 1990 to 2010. Link: www.atmos-chem-phys.net/15/13299/2015/.

malfunction of equipment. Of these, 37 plants failed to comply with the required NO_x limit, while the remaining 21 plants failed in SO_2 compliance.

Based on this, the non-compliance rate in China can be estimated to be less than 2 per cent; given that there are about 2,600 coal-based units this seems very low. It is possible that penalty notices are issued only in case of gross non-compliance by power plants. Further, there could be cases of under-reporting, which have not been caught due to inadequate monitoring.

Progress with ultra-low norms: According to the MEP, nearly 100 GW of coal-based capacity installed across the country had completed the ultra-low emission technological transformation by the end of 2015. This is targeted to increase to 420 GW by the end of the Thirteenth Five Year Plan period.

Further, the ministry released the Full Implementation Plan of Ultra-Low-Emission Coal-Fired Power Plants and Energy-Saving Retrofitting Programme in 2015, aiming to accelerate its implementation across the country. The overall target of the government is to achieve ultra-low emissions across the entire sector by 2020, especially for all new power plants. To accelerate the process of retrofitting of existing units, the eastern region (11 provinces and municipalities) have been given the target of completing the transition by 2017, the central region (eight provinces and municipalities) by 2018, and the western region (12 provinces and municipalities) by 2020.

The process of implementation of emissions standards in China was relatively smooth due to the gradual cuts in limits and dominant presence of the government in the generation segment

Implementation challenges

The process of implementation of emission control standards in China was relatively smooth due to the gradual cuts in emission limits as well as the dominant presence of the government in the power generation segment. This was further supported by the financial incentives provided by the government in the form of subsides on equipment, power purchase guarantee, premium tariff rates, etc. However, various challenges still remain in the technical implementation and reduction of pollutants.

- **Low efficiency of pollution control devices:** The average desulphurization efficiency of coal-based power plants in China has been increasing steadily, yet it reached only 77.2 per cent by 2012, lower than the desired levels of 90 to 95 per cent.[6] See *Table 16: Average efficiency of pollutants removal facilities in thermal power plants in China*.

  The average national denitrification efficiency was even lower at only 10.2 per cent in 2012. The low level of efficiency is attributed to limited number of installations, inadequate operation rate of equipment, and loose enforcement of the regulations.

  In recent years, the efficiency levels have probably improved due to the tightened emission standards (enforcement of 2011 standards started in 2014 for existing units), application of CEMS, and strengthening of supervisory monitoring by local Environmental Protection Boards (EPBs). A key challenge has been with respect to smaller units, as it is technically challenging to increase the efficiency levels of smaller desulphurization

Table 16: Average efficiency of pollutants removal facilities in thermal power plants in China

Removal efficiency of equipment remains low, despite improvements

Year	Desulphurization		Denitrification	
	Number of installed units	Removal efficiency (per cent)	Number of installed units	Removal efficiency (per cent)
2010	3,266	69.5	N.A.	N.A.
2011	3,379	74.5	274	6.5
2012	3,465	77.2	438	10.2

Note: Removal refers to the pollutants removed at the sectoral level.
Source: Zhu L et al. The Medium and Long Term Strategy Research for Air Pollution Control and Environmental Protection in China Coal-Fired Power Sector. China Electric Power Press (in Chinese)

facilities. In China, the smaller generation units are estimated to account for 25 per cent of the generation capacity, while contributing almost half of total SO_2 emissions.

- **Low utilization of pollution control equipment:** Desulphurization and denitrification facilities entail a large one-time investment cost, followed by continuous O&M costs. These costs are generally subsidized through a premium or preferential tariff available to power plants with eligible desulphurization, denitrification and de-dusting equipment installed and in operation. Often times, plants have tried to receive subsidies without adequately running the pollution control devices. Dealing with such cases has become the focus of the provincial EPBs attention in recent years.

- **Limited capability of monitoring devices:** Presently, China has some of most stringent emission norms in the world, which have made monitoring technically challenging. For instance, ultra low emission standards of 10 mg per m^3 limit for PM emissions is so low that it falls within the detection error range of some monitoring instruments. Monitoring equipment installed at several power plants are not able to accurately monitor emissions.

- **Limited capability of enforcement bodies:** While China has been making concerted efforts to improve the enforcement of emission norms, the capability of the enforcement divisions remains limited. Against a total number of 3,000 EPBs and 180,000 staff members at the local level, the employee strength of MEP is limited to 400. This makes the task of monitoring local level groups very challenging. Further, implementation of laws and regulations are often subject to corruption and local protectionism.

- **Quality of emissions data:** The quality of environmental data suffers due to the use of varied statistical and calculation methodology. While some power plants use real-time monitoring data through online systems, others use material balance or emission factor methods to estimate the emissions data. Such differences make it difficult to reflect the actual emission levels of power plants.

Compliance and monitoring mechanisms

Monitoring in China

In China, provincial EPBs and regional monitoring supervision centers under MEP play a key role in enforcing compliance by power plants. Since 2010, MEP has been releasing annual notices on non-compliance based on both on-site and CEMS data on its official website. Financial penalties are issued in case the power plant is not able to meet the annual benchmark in-operation rate of 90 per cent.

However, gaps exist in the monitoring practices adopted in China due to the inadequate manpower and technical capacity of EPBs compared to the massive size of coal-based generation fleet. Although the overall mechanism of CEMS implemented across power plants is similar, differences exist in the manner in which provincial EPB work in supervising the generated data.

Chinese experience with CEMS

CEMS was introduced in China during the 1980s, however, the 1996 emission standards first introduced CEMS for thermal power plants. By 2004, around 400 CEMS devices were installed in 180 coal power plants. But only about 20 per cent of these devices were operating efficiently. Further, many local EPBs were not accepting data generated through CEMS.

Almost all CFPPs in China are equipped with CEMS and real-time data is being monitored by EPBs and MEP

Measures for the Automatic Monitoring and Management of Pollution Sources released in 2005 reinforced the requirement of installing CEMS for monitoring both air pollution and wastewater discharge. By 2010, local EPBs started accepting CEMS data, although with some degree of distrust over reliability. Now, almost all CFPPs are equipped with CEMS and real-time data is being monitored by the environmental monitoring departments under local EPBs and MEP.

In 2014, the NDRC and the MEP jointly promulgated the *Measures for the Supervision and Management of Environmental Protection Electricity Prices and Environmental Protection Facilities for Coal-fired Generating Units*, which established the requirement of online monitoring of the emissions data. It required CEMS to have two channels to verify the authenticity of data. It also established penalties for fraudulent CEMS and distributional control system (DCS) data.

CEMS specifications and requirements: Chinese governmental departments have introduced more than sixty monitoring standards, technical specifications and equipment standards for CEMS, as well as specified the provisions for CEMS data collection, processing and reporting. By December 2015, there were more than 50 certified CEMS manufacturers and more than 60 types of qualified product models available in the market.

CEMS maintenance is required to follow the HJ/T 75-2007, which specifies the exhaust parameters and the main technical indicators of CEMS, namely testing items, installation location, commissioning and testing methods, acceptance methods, daily operation and management, daily operation quality assurance, data review, and reporting data format.

Data collection, reporting, and communication protocol should conform with the requirements in the *Standard for Data Communication of Pollution Emission Auto Monitoring System* (HJ/T212-2005), to standardize data transmission and ensure the connectivity among all kinds of CEMS equipment, transmission network, and environmental protection department application software system. This Standard also specifies the CEMS monitoring center, and automatic monitoring equipment between the data communication, control and alarm information transmission protocol.

Power plant experience with CEMS O&M: A survey conducted by CEC and other power corporations revealed that 99 per cent of the power plants were meeting the seven-day technical specification requirement of CEMS. About 71 per cent of the surveyed plants were utilizing the services of third party O&M providers.

