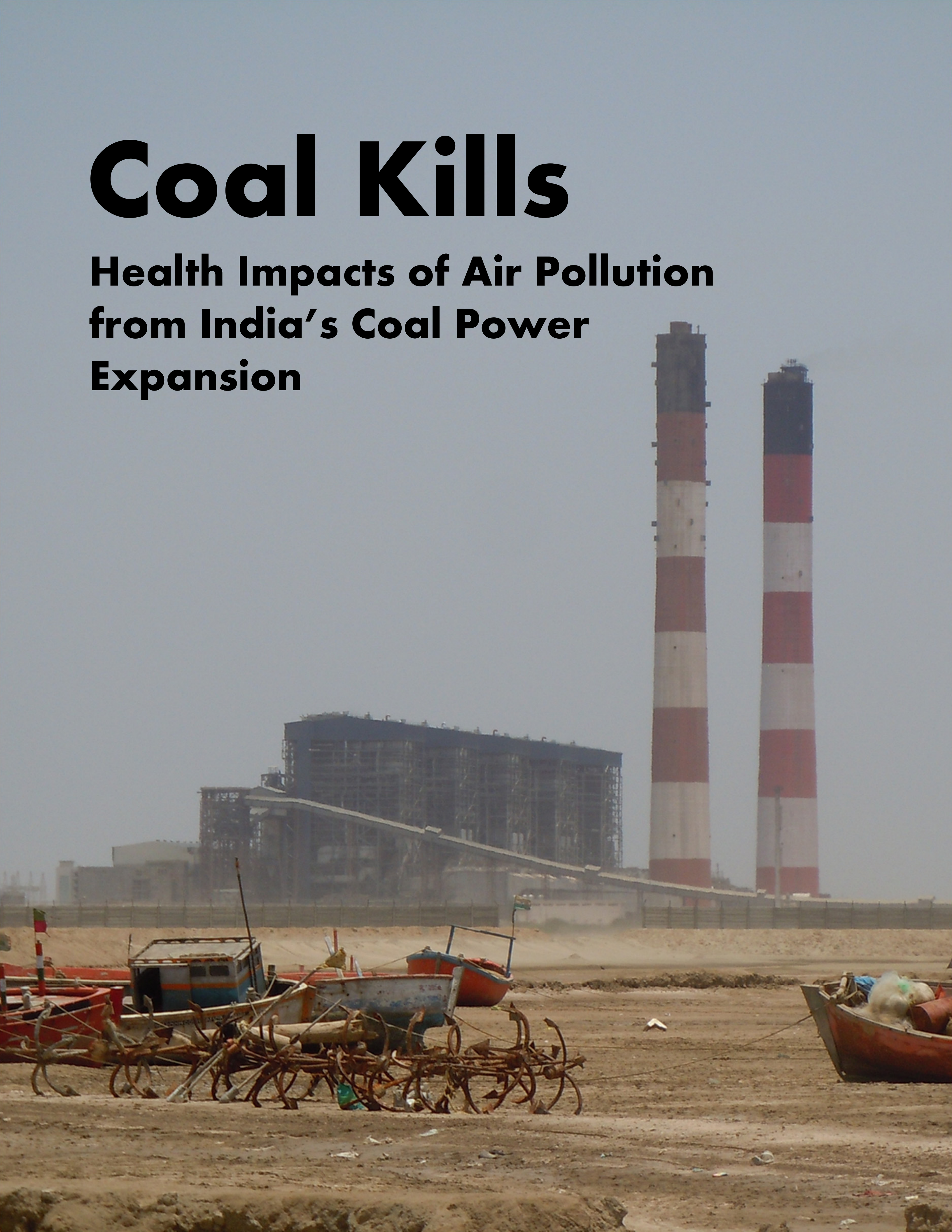
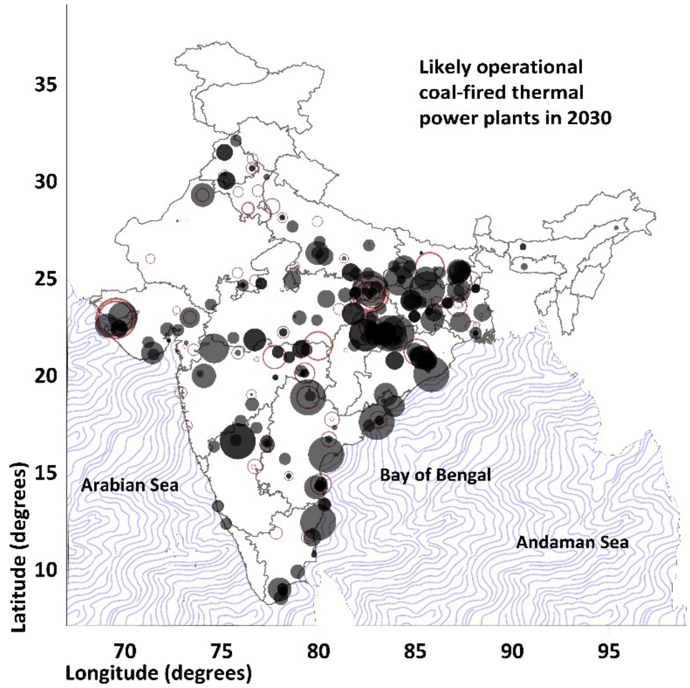
Coal Kills

Health Impacts of Air Pollution from India's Coal Power Expansion





Clusters of coal-fired thermal power plants in 2030. The brown circles represent the thermal power plants operational in 2014 and the second colour represents all the expansions likely to be operational in 2030. The largest circle is 4620MW. Note that many of these circles are overlapping due their close proximity

Report written and edited by staff @ Conservation Action Trust (India) and Urban Emissions (India)

Founded in 2005, the Conservation Action Trust is a non-profit organization dedicated to the protection of the environment through advocacy and action.

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Acronyms and Abbreviations

$\mu g/m^3$	micro-grams per cubic meter
1 crore	10,000,000
3D	Three-dimensional
CAMx	Comprehensive Air Quality Model with extensions
CEA	Central Electrical Authority
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COPD	Cardio Obstructive Pulmonary Disorder
CPCB	Central Pollution Control Board
ESP	Electro Static Precipitator
EU	European Union
FGD	Flue Gas Desulphurisation
GBD	Global Burden of Disease
GDP	Gross Domestic Product
GW	Gigawatt
Hg	Mercury
INR	Indian Rupees
km	Kilometre
Kwh	Kilowatt-hour
mg/Nm^3	milli-grams per normal cubic meter
MoEF	Minister of Environment, Forest, and Climate Change
MW	Megawatt
MWh	Megawatt-hour
NCEP	National Centre for Environmental Prediction
NO_x	Nitrogen Oxides
NTPC	National Thermal Power Corporation
PM	Particulate Matter
PM_{10}	Particulate Matter (with aerodynamic diameter less than 10 µm)
$PM_{2.5}$	Particulate Matter (with aerodynamic diameter less than 2.5 µm)
SO_2	Sulphur Dioxide
TPP	Thermal Power Plants
USA	United States of America
USD	US Dollar
VOC	Non-methane Volatile Organic Compounds
WHO	World Health Organisation

EXECUTIVE SUMMARY

As the 3rd largest economy in the world with more than a billion people, the supply of power in India can scarcely keep up with demand. Across the country, households and industry suffer from regular power cuts, while more than 400 million lack access to even this unreliable supply. Given the energy scenario, the need to expand power generation capacity and deliver more electricity for India is immediate. To meet the growing electricity demand, the expansion of the coal-fired thermal power plants (TPPs) is the most likely scenario, which consequently also leads to an array of environmental and health impacts.

Our last assessment, found significant impacts from the existing fleet of coal fired TPPs including between 80,000 and 115,000 deaths annually due to exposure linked their particulate emissions in 2011-12. Keeping that in perspective, this study is an attempt to help rationalise the discourse around expansion of coal power generation - with the goal of presenting the likely impacts of planned future coal-fired TPPs and the likely benefits of more stringent environment regulations on human health.