The survey also revealed the challenges being faced by power plants, including failure of monitoring instruments; insufficient capacity of O&M personnel; slow response of third party O&M providers; and large capital pressure of component replacement. Further, the error limits of existing CEMS technologies make it difficult to detect and monitor flue gas emissions, especially for low concentrations of PM under special emission limits and ultra-low emissions norms.[7]

In two years since the issuance of directions by CPCB, nearly 80 per cent of the 2,700 plants that were required to install CEMS in India had done so

Monitoring in India

In India, emission norms for industries, including thermal power sector, are notified by the MoEF&CC based on inputs from CPCB, while monitoring and implementation is largely led by the state PCBs. Installation of CEMS for reporting and monitoring of real-time data on emissions performance of power plants is a relatively recent phenomenon in the country.

Indian experience with CEMS

CEMS installation took off in India in response to directions issued by the CPCB in February 2014, which mandated its installation for real-time monitoring of air emission and effluent quality across 17 highly polluting industries (including coal-based power sector) and common pollution treatment facilities. In two years since the issuance of the directions, nearly 80 per cent of the 2,700 plants that were required to install CEMS had done so.

According to the MoEF&CC, of the 162 standalone power plants in the country, CEMS were installed in 142 plants as of March 2017. Of these, 102 plants have started online transmission of emission and effluent data to the CPCB.

But, serious questions have been raised with respect to the quality of data generated by the CEMS. There is a general lack of understanding in Indian industries and regulators about CEMS. These issues emerged during the survey conducted by CSE in 2016 across various sectors to understand the progress of CEMS installation in India.[8] The key results are:

- **Improper device installation and operation:** All of the surveyed plants had installed CEMS for measuring discharge emissions and effluents; however, the equipment were not working due to component failure in case of 15 per cent of surveyed plants. Nearly 40 per cent of the plants had not installed a camera and a flow meter, while another 15 per cent had not completed installation of continuous PM monitor.

- **Lack of knowledge on CEMS including certification:** Only one-third of the surveyed plants had sufficient knowledge about correct installation, maintenance and proper operation of CEMS. Further, lack of CEMS certification system in India meant vendors often suggested inappropriate devices.

- **Lack of regular maintenance:** A majority of the plants were dependent on vendors for regular maintenance, adjustments and drift or span check. Given that frequent visits by vendors is not possible, daily drift check was not being done. Till date, no third party labs have been recognized to carry out such jobs for CEMS.

China has adopted an incentive-based mechanism for implementation and adoption of tighter air emission standards for coal-based power plants

- **Lack of guidance manual, lab empanelment and device certification system:** Pollution control regulators are yet to provide detailed guidelines covering critical information such as device selection, installation, O&M, and data transfer. Regulators have also not yet finalized plans to develop lab empanelment and device certification systems.

- **Lack of skilled manpower:** Nearly 60 per cent of the plants did not have a dedicated employee to supervise real-time monitoring system. Majority of the plants have given the responsibility to the environment department, which generally lacks the technical understanding of such equipment. Similarly, the shortage of skilled manpower in state PCBs has resulted in inadequate guidance on CEMS implementation, analysis, and identification of defaulters.

Notably, MoEF issued a draft notification in 2015 to make installation of CEMS legally binding, however, the notification was put on hold due to the lack of basic infrastructure and understanding for implementing CEMS.

Incentive and assistance mechanism

Incentives and assistance mechanism in China

- **Financial support for coal-based power plants:** China adopted an incentive-based mechanism for implementation and adoption of tighter air emission standards for coal-based power plants. This was achieved by subsidizing the cost of pollution control equipment through the industrial restructuring fund as well as by providing purchase guarantees and providing premium tariff rates for low-emission power plants.

- **Easy loans:** Support for installation of pollutant control technologies was available for the coal-based sector in the form of easy and cheap loans ,available through a largely state-owned financial system. Chinese banks are usually willing to give loans to the power industry since it comprises mostly state-owned enterprises. The interest rate tends to range from 4 to 7 per cent.

- **Subsidies provided by Central and provincial governments:** In 2004, the Central government established special funds for meeting the financing gaps in environmental protection. Air pollutants' control projects for thermal power sector were included in the fund in 2005. Under this, funding support is given to innovative technology deployment in desulphurization and denitrification.

  Further, grants at the provincial level have also been provided to enhance the penetration rate of the abatement equipment. These grants are usually at no cost, and sometimes part of the grants is in the form of interest subsidy.

- **Power purchase guarantee and premium rates for low-emission plants:** Chinese government provides premium to generators that have installed emissions control equipment and achieved emissions standards.

  - **Desulphurization tariff:** This was initially introduced in 2004 by the NDRC to encourage the installation of FGD in new coal-based plants at a rate of CNY 0.015 per kWh over and above the on-grid tariff. Since 2007, the tariff rate has been made available to both new and existing plants with verified desulphurization facilities.

  - **Denitrification tariff:** By the end of 2011, 14 provinces in China piloted this for new generation units at a rate of CNY 0.008 per kWh. This was adopted at the national level in January 2013. In August 2013, NDRC raised the tariff rate to CNY 0.01 per kWh, primarily in response to the power sector's concerns that the previous rates were too low to cover the additional costs for running the equipment.

  - **Green tariffs:** Since 2014, government has approved 'environmental protection tariff' or 'green tariff' for coal-based units for installing desulphurization, denitrification and de-dusting equipment, following verification of performance by environmental departments. Since 2015, inspections are being carried out jointly by the provincial price bureaus and EPBs as per the NDRC orders to check for frauds.

    Green tariff-levels are determined by local governments and average around CNY 0.027 per kWh, including CNY 0.015 per kWh for desulphurization, CNY 0.01 per kWh for denitrification, and CNY 0.002 per kWh for PM removal.[9] In 2014, the actual subsidy in the form of green tariff amounted to over CNY 94 billion, and is estimated to have increased to CNY 113 billion in 2014, implying that more than 83 per cent of total generated power had been subsidized under the green tariff scheme.

  - **Payment mechanism:** For desulphurization tariff, the payment method is to allow the increase first and make adjustments later as per actual performance. But for denitrification and de-dusting tariffs, the electricity prices are passed through after the verification from EPB, and rebates are provided on a quarterly basis.

Grants at the provincial level in China have also been provided to enhance the penetration rate of the abatement equipment. These grants are usually at no cost, and sometimes part of them is in the form of interest subsidy

- **Special incentives for ultra-low emission plants:** NDRC, NEA and MEP have collectively proposed introduction of an ultra-low emission unit tariff subsidy policy. Accordingly, all ultra-low emission coal-based power plants connected with the grid before 1 January 2016 will avail an additional premium of CNY 0.01 per kWh. For the ultra-low emission plants connected with the grid after 1 January 2016, an additional premium of CNY 0.005 per kWh has been suggested. Premium payments will be paid directly on a per hour basis when ultra-low emissions standards are achieved.

- **Technical assistance for installation of pollution control equipment:** In 2005 and 2010, MEP released several technical guides for promoting deployment of de-dusting, desulphurization and denitrification equipment, covering all major technologies. These guidance documents have eased the process of equipment procurement and installation by providing detailed specifications on planning, design, review, procurement, construction and installation, commissioning, and inspection and operation management of the pollutants abatement equipment.

At the Central government level in China, MEP verifies pollutants emission performance of coal-based power plants on an annual basis, and issues penalty notices to non-performing plants

- **Preferential dispatch policies:** Chinese government has introduced a preferential dispatch mechanism to provide additional support to ensure compliance with emission norms. The state council had issued the *Dispatch Regulation of Energy-saving Electricity* (Interim) in 2007, under which dispatch regulation was introduced in selected provinces such as Jiangsu and Guangdong on a trial basis. In 2008, the final regulations were published with the following mechanism:

    - Priority in dispatch is first given to renewable power generation resources, and then to fossil fuel-based plants in the order of energy consumption and pollutant discharge level.

    - For coal-based units, the dispatch priority is in accordance with the coal consumption rate, i.e., for the same rate of coal consumption, units with lower emission levels are dispatched first.

    In addition, the NDRC and the NEA released the *Interim Measures for Alternative Management of Reduction of Coal Consumption in Key Areas* in 2014, stating that utilization hours will be increased for generating units achieving higher energy efficiency and environmental protection targets. Under this, CFPPs that reach the ultra-low emissions level will be entitled more utilization hours and, therefore, more on-grid electricity in the following year.

- **Financial disincentives for non-compliance to norms:** At the Central government level, MEP verifies pollutants emission performance of coal-based power plants on an annual basis, and issues penalty notices to non-performing plants. In 2014, such notices were issued to 46 power plants for not fulfilling emissions standards, unreliable CEMS data, or equipment malfunctions. The general mechanism related to imposition of penalties is as follows:

- In case of abnormal operation of the devices, abnormal use of CEMS, monitoring data fraud, and unsual pollutants discharge, local environmental protection departments impose fines in line with Article 46 of the 'Law on Air Pollution Prevention and Control' and Article 18 of the 'Measures for the Automatic Monitoring and Control of Pollution Sources'.

- The non-compliant plants have 30 working days (from the date of penalty announcement) to rectify performance, and report compliance with MEP, the regional environmental protection supervision Center and the provincial EPB. Failure to do so is subject to further punishment.

- Within 15 working days, the provincial EPB determines the amount of SO_2 and NO_x discharge fees to be paid by the non-compliant plant and publicly declares the amount of discharge fee surrendered.

- Within 30 working days, the provincial EPB asks the non-compliant plants to return the difference of environmental protection electricity prices.

Significantly, China's new Environmental Protection Law increased penalties for non-compliance with emission norms, which were initially so low that the cost of non-compliance was lower than that of compliance. The new law used provisions similar to the US environmental law, allowing penalties to accumulate each day after the polluter receives a compliance order. This helps in reducing delays in compliance, and in properly calculating the value of non-compliance.

China's new Environmental Protection Law increased penalties for non-compliance with emission norms, which were initially so low that the cost of non-compliance was lower than that of compliance

Finally, stricter punishments for government and administrative officials were proposed under the law, such as detention, potential criminal penalties, or removal from their posts.

- **CEMS data for imposing penalties:** Several provinces and municipalities including Liaoning, Shanxi and Chongqing have introduced relevant provisions for using CEMS data as an evidence for administrative penalty for the automatic monitoring of pollution sources. For instance, the *CEMS Data Applicable to Environmental Administrative Penalties Approach* (Interim) enacted by Liaoning's EPB, calls for imposing penalties ranging between CNY 3,000–100,000 depending on the number of continuous exceedance of CEMS data from the standard base point (hourly average CEMS data) within the assessment period of 15 days.

Incentives in India

Cost-plus increase in generation tariff: In India, tariffs are generally determined on a cost-plus basis. Therefore, any justified increases in capital and operational cost of a power plant is allowed as 'pass through' in tariff determination. Thus, power plants should not face any difficulty in duly recovering the investment and operational cost of newly installed pollution control devices. While the power industry estimates had initially indicated a high tariff impact of Rs 0.40-0.50 per kWh for implementation of pollution norms, more recent estimates from regulators and government indicate a substantially moderate impact of Rs 0.20-0.30 per kWh (as discussed earlier).

The government will need to support the sector by expediting tariff hikes. This can be achieved by benchmarking of costs by CERC with the help of CEA; together with the development of simplified application processes.

Recent estimates from regulators and government indicate a substantially moderate tariff impact of Rs 0.20-0.30 per kWh

Need for financial support: The installation of pollution control devices involves heavy investments. It is estimated that implementation of the new norms will require an aggregate investment of almost Rs 720 billion (US$ 11 billion) over the next three years. CSE's research has revealed that economic hurdles are acting as a key impediment in implementation of tighter standards. Unlike China, Indian power generators do not have easy access to cheap loans. Also, given the weak financial health of generators (especially the state-owned ones), tariff approval would need to be expedited.

CSE has recommended strongly that the government of India support these investments through soft loans. The government is still considering a proposal to use the coal cess of Rs 400 per tonne levied on all coal buyers to support the investment through soft loans or other financing mechanisms. More clarity on ways to recover cost and maximize tariff will also help the coal-based power generating companies, especially financially stable ones, to raise debt from banks.

Other suggested support measures: Plants that can take a leadership role in procurement and installation of pollutant equipment should be provided incentives like priority in dispatch. Indian regulators must introduce mechanisms like preferential tariffs linked with actual performance to ensure that installed pollutant control devices are actually utilized by power generation companies.

Other measures

Shutting old power plants: Both India and China are planning to retire a sizable number of their old and inefficient coal-based power generation plants, driven both by economic and environmental considerations.

- **Chinese government targets annual shutdown of 4 GW of old capacity and has cancelled several approved projects:** China's Thirteenth Five Year Plan targets annual closure of almost 4 GW of obsolete capacities. According to the *Notice on Improving the Orderly Development of Coal-fired Power*

Plants issued by NDRC and NEA, Chinese government is going to phase out obsolete CFPPs which have served a long life, and failed to meet the basic standards of energy efficiency, environmental protection and safety. Priority will be given to CFPPs below 300 MW that have been operating for over 20 years utilizing pure condensate and pumping condensate technologies.

Since 2015, Chinese Central government has been periodically cancelling approvals given for new coal-based projects by provincial authorities. In March 2016, the NEA issued an order suspending approval of new projects across 13 provinces till 2017, and delayed contribution of new projects in another 15 provinces. The order affected nearly 110 GW of proposed capacity. In October 2016, the Central government issued another order halting construction work at projects with a combined capacity of 17 GW.

Overall, under the ongoing Thirteenth Five Year Plan (2016–20), the government has decided not to approve any new coal-based plants during the first two years. By the end of the plan period (by 2020), the total coal-based capacity is expected to remain below 1,100 GW, ultra-low emission standards are targeted to be implemented across 420–580 GW of capacity; and retrofits are planned across 340 GW of capacity for efficiency upgradation.

Both India and China are planning to retire a sizable number of their old and inefficient coal-based power generation plants, driven both by economic and environmental considerations

- **Indian government has announced plans to retire 9.7 GW old capacity:** The Central government is planning to shutdown some of the old and inefficient power plants, while announcement of new projects has already slowed down over the past year, on account of existing surplus supply, sharp increase in renewable generation, and moderating growth of demand for electricity.

  The CEA, in its 2015 report on *Replacement of Old and Inefficient Units with Supercritical Units* identified power plants aggregating 32.8 GW of capacity that were more than 25 years of age and had outlived their useful life for replacement. Of these, the Central body identified only 5.9 GW of projects for retirement and replacement with supercritical units. Later, the CEA identified another 3.8 GW of coal-powered capacity based on operational performance. Essentially, the CEA has suggested that power plants aggregating over 22 GW can continue to operate.[10]

  In contrast, CSE has recommended that around 20 GW of power plant capacity should be retired over a short period of two to three years based on an analysis of their performance. Of these, 11.9 GW of capacity consists of water-inefficient OTC system-based plants. Additional 8.5 GW of plants were identified for shutting down based on a combination of criteria—high tariff (over Rs 4 Rs per kWh), low efficiency (less than 30 per cent), low plant load factor (less than 50 per cent), low availability (less than 75 per cent), and high PM emissions (over 200 mg/Nm^3).