Our key findings are

- **Coal generation capacity grows 300%** - The total installed capacity is expected to increase three times from 159 GW in 2014 to 450 GW in 2030; under the proposed list of power plant projects. Largest (three fold) expansions are expected in the states of Andhra Pradesh, Odisha, Chhattisgarh, Bihar, and Jharkhand, all of which have coal reserves. A two fold expansion is expected in the states of Karnataka, Madhya Pradesh, Maharashtra, Punjab, Tamilnadu, and Uttar Pradesh
- **Coal consumption increases 200-300%** - The total coal consumption is estimated to increase 2-3 times from 660 million tons/year to 1800 million tons/year; accordingly the CO_2 emissions from 1,590 million tons/year to 4,320 million tons/year
- **Air emissions at least double through 2030** - The PM, SO_2, and NO_x emissions will at least double in the same period. Most of the planned plants are supercritical- and ultra-TPPs, which tend to utilise less coal per MWh of electricity generated. With no emission regulations in place for SO_2 and NO_x, these are assumed uncontrolled and allowed to release through the elevated stacks for dispersion
- **100% increase in health impacts** - The total premature mortality due to the emissions from coal-fired TPPs is expected to grow 2-3 times reaching 186,500 to 229,500 annually in 2030. Asthma cases associated with coal-fired TPP emissions will grow to 42.7 million by 2030
- **Limited emission standards for power plants** - India currently has no standards for either SO_2 or NO_x both of which drive a large portion of the estimated these health impacts – in the form of secondary suphates and secondary nitrates.

Technology improvements worldwide have made electricity generation more efficient and hence cleaner and safer for the environment. Establishing standards, especially for SO_2 and NO_x, at par with those observed in USA, EU, and China, and mandating the flue gas desulphurization (FGD) systems like limestone injection during the combustion process, wet FGD using limestone scrubbing, and high efficiency regeneration, could reduce the annual premature mortality by at least 50% every year.

50% health benefits with FGD

Anticipated health impacts of planned coal-fired TPPs and likely number of lives saved by operating a flue gas desulphurization unit at all the coal-fired TPPs in India

	Premature mortality under no FGD	Lives saved under 60%- and 95%- FGD efficiency	Monetary benefits under FGD (crores)
Year 2017	112,500 – 126,000	39,000 – 63,000	7,800 – 12,600
Year 2020	132,500 – 153,500	45,000 – 74,000	9,000 – 14,800
Year 2025	164,000 – 197,500	54,500 – 90,500	10,900 – 18,100
Year 2030	186,500 – 229,500	61,000 – 101,500	12,200 – 20,300

Our key recommendations are

- **Set emission standards** - Immediate introduction of emission standards for SO_2, NO_x, and Mercury for all the coal-fired TPPs
- **Mandate FGD at the plant level** - Regulating emissions at the plant level by mandating FGD operations for all the existing, the newly commissioned, and the planned TPPs in India, to benefit from the associated reduction in the ambient PM pollution
- **Practice rigorous monitoring** - Introduction of protocols to continuously monitor emissions at all stacks and make the data available to pollution control authorities, civil society, and the public, for further analysis, scrutiny of the emission loads, and verifications. At present, there is absolutely no data available publicly on emissions or the ambient concentrations surrounding the TPPs. The larger TPPs are suposedly equipped with continuous stack monitors; however this information is not open
- **Ensure transparency** - Use of information to enforce the emission and pollution standards as necessary, pending the introduction of emission standards and protocols to release monitoring data
- **Improve EIA protocols** – The environment clearance procedures require self assessment for only 10km radius of the TPPs; whilst the impacts are observed at much greater distances, considering the minimum stack height for a 500MW TPP is 275m.

1. BACKGROUND

The direct link between outdoor air pollution and human health has been extensively documented. Most notable of the health impacts resulting in premature deaths include chronic obstructive pulmonary disease, respiratory infections, heart diseases, strokes, and cancers of trachea, bronchitis, and lung. Of all the pollutants, the public health concerns in India are focused on particulate matter (PM) that contributes to a host of cardiopulmonary ailments and increasing the risk of premature death. Epidemiological studies conducted in India also highlighted the linkages between outdoor air pollution and premature mortality, hospital admissions, and asthma cases[1].

The global burden of disease (GBD) for 1990-2010 quantified the trends of more than 200 causes of death and listed outdoor air pollution among the top 10 risks for India, with the outdoor $PM_{2.5}$ and ozone pollution contributing to an estimated 695,000 premature deaths[2]. $PM_{2.5}$ refers to particulate matter less than 2.5µm in aerodynamic diameter. The ambient PM pollution was ranked 6th in 1990 with 440,000 annual deaths, which moved to 5th overall in 2010. The morbidity and mortality burden of outdoor air pollution is particularly costly in terms of work days lost, lost productivity, and loss in terms of gross domestic product (GDP), which was approximately USD 23.4 billion and 1.7% of national GDP in 2009[3].

Table 1: Ranking of health ricks in India in 2010 (GBD, 2012)

Health Risk	Premature deaths
Dietary Risks	1.622 million
High Blood Pressure	1.072 million
Household air pollution	1.022 million
Smoking	1.008 million
Ambient PM pollution	0.627 million
High fasting plasma glucose	0.618 million
Physical inactivity	0.436 million
Alcohol use	0.349 million
Occupational risks	0.342 million
Childhood underweight	0.213 million

Air quality is a cause for concern in India, with air pollutants including PM, sulphur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO), and ozone, often exceeding the national ambient air quality standards. According to the World Health Organisation (WHO), 37 cities from India feature in the top 100 world cities with the worst PM_{10} pollution, and the cities of Delhi, Raipur, Gwalior, and Lucknow are listed in the top 10 (WHO, 2014)[4]. A similar assessment by WHO, in 2011, listed 27 cities in the top 100. More than 100 cities under the national ambient monitoring program exceed the WHO guideline for PM_{10}. The most commonly identified urban sources are

[1] Guttikunda et al. (2014) "Nature of air pollution, emission sources, and management in the Indian cities" @ http://www.sciencedirect.com/science/article/pii/S1352231014005275

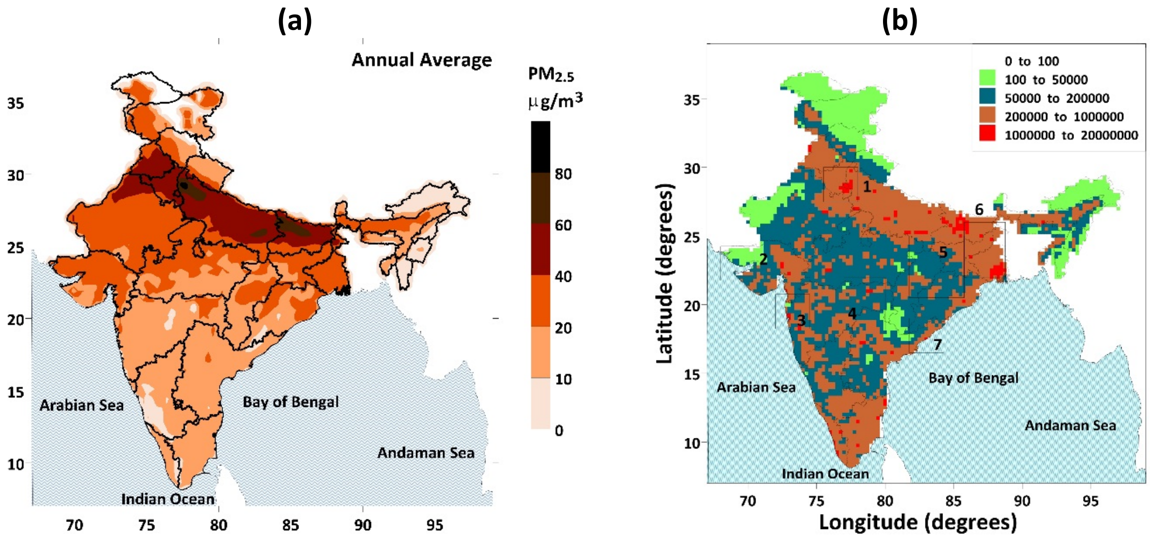
[2] The methodologies and a compilation of air pollution and health related studies worldwide, along with the results of the global burden of disease assessments for 1990-2010 are presented by the Institute for Health Metrics and Evaluation (IHME) @ https://www.healthdata.org