Coal consumption controls: The *Air Pollution Prevention Action Plan* issued by China in 2013 but special emphasis on controlling coal consumption, targeting to reduce the share of coal in total energy consumption under 65 per cent by 2017.[11] The highly polluted regions of BTH, YRD and PRD are targeting to achieve negative growth in total coal consumption by gradually increasing dependence on power imports from other regions, and on natural gas- and renewable energy-based power generation.

While Indian government has not announced any caps on coal-based power generation capacity, its capacity growth momentum is expected to lose steam as very few coal-based power plants have been announced in the country in the past couple of years. This is primarily on account of the existing surplus generation capacity in the country, as well as due to the weakening financial health of the sector. The share of coal in aggregate installed capacity may also decline in response to the government's target of increasing the renewable generation capacity to 175 GW by 2022.

Cap and trade programmes for emissions: Pilots have been launched in China since the mid-1990s, which have expanded from city- to province-level; during 2007–14, provinces and municipalities issued regulations and policy documents stipulating the validation of emission rights, pricing design, initial allocation approach, trading rules and transaction management requirements, etc.

So far, emissions trading is being carried out in 16 pilot provinces and municipalities, mainly for SO_2 emissions, while NO_x emissions trading is limited to Hebei, Henan and Fujian provinces. As per the latest available data, by the end of 2013, the total emissions trading transactions in the pilot provinces amounted to CNY 4 billion (IDR 7.7 trillion). In Shanxi itself, total amount of SO_2 trading during the years was CNY 62 million (IDR 119 billion), and NO_x was CNY 130 million (IDR 251 billion).

The government is planning to expand the scope of emissions trading platforms. In August 2014, State Council released a paper on the *Guidance on Further Piloting the Pollutant Discharge Permit and Trading of Emission Permits*, for further promotion of air pollutants emissions trading.

In 2016, MEP released the *Circular on Printing and Distributing the Interim Provisions on the Administration of Pollutant Discharge Permits* aiming to provide details of the operation of a new discharge permit system, focusing on high polluting sectors like power and paper. However, the pace of implementation of these measures has been slow.

PART 3 Where does Indonesia go from here?

Indonesia must adopt a balanced approach in deciding new emission standards, in a way that maximizes benefits in terms of aggregate reduction in the pollution load, while being economically feasible. In this, Indonesia has the opportunity to learn from the experience with emission control of other emerging economies like India and China. A comprehensive study of the two countries indicates that there are three crucial factors in deciding emissions norms—age, size, and the geographical concentration of the capacity.

While the technology available globally can cut pollutant emissions to any desired level, age and size of the units determine technical feasibility of meeting norms and economic viability of investments in pollution control devices. Tightest norms are suggested for larger-sized and newer units, while the norms for some of the small and old units need not change by much. Geographical concentration drives the need for tighter standards as areas with clusters of coal-plants suffer from higher pollution load.

6. Recommendations

The experience of India and China with respect to deciding and implementing new emission standards suggests that a number of factors need to be considered. The age and size profile of power generation units is a crucial factor, as it determines technical achievability of emission cuts and economic feasibility of investment. Indonesia must also draw lessons from the standards set in developed countries, as China and India have done. Further, the Indonesian government could consider adoption of regional emission norms for areas with high concentration of coal-based capacity or high air pollution, something that China has done. The idea of regional standards is being discussed in policy circles in India also.

CSE and ICEL have prepared a preliminary set of recommendations for Indonesian stakeholders to consider. These suggestions are meant to be used as a starting point for discussion and are based on:

a) Analysis of Indonesian coal-based power fleet including age, size, technology and the capacity growth plans. This was supplemented by a study of plant-wise emissions and pollution control technology in a sizable share of Indonesia's power capacity.

b) CSE's experience in conducting a comprehensive study of Indian power sector and assisting Indian regulators in drafting the new norms—given the similarity between the power sector of the two countries, CSE believes, the Indian study may be useful for Indonesian stakeholders.

c) Detailed study of China's experience, which was conducted by a Chinese think-tank Rock Environment and Energy Institute. The study provided further rationale for the various norms recommended below. In fact, the Chinese study also helped Indian stakeholders in building support for the new norms, by demonstrating that they are needed and achievable (from the perspective of technology and timing).

There are a number of factors and methodologies that Indonesia must consider while defining its new emission norms. These methodologies are not mutually exclusive, but should be considered in combination.

- **Distinction based on the vintage of power plants:**
    - **Most stringent norms for upcoming power plants:** 34.8 GW of new coal-based capacity is expected to come up in Indonesia by 2025. Nearly 60 per cent of this capacity comprises large units of 600 MW and above size. Such units can easily meet global pollutant standards given that there are no techno-economic limitations. As such, it is feasible for these units to meet a standard of 30 mg per Nm^3 for PM, 100 mg per Nm^3 for SO_2, and 100 mg per Nm^3 for NO_x emissions.

Table 17: Suggested standards based on the age distribution of Indonesia's coal-based capacity

Tightest emission standards should be imposed on newer units, given the techno-economic considerations

Year of commissioning	Aggregate capacity (MW)	Suggested standards (mg/Nm^3)		
		PM	SO_2	NO_X
Pre-1990	1,730	150	750	850
1990–2005 *	6,284	50–100	300–600	300–600
2006 onwards *	16,238	50	200–300	200–300
Total existing	24,764	-	-	-
Upcoming capacity	34,800	30	100	100

*Range based on size with smaller units having looser norms
**Age data not available for capacity totalling 512 MW
Source: CSE, 2017

- **Grant of wavier for plants over 25 years of age:** Units installed prior to 1990 aggregate to a very small capacity of 1.7 GW. The government may consider continuing with the existing standards for these units. Heavy investments needed in pollution control equipment (especially for SO_2 and NO_x control) may not be feasible for such units given that they are nearing the end of their designed life. However, their utilization should be minimized with dispatch priority given to cleaner, newer plants.

- **Gradual shutdown of old inefficient plants:** Such units may be considered for a gradual shutdown and replacement over the coming years based on a detailed economic–technical performance analysis. This could include consideration of a number of parameters including cost of generation, efficiency, load factor, capacity factor, plant availability and emissions levels.

- **Standards for other existing plants (installed since 1990):**

  - **Strict standards for PM emissions:** Stringent PM emission standards of 50-100 mg per Nm^3 can be prescribed for all existing power plants, given that these were already required to meet a standard of 100-150 per Nm^3. Upgrading existing ESP systems to achieve lower emission levels is neither technically challenging nor time consuming.

  - **Moderate to strict standards for SO_2 and NO_x control:** For SO_2 and NO_x, a distinction can be made between units commissioned prior to and post-2006. It was a landmark year because it marks the launch of FTP-I and, thus, the start of governments concerted efforts towards promoting coal-based generation. Plants commissioned since 2006 comprise mainly larger units (with better technology) and account for 66 per cent of the total existing capacity. These have higher techno-economic viability of investments in emissions control.

SO_2 and NO_x emission standards can be kept at a moderate level for plants commissioned between 1990 and 2006 (about 6.3 GW of capacity) given the limited technical and investment ability of existing power plants. This could be 300–600 mg per Nm^3 for SO_2 and NO_x control.

However, for plants commissioned after 2006 (about 16.2 GW of capacity), standards must be maintained at high levels. The standards for this category could range from 200–300 mg per Nm^3 for NO_x and SO_2 control.

- o For mercury control, understanding the mercury component in coal is important. Indonesia can adopt a standard of 0.03 mg per Nm^3 for mercury control for all generation units (old and new), similar to India and China (which in turn was based on studies conducted in the US and Germany).

- **Distinction based on size of existing power plants:**

  - o **Retain old norms for very small units:** Very small units of less than 100 MW capacity aggregate to a very small capacity of 2.6 GW. Existing standards for PM, SO_2 and NO_x can be retained for these units as their aggregate pollution load is small and the techno-economic feasibility for investments in pollution control devices is low. However, their utilization (i.e. capacity factor) should be kept at the minimum possible.

  - o **Moderate norms for small-sized units:** For small sized units ranging from 100 to 300 MW (adding to only 3.5 GW of capacity), the new recommended norms can be maintained at moderate levels (especially for SO_2 and NO_x ranging from 300-600 mg per Nm^3). This is also due to the small aggregate pollution load of these units and the low techno-economic feasibility.

  - o **Strict norms for larger sized units:** Large-sized units of over 300 MW add to a significant capacity of 18.5 GW. There should not be techno-economic restrictions of these units investing in pollution control

Table 18: Suggested standards based on the size distribution of Indonesia's coal-based capacity

Tightest emission standards should be imposed on large units, given the techno-economic considerations

Unit size	Aggregate capacity (MW)	Suggested standards (mg/Nm^3)		
		PM	SO_2	NO_x
0–99 MW	2,561	150	750	850
100–299 MW *	3,544	50–100	300–600	300–600
300–599 MW *	8,195	50	200–300	200–300
Over 600 MW	10,464	50	200	200
Total	24,764	-	-	-

*Range based on age with older units having looser norms
Source: CSE, 2017

Table 19: Profile of existing and upcoming coal-based power plants in Banten

Majority of the provincial capacity comprises large units installed since 2006

Unit size	Existing capacity				Upcoming capacity
	Pre 1990	1990-2006	2006 onwards	Total	
300-599 MW	1,600	-	1,545	3,145	315
Over 600 MW	-	1,800	625	2,425	5,225
Total	1,600	1,800	2,170	5,570	5,540

In MW
Source: Analysis based on MEMR dataset

devices. The benefit in terms of pollution control per unit of investment in also highest in case of larger-sized units. As such, these units can be required to meet tight standards of 50 mg per Nm^3 for PM, 200–300 mg per Nm^3 for SO_2 and NO_x.

- **Distinction based on location:**
  - Stringent standards must be prescribed for regions with high concentration of coal-based power plants. At present, the island of Java has the highest installed generation capacity of 18.9 GW among all regions, which is expected to increase to 37.4 GW by the end of 2025. Notification of tighter standards for the provinces in the island will lead to a significant aggregate impact, given that it will affect nearly 65 per cent of the capacity installed in Indonesia. Further, implementation of tighter standards is feasible in the region as almost the entire existing and upcoming capacity comprises larger-sized units (of over 300 MW).
  - Given the existing and upcoming coal-based projects, the provinces of Banten and Central Java will each account for over 11 GW capacity (one-fifth of the total) by 2025. Prescribing stringent norms for these two provinces could significantly reduce the air pollution impact from high concentration of power plants.
  - The case for notifying stricter standards for Banten is further strengthened on the grounds that most of the existing and upcoming plants in the state are located in the north-eastern area, close to the national capital region of Jakarta.
  - **Regional standards based on ambient air quality:** Varied standards can also be prescribed for power plants located within a region or province or locality, if the ambient air quality fails to meet pre-determined standards. With growing industrialization and urbanization, air pollution has been increasing in a number of Indonesia cities and localities on account of increased pollution from stationary and non-stationary sources. Identification of these regions would require the government to collect and analyze data on regional ambient air quality.

7. The way forward

Indonesia is clearly set on expanding its coal-based power generation capacity over the coming years, driven by energy security concerns. Given the country's expansion plan, with the existing norms in place, emissions inventory of PM, SO_2 and NO_x from coal-based power plants in Indonesia will increase two- to three-times, which would be detrimental to the country's air quality. Global experience clearly establishes that implementation and enforcement of stringent norms can be pivotal in controlling the emission of pollutants.

Thus, Indonesia cannot afford to delay notification of new stringent emission norms for coal-based power plants any further, in order to bring it at par with the levels achieved by other Asian giants like India and China. The MoEF has rightfully included revision of emission norms in their annual work plan. The process of emissions revisions must be expedited and technical consultations must be initiated at the earliest in order achieve the target over the coming few months. Meanwhile, in addition to the notification of norms, the government must also be mindful of the following:

Develop baseline data: In order to arrive at appropriate emission standards, it is imperative that the government immediately take steps to develop clear baseline data on the following:

- Data on the actual pollution performance of the all existing power plants
- Detailed mapping of power plants in terms of boiler technology, fuel quality and operational performance
- Detailed technical data on the pollution control equipment currently installed at the power plants
- Detailed information on the space availability in the existing power plants for installation of pollution control devices (especially FGD)

Technical support for implementation: The government must release technical guides or specifications for installation of pollution control equipment. This can help save time in debates about technology availability and suitability (as happened in India's case). Further, it is crucial that the government undertakes broad cost analysis of installing these technologies in Indonesian power plants to provide a benchmark reference. These guides would help in ensuring that equipment quality is maintained and help tariff regulators in assessing technology choices and investment costs.

CEMS—strengthen monitoring and reporting: A strong emissions data reporting and monitoring systems forms the backbone of effective compliance and enforcement of norms. At present, the MoEF is not tracking the emissions performance of all plants. While CEMS has been implemented across all power plants, the data generated seems to have some flaws. There is no reliable information on how many of the CEMS are actually connected to the LEBs or MoEF networks.

Under a tighter emission standard, the role of regency or city level LEBs for supervising compliance to emission standards will also increase. The government must put in checks and balances in place to discourage data manipulation.

Establish tight timelines: There are several compelling reasons to ensure the timelines are tight. First, the country is planning a rapid growth in coal-based power capacity—it is most efficient to ensure pollution control technologies are installed at the inception stage itself of the rapidly growing capacity. Second, tight timelines will ensure that pressure is maintained on the industry. Third, rising pollution problems require urgent action.

In this respect, Indonesia can learn from the experiences of other countries. South Africa had given the sector five years to comply—at the end of the five-year period, the industry asked for five more years. Both China and India have chosen to insist on ambitious timelines. Short timelines ensure various stakeholders monitor progress closely, which is very important in emerging economies where regulatory oversight is weak.

Establish robust processes to monitor implementation: It is crucial for the regulators to closely monitor the progress achieved by the power plants in procuring and installing pollution control devices to ensure that the timelines are met. Beyond monitoring, a national level dialogue at an early stages with all stakeholders involved will also help to identify any issues and propose policy solutions. For instance, the Indian government is now taking steps to establish procedures to monitor installation of new equipment, after the power plants reported little progress in over a year.

Financial support for implementation: Implementation of emission norms often becomes challenging for power plants due to financial hurdles. This can be addressed by the government by developing appropriate financial models that ensure easy access to cheap loans and guarantee effective return on investment, such as:

- Ensuring availability of soft loans for power plants to install or upgrade pollution control equipment
- Availability of subsidies for investments in pollution control devices, to help offset installation cost
- Effective inclusion of the cost of equipment investment and operation in the generation and retail tariff

Incentives for effective enforcement: Over the longer term, the government must also introduce incentive mechanisms to ensure that the power plant operators maintain high operational efficiency of pollution control devices (a key lesson from China). This can be achieved through:

- Introduction of green tariffs based on the performance of desulphurization, denitrification and de-dusting equipment, after thorough verification of the performance by the LEBs

- Introduction of special incentives such as premium payments for power plants that achieve a much lower emissions, against the levels required by the standards

- Development of preferential dispatch policies to give dispatch priority to clean energy source such as renewable energy and low emissions-coal based power

Disincentives for non-compliance with norms: Implementation of stringent norms must necessarily be backed by an effective and strong penalty mechanism. In order to be effective, the cost of non-compliance (scale of penalties imposed) must be higher than the cost of compliance with the norms. These penalties must be allowed to accumulate till the generation units start reporting compliance, in order to make the system more stringent (as is the case with China and US). The system can be made more efficient by providing legal sanctity to the use of CEMS-generated data for imposition of these penalties.