[3] "An Analysis of Physical and Monetary Losses of Environmental Health and Natural Resources in India", Policy Research Working Papers, WPS-6219, The World Bank, Washington DC, USA.

[4] The monitoring data is collected from the National Ambient Monitoring Program (NAMP), which collects 24-hour averages of PM_{10}, SO_2, and NO_2, 2-3 times per week, at 342 manual stations in 127 cities. This network is operated, managed, and data is disseminated by the Central Pollution Control Board (CPCB).

vehicles, manufacturing industries, diesel generator sets, construction activities, road dust, waste burning, combustion of oil, coal, and biomass in the households, and marine/sea salt.

Figure 1: (a) Ambient $PM_{2.5}$ concentrations derived from the satellite observations [5] (b) Gridded population in India for 2011 [6]



Only a handful of Indian cities have coal-fired thermal power plants (TPPs) within the city limits (for example Delhi, Chennai, Mumbai, and Ahmedabad), which otherwise tend to underestimate their contribution (and of coal combustion) to urban air pollution. The ambient $PM_{2.5}$ concentrations (**Figure 1a**) in the Indo-Gangetic plain are high and this overlaps with the highest population density (**Figure 1b**) in the country. This region also has the largest number of brick kilns with old and inefficient combustion technology, using a mix of biomass and coal for combustion. The states of Bihar, West Bengal, Jharkhand, Odisha, and Chhattisgarh harbour the largest coal mines in the country, and a cluster of TPPs. Several of the large TPPs also exist in the states of Punjab, Haryana, Delhi, and Uttar Pradesh, making the north and north-eastern belt the most polluted. Using the OMI satellite data, Lu et al. (2013) reported that the annual average SO_2 concentrations in coal-fired power plant regions of India increased by more than 60% between 2005 and 2012[7]. The coal-fired TPPs contribute to ~50% of the total annual SO_2 emissions and ~15% of the total annual $PM_{2.5}$ emissions in India[8].

An Impact assessment of the coal-fired TPPs in India, those operational in 2011, was conducted in 2012-13[9]. Following the methodology, this research study aims to present the likely impacts of

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[5] Methodology on the satellite data retrievals and uncertainties is explained by van Donkelaar et al (2010). The report and data is available @ http://fizz.phys.dal.ca/~atmos/martin/?page_id=140

[6] Grid resolution is 0.25° and gridded data is obtained from GRUMP @ http://sedac.ciesin.columbia.edu and adjusted to the 2011 state totals from Census @ http://censusindia.gov.in

[7] Details on the satellite data retrieval procedures and analysis is presented in "OMI Observations of Inter-annual Increases in SO_2 Emissions from Indian Coal-Fired TPPs during 2005–2012" @ http://pubs.acs.org/doi/abs/10.1021/es4039648

[8] National emissions inventories for multiple years and for multiple sectors is compiled by IIASA as part of the GAINS-India program; and used for science and policy discussions. More details @ http://www.iiasa.ac.at

[9] More details of the study and methodology are available @ http://www.urbanemissions.info

the proposed coal-fired TPPs to come online through 2030 and the likely benefits of more stringent environment regulations on human health.