Building public support: There is a growing awareness among people, especially the ones living in urban areas, regarding the harmful effects of air pollution. Already, the country's media has been providing wide coverage to such issues. However, there is a need to sensitize people further about the impact of emissions on air quality and health and the outsized role of coal-based power. This would help build support for government's intervention in the area. It is also crucial to address public apprehensions about the cost of pollution control with data showing it will be manageable. Also, the government needs to explain that the long term costs on health and livelihood far outweigh the cost of pollution control, and are borne by the poorest people.

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Appendices

Appendix 1: Technology options

Technologies to control particulate matter (PM), sulphur dioxide and nitrogen oxides emissions are mature, and have been widely used for the past two-three decades. They are being used across the world for a range of coal quality and operating conditions. Many large-scale manufacturers, including GE-Alstom, Mitsubishi, Andritz, Black & Veatch, Doosan etc., are supplying the technologies required to meet stringent emission norms.

1. Particulate matter

Power plants generate dust of about 10 microns size on burning pulverized coal. Most power plants have deployed some technology to control PM emission. Electrostatic precipitator (ESP) is the most popular device and technology globally, while a number of power plants also utilize bag filters and house and fabric filters.

Electrostatic precipitator

The performance of an ESP depends on several factors—the specific collection area, the duration and volume of the flue gas that comes in contact with the electrode, the voltage used to create electric fields, the way electric current is passed, the resistivity shown by the ash particles to get charged, and the way the collected ash is dislodged.

While ESPs were designed to operate with an efficiency of 99.9 per cent to limit PM levels, the emissions often tend to be higher due to poor maintenance. Inefficiency of removal systems and discharge electrodes are two major issues in maintenance. Preliminary assessment of existing ESPs should, therefore, consist of a review of their performance deviation from design and assessing issues related to the voltage in electrodes.

Options for upgrading ESP

ESP performance can be enhanced by process, mechanical, electrical or control changes in the device. The relevant technique is selected depending on the reduction required in dust concentrations. For example, if dust concentrations have to be sharply reduced, say from 500 to 50 or 30 mg/ Nm^3, then mechanical changes are made; for lesser reduction, say from 75 to 50 mg/ Nm^3, process changes may be sufficient, in certain cases combination of the techniques are used depending on the condition of the device.

Refurbishment solutions

For ESPs that were designed for higher emission levels and require upgradation, various techniques can be considered, on a case-to-case basis, depending on space and technical parameters. Increase in specific collection area has been tried in several retrofit installations and has led to dramatic increase in collection efficiency. Any of the following can be done to increase the specific collection area of an ESP:

- **Adding fields in series to an existing ESP:** Research indicates that collection efficiency of ESP can be improved from 99.2 to 99.8 per cent, by doubling the size of the installed ESP. This solution is recommended when sufficient space exists.

- **Placing additional ESPs parallel to an existing ESP:** When adding fields in series is not feasible due to space constraints, addition of ESPs in parallel is recommended. Parallel ESPs have multiple inlets in contrast to series ESPs, hence they require redesign of flue gas flow and dust redistribution calculations. Multiple inlets for parallel ESPs would lead to excess pressure drops and higher electricity consumption.

- **Adding new internals by increasing the casing height:** This is a suitable method when neither parallel nor series addition is possible, and improving collection efficiency by increasing the specific collection area is a necessity. Wider spacing is created between electrodes when increasing the height so that civil foundation load does not increase; to compensate for the wider spacing, higher frequency transformer-rectifier sets are used.

- **Replacing old ESPs with new ones:** This is suggested when significant improvement is required in collection efficiency and the performance of old ESPs is seriously degraded.

- **Filling the dummy fields of ESPs:** This option may be available for only a few units, it involves filling electrodes in a compartment that was left empty during early phases of the construction for later augmentation.

Solutions for minor improvements

The following are some other advanced solutions suggested for minor reduction of emissions. These techniques are suitable mostly for low resistive dust and coarse ash particle.

- **Optimizing power supply:** Switch mode power supply units are suggested to lower ripple voltage delivered to ESPs which can lower its performance.

- **Introducing more bus bars and transformer rectifier sets:** Corona power is increased by introducing new bus bars and improving voltage of the ESPs. This method is suitable for low resistivity and coarse particle ash.

- **Conditioning flue gas (FGC):** Ammonia, sulphur trioxide and sodium can be used as reagents for conditioning flue gases by constructing a simple mechanical system. However, this may result in contaminated ash generation. Improper maintenance of the system can lead to corrosion and clogging.

ESP specifications of coal power station in India

Inlet dust concentration	40–100 g/ Nm^3
Specific collection area	130–250 m^2/ (m^3/ s)
Operational voltage	30–95 kV
Resistivity of dust	10-11–10-15 ohm/ cm
No. of ESP electrodes	24–32
No. of fields	3–5
Mode of energy	Semi-pulse, intermittent or multi-pulse mode
Designed collection efficiency	More than 99.5 per cent

Source: Centre for Science and Environment, 2016

Options for upgrading ESP

CONTROLS
- Improved diagnostics of operating behavior and faults
- Micro-processor based intermittent charging controllers

PROCESS
- Flue gas conditioning

ELECTRICAL
- Increased rating of TR sets
- Increased high-tension sectionalisation

MECHANICAL
- Augumenting collection area
- Electrode strength & alignment

- Introducing a bag filter in an existing ESP's casings, changing electrodes etc.

Bag filters
Bag filters and houses or fabric filters are an alternate technology to control PM emissions. About 35 per cent of coal-based power plants in the US and about 10 per cent of plants in China have installed bag filters or their hybrids (i.e. in combination with an ESP). These are generally recommended for flue gas volumes in the range of 0.1–0.5 million Nm^3/ h, which is the flow rate in units smaller than 150 MW. Efficiency of bag filters may be up to 99 per cent, but it could drop to 90 per cent if even one of the thousands of bags in the filter gets damaged. Though bag filters occupy less space they consume more auxiliary energy for operation than ESPs.

Technology comparison between wet and dry FGD

Parameter	Wet FGD	Dry FGD
Commercially available range	~ 1,100 MW	300–400 MW single absorber For novel integrated desulphurization (NID) each module of 75 MW_e
Types	1) Seawater 2) Freshwater	1) Spray dry absorber (SDA) 2) Circulating dry absorber 3) NID.
SO_2 removal efficiency	Upto 99 per cent	Upto 99 per cent (90–95 per cent for SDA)
Capital cost	Freshwater FGD: x (~50 lakhs/MW) Seawater FGD: 0.8x	0.7 x
Sorbent	Freshwater FGD: $CaCO_3$ Seawater FGD: No sorbent	CaO/ $Ca(OH)_2$
Sorbent use	Approximately 1.5–2 tonne limestone consumed per tonne SO_2 removal	Approximately 0.75–1.5 tonne lime consumed per tonne SO_2 removal
Sorbent cost (Rs/tonne)	~ 2000	~ 6000
Water consumption in m^3/MWh	1.0 with gas-to-gas heat exchangers(GGH) 1.4 without GGH	0.7
Auxiliary power consumption	Freshwater FGD: 0.7 per cent Seawater FGD: 0.7–1.5 per cent	1–2 per cent
Condition of existing stack	Existing stacks to be modified in all cases	Existing stacks can be used without modification
FGD by-product	Freshwater FGD: gypsum Seawater FGD: No by-product	$CaSO_3$/$CaSO_4$: Has to be landfilled
Wastewater	Generates	Doesn't generate
Erection period	Upto 50 MW~ 12–14 months 50-200 MW~ 14–18 months 200-500 MW~ 18–24 months > 500 MW ~ 24–30 months	Up to 50 MW~ 12–14 months 50–200 MW~ 14–18 months
Downtime	Up to 50 MW ~ 2–3 weeks 50-200 MW ~ 3–4 weeks 200 MW and above ~ 4–6 weeks	4-6 months (due to renovation/modification in existing PM control equipment such as bag filter/ESP)

*Assuming sulphur content 0.5 percent in coal and stochiometric consumption of sorbents
Source: NTPC Limited

2. Sulphur dioxide

SO_2 emissions can be controlled—before combustion by lowering sulphur content in the fuel; during combustion by injecting sorbents such as limestone; after combustion, by treating flue gas with sorbents in flue gas desulphurization (FGD) devices or in ducts. Sorbent injection during combustion, though successful in smaller plants, has not been established for utility or larger plants. That makes FGD the most widely-used technology because of its high capture rate. The technology is mature—it has been used for several decades in a variety of operating conditions and for coals of different compositions

FGD technology

An FGD device is a chemical vessel which captures SO_2 in flue gas. SO_2 is made to react with an alkali, usually limestone, owing to its cheap and wide availability, to precipitate the pollutant as salt (gypsum). It is a well established technology, with over 40 per cent of worldwide coal capacity estimated to have installed FGD.

FGD technologies can be classified as once-through and regenerable, depending on how sorbent is treated after it has absorbed SO_2. So far, regenerable processes are being used only marginally because of high costs. Major FGD systems are limestone-based wet, dry and seawater FGD units. Estimates indicate that over 90 per cent of the worldwide FGD systems are wet.

Space requirement: An FGD system has several components—limestone handling, duct area, scrubber and dewatering systems. The space requirement depends on common systems in case multiple units coexist in one place (e.g. 4 x 150 MW or 5 x 800 MW). In such plants, limestone handling and dewatering systems can be common for multiple units. Usually two–eight acres space is required for wet FGD units, which can be in fragments. Different sub-components can be situated in non-contiguous areas.

Timelines: The construction of an FGD unit involves both civil and mechanical work— installation of scrubbers, gas re-heaters, ducting and chimney lining, or the construction of a new chimney. Typically, construction requires about 18 months for a 500 MW unit. The shutdown time to hook up a wet FGD system to the unit takes upto one month, depending on the chimney construction.

3. Oxides of nitrogen

Nitrogen in fuel and air used for combustion reacts with oxygen in the combustion chamber at high temperatures to form oxides of nitrogen. Formation of oxides of nitrogen can be controlled by using low-NO_x burners or staged air combustions, over-fire air, secondary over-fire air supply, or through flue gas treatment after combustion

Burner modification

Low-NO_x burners are boilers having extra ports to supply air and fuel compared to conventional burners. By altering the air–fuel mix, temperatures at different locations in a boiler are kept below a certain level so reaction between nitrogen and oxygen is minimized and relatively lower quantity of NO_x is formed. These technologies are the basic and most cost-effective control mechanisms. The process has a relatively low capture efficiency of around 50 per cent, which means NO_x emissions can be cut down to around 400mg/ Nm^3.

Alternate ports for air, called over-fire air (OFA) ports and fuel ports, are provided in the boiler. They require about a metre of space over the burners in the furnace and appropriate space around the boiler and duct. From design survey to installation, this could take four-five months.

Technology comparison of NO_x control technologies

Available technology	In combustion	Post combustion	
	Combustion modification	Selective non-catalytic reduction (SNCR)	Selective catalytic reduction (SCR)
Variants and measures to control NO_x	• Low-NO_x burner, • Wind box modification • Various type of "over fire air" (OFA) processes	Reagent: Anhydrous/Aqueous ammonia or urea	Catalyst type: Plate/honey comb Reagent: Anhydrous/Aqueous ammonia or Urea
Installation Cost	0.1-0.15 Cr/MW	0.04 Cr/MW*-0.15 Cr/MW	0.2 Cr/MW** 0.15 Cr/MW*** (Hybrid)
Reagent quantity	None	For every ton NO removal 1.1 tonne ammonia# is required or 2 tonne of urea	For every ton NO removal 1.1 tonne ammonia## is required or 2 tons of urea
Operational Cost	None	INR 21,000 / tonne (imported technical grade urea)	Rs 2.5-2.7 lac/MW (catalyst replacement—once in three years)
Process of NO_x reduction	Staging of combustion air	Using Ammonia Nitric oxide reacts with ammonia and oxygen to form nitrogen and water. Using Urea Nitric oxide reacts with urea and oxygen to form nitrogen, water and carbon di oxide.	Nitric oxide/nitrogen dioxide reacts with ammonia and oxygen to form nitrogen and water.
Ammonia slip (excess ammonia from the nozzle which can potentially react with sulphur in the flue gas and form ammonium bisulphite increasing corrosion of the pre-heater)		Less than 2.5 ppm (possible to limit less than 0.5 ppm)	
SO_2 to SO_3 conversion		Less than 1 percent	
Maldistribution or improper mixing		Less than 5 percent	

*If base NO_x level less than 400 and target 300 mg/Nm3
**If base NO_x level less than 500 and target 300 mg/Nm3
***If base NO_x level less than 450 and target 300 mg/Nm3
#1 mol of nitric oxide reacts with 1 mol of ammonia and ¼ mol of oxygen to produce 1 mol of nitrogen and 3/2 mol of water. molar mass of nitric oxide = 20 and ammonia = 17; nitric oxide: ammonia = 20:17; considering wastage 30% nitric oxide: ammonia requirements = 1:1.1
##1 mol of nitric oxide reacts with 1 mol of ammonia and ¼ mol of oxygen to produce 1 mol of nitrogen and 3/2 mol of water. molar mass of nitric oxide = 20 and ammonia = 17; nitric oxide: ammonia = 20:17; considering wastage 30% nitric oxide: ammonia requirements = 1:1.1
Source: NTPC Limited and CSE survey of manufacturers

Flue gas treatment

To reduce NO_x levels to 100 mg/ Nm^3 post-combustion, NO_x control technologies—selective catalytic reduction (SCR) technology or selective non-catalytic reduction (SNCR) technology—need to be employed. These control technologies split the nitrogen oxide molecules in the flue gas into nitrogen and oxygen with the help of a catalyst or reducing agent.

Selective non-catalytic reduction (SNCR) reduces NO_x by reacting urea or ammonia with NO_x at temperatures of around 900–1,100 °C. Urea or ammonia is injected into the furnace in the post combustion zone to reduce NO_x to nitrogen and water.

Selective catalytic reduction (SCR) utilizes ammonia as a reagent that reacts with NO_x on the surface of a catalyst. The SCR catalyst reactor is installed at a point where the temperature is about 300–390 °C, normally placing it after the economizer and before the air pre-heater of the boiler. The SCR catalyst must be replaced periodically. Typically, companies will replace a layer of catalyst every two to three years. Multiple layers of catalysts are used to increase the reaction surface and control efficiency.

Installation of a 500 MW SNCR system usually requires about four months.

4. Mercury

Some degree of co-benefit in mercury control can be achieved with air pollution control devices installed for removing NO_x, SO_2 and particulate matter from coal-fired power plants' combustion flue gases. However, the capture of mercury across these devices can vary significantly based on coal and flyash properties (including unburned carbon), and configuration of the device etc., with the level of control ranging from zero to more than 90 per cent. In addition, the following technologies are available to limit mercury emissions:

Bromide salt addition or halogen addition: The least expensive technology for controlling mercury is bromine salt additives. However, these require a scrubber. Halogen (bromine) addition to flue gas increases oxidized mercury that is easier to capture in a downstream scrubber or in a PM control device.

Activated carbon injection: Particles of activated carbon are injected into the exit gas flow, downstream of the boiler. The mercury attaches to the carbon particles and is removed in a traditional particle control device.

Appendix 2: Data set

Indonesian National Ambient Air Quality Standards

Parameter	Period of measurement	Quality standards
SO_2 (Sulphur dioxide)	1 hour, 24 hours, 1 Year	900 ug/Nm^3, 365 ug/Nm^3, 60 ug/Nm^3
CO (Carbon monoxide)	1 hour, 24 hours, 1 Year	30,000 ug/Nm^3, 10,000 ug/Nm^3
NO_2 (Nitrogen dioxide)	1 hour, 24 hours, 1 Year	400 ug/Nm^3, 150 ug/Nm^3, 100 ug/Nm^3
O_3 (Oxidants)	1 hour, 1 Year	235 ug/Nm^3, 50 ug / Nm^3
HC (Hydrocarbon)	3 hours	160 ug/Nm^3
PM_{10} (Particles < 10 um)	24 hours	150 ug/Nm^3
$PM_{2.5}$	24 hours, 1 hour	65 ug/Nm^3, 15 ug/Nm^3
Pb (Lead black)	24 hours, 1 hour	2 ug/Nm^3, 1 ug/Nm^3
Dustfall (Dust falling)	30 days	10 $tonne/km^2$/Month (Settlement), 20 $tonne/km^2$/month (industry)
Total fluorides (as F)	24 hours, 90 Days	3 ug/Nm^3, 0.5 ug/Nm^3
Fluor index	30 days	40 ug/100 cm^2 of filter paper limed
Chlorine and chlorine dioxide	24 hours	150 ug/Nm^3
Sulphate Index	30 days	1 mg SO_3/100 cm^3 of lead peroxide

Source: Government Regulation om Air Pollution Control, 1999

Age-size matrix of Indonesia's coal-based generation fleet (MW)

	0-99 MW	100-299 MW	300-599 MW	Over 600 MW	Total
Pre-1990	130	-	1,600	-	1,730
1990–2005	1,034	200	800	4,250	6,284
2006–15	885	3,344	5,795	6,214	16,238
NA	512	-	-	-	512
Total existing capacity	2,561	3,544	8,195	10,464	24,764
Upcoming capacity	2,967	7,255	2,765	19,179	32,166
Grand total	5,528	10,799	10,960	29,643	56,930

Note: Number of existing units will be slightly higher than 142 given that unit-wise information was not available for 7 plants. The analysis for upcoming capacity is based on 32.2 GW of steam-based capacity for which unit-wise data was available.
Source: Analysis based on MEMR data

Region-size matrix of existing coal-based generation fleet in Indonesia

Region	0–99 MW	100–299 MW	300–599 MW	600 MW and above	Total
Java	315	-	8,195	10,464	18,974
– East Java	140	-	1,780	3,925	5,845
– Banten	175	-	3,145	2,425	5,745
– Central Java	-	-	1,230	3,454	4,684
– West Java	-	-	2,040	660	2,700
Bali	-	380	-	-	380
Sumatra	880	2,914	-	-	3,794
Eastern Indonesia	1,366	250	-	-	1,616
Total	2,561	3,544	8,195	10,464	24,764

All numbers in MW
Source: Analysis based on MEMR data

Region-size matrix of upcoming coal-based generation fleet in Indonesia

	0–99 MW	100–299 MW	300–599 MW	600 MW and above	Total
Java	-	400	665	17,379	18,444
– Banten	-	-	315	5,225	5,540
– West Java	-	-	-	5,320	5,320
– Central Java	-	-	-	6,834	6,834
– East Java	-	400	350	-	750
Bali	-	-	-	-	-
Sumatera	85	2,885	2,100	1,800	6,870
Eastern Indonesia	2,882	3,970	-	-	6,852
Total	2,967	7,255	2,765	19,179	32,166

Note: Based on 32.2 GW of steam-based capacity for which unit-wise data was available.
All numbers in MW
Source: Analysis based on MEMR data

Maximum pollutant emission reported by coal-based power plants in Indonesia (mg/m^3)

Plant	Unit number	Unit size	Year	PM	SO_2	NO_x
Plant A	1	400	1985	111.9	716.7	448.7
	2	400	1986	135.8	678.7	563.7
	3	400	1989	103.0	416.8	466.4
	4	400	1989	121.8	687.0	812.4
	5	600	1997	123.6	673.6	481.8
	6	600	1997	130.7	564.1	418.5
	7	600	1998	107.9	637.2	486.0
Plant B	1	400	1994	90.2	617.5	104.5
	2	400	1995	111.3	576.5	114.8
Plant C	1	710	2006	5.1	523.0	456.0
	2	710	2006	6.1	467.0	486.0
	3	710	2012	58.2	131.4	280.5
	4	710	2012	56.6	97.3	443.2
Plant D	1	300	2006	149.1 149.1	229.0 229.0	473.6 473.6
	2	300	2006			
Plant E	1	660	2012	63.7	715.7	191.4
Plant F	1	625	2011	134.3	578.3	559.1
Plant G	1	315	2011	56.7	654.3	377.5
	2	315	2011	64.6	649.7	262.0
Plant H	1	350	2013	94.1	445.2	164.3
	2	350	2014	97.8	502.2	213.5
	3	350	2014	96.2	412.8	149.3
Plant I	1	815	2012	37.2	22.4	215.6
Plant J	1	660	2012	17.6	177.3	229.1

Source: MoEF

Major policies related to air pollution and air quality in China

Year	Policies Related to Air Pollution
1982	Set the limits for TSP, SO_2, NO_2, lead and BaP
1987	*Law on Air Pollution Prevention and Control*
1989	*Environmental Protection Law*
1991	*Emission Standard of Air Pollutants for Thermal Power Plants*
1995	*Law on Air Pollution Prevention and Control'* (First Amendment)
1996	*Emission Standards of Air Pollutants for Thermal Power Plants* (First Amendment)
2000	*Law on Air Pollution Prevention and Control'* (Second Amendment)
2003	*Emission Standard of Air Pollutants for Thermal Power Plants* (Second Amendment)
2006-2010	• *11th Five Year Plan'* (with emphasis on coal power plant efficiency) • *Emission Standards of Air Pollutants for Thermal Power Plants* (Third Amendment)
2012	• AQI (Air Quality Index) to include PM and Ozone in replacing API (Air Pollution Index) • First $PM_{2.5}$ limitations set forward under the *National Ambient Air Quality Standards* (NAAQS) ○ Standards took effect at different rates throughout the country ○ 2012: Beijing-Tianjin-Hebei, Yangtze River Delta, Pearl River Delta, provincial capitals ○ 2014: key environmental protection cities ○ 2015: prefecture-level cities ○ 2016: nationwide implementation • Five Year Plan includes clean energy and sustainable growth plans • 'Airpocalypse' happened in December in Beijing
2013	• Start to publish monitoring results of $PM_{2.5}$ across 74 cities • At the State Council Executive Meeting, Premier Li Keqiang establishes 10 major air pollution measures, namely the 'Air Pollution Prevention Action Plan', mandating 15-25% $PM_{2.5}$ reductions in key cities and 10% PM_{10} reductions in all other cities by 2017 per a 2012 baseline
2014	• Coal Mining Capacity Retirement • Coal Fired Power Generation Action Plan (emissions standards for new coal fired plants) • *Law on Air Pollution Prevention and Control* (Third Amendment), cancellation of all coal subsidies • US-China joint announcement to peak CO_2 emissions • *Interim Measures For The Administration Of Coal Consumption Reduction In Key Regions* established hard coal caps in Key Regions
2015	• New *'Environmental Protection Law* put into effect (amended in April 2014) • *Industrial Clean Coal Utilization Action Plan* as the roadmap for emissions and efficiency standards for heavy industry coal use • *Clean Coal Utilization Plan* combined all smaller coal oriented policies from the past few years
2016	*Law on Air Pollution Prevention and Control* (amended in August 2015)

Source: REEI compilation, 2017

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