Box 1: Health Hazards of Emissions from the Coal-Fired Thermal Power Plants in India (Press Information Bureau of India, August 2013)

Government is aware of the report titled "Coal kills- An assessment of death and disease caused by India's dirtiest energy source" which was published in Dec 2012. The report shows that in 2011-2012, emission from Indian coal plants resulted in 80,000 to 1,15,000 premature deaths and more than 20 million asthma cases from exposure to air pollution. The study quantified additional health impacts such as large number of cases of heart attacks, emergency room visits, hospital admission and lost workdays caused by coal based emissions. The study estimates that monetary cost associated with these health impacts exceeds Rs. 16,000 to 23,000 crores per year.

Central Electricity Authority (CEA) has informed that Ministry of Power has constituted a Standing Committee on occupational health and safety of workers of TPPs. The committee has members from various stake holders. On the recommendations of the standing committee a task force was constituted which has submitted its report on 06/08/2013.

Considering the impact of the emissions on the environment including human health, the central Pollution Control Board under Ministry of Environment and Forest has informed that following steps have been taken to prevent/minimize emissions from TPPs:

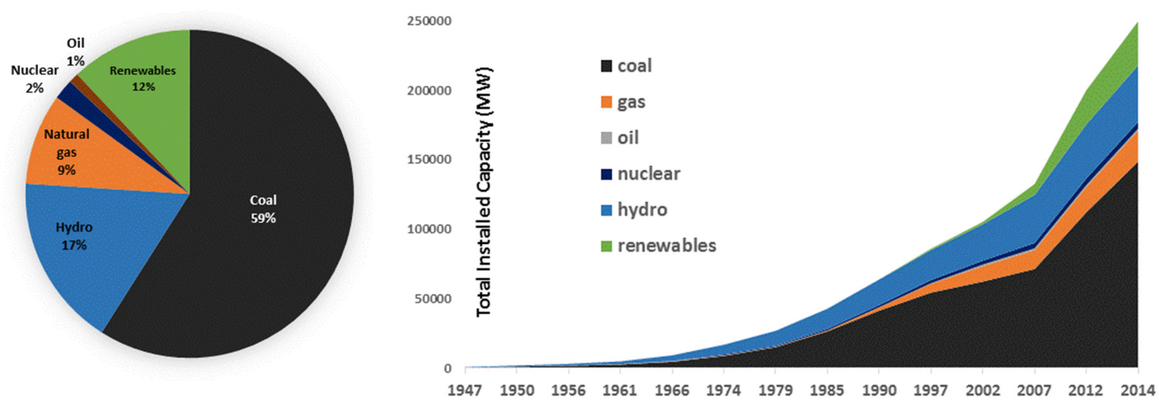
- Developed emission and effluent standards for control of air & water pollution
- To minimize dust generation, power plant has been directed to use beneficiated coal not having ash content more than 34% (low ash coal).
- In order to mitigate problems related to flyash disposal such as land degradation, fugitive dust emission from ash ponds, flyash utilisation has been made mandatory since September 14, 1999.
- Emphasis is giving to cleaner coal technology (like supercritical, Circulating fluidized Bed Combustion) while granting environmental clearance to new coal based TPPs.
- Asking TPPs to install pollution control systems for control of SO2 emission on case to case basis wherever need is felt based on ambient air quality and sensitivity of area.
- National Ambient Air Quality standards have been notified which are to be met by applying suitable control measures by the all air polluting industries including TPPs.

This information was given by Union Minister of Health & Family Welfare Shri Ghulam Nabi Azad, in written reply to a question in the Rajya Sabha today.
BN/HB (Release ID :98090)

2. COAL-FIRED THERMAL POWER PLANTS in INDIA

India is the 4th largest consumer of electricity in the world, with coal as the primary fuel of choice for power generation and this will only get larger in the coming years. Most of the existing coal-fired TPPs are based on conventional pulverized coal or fluidized bed combustion technology. Some newer projects plan to use supercritical- and ultra- steam conditions, which offer better performance ratios.

Figure 2: (a) Sources of electricity in India, based on the installed capacity in 2013 and (b) Growth of installed power generation in India



Source: Central Electrical Authority, 2013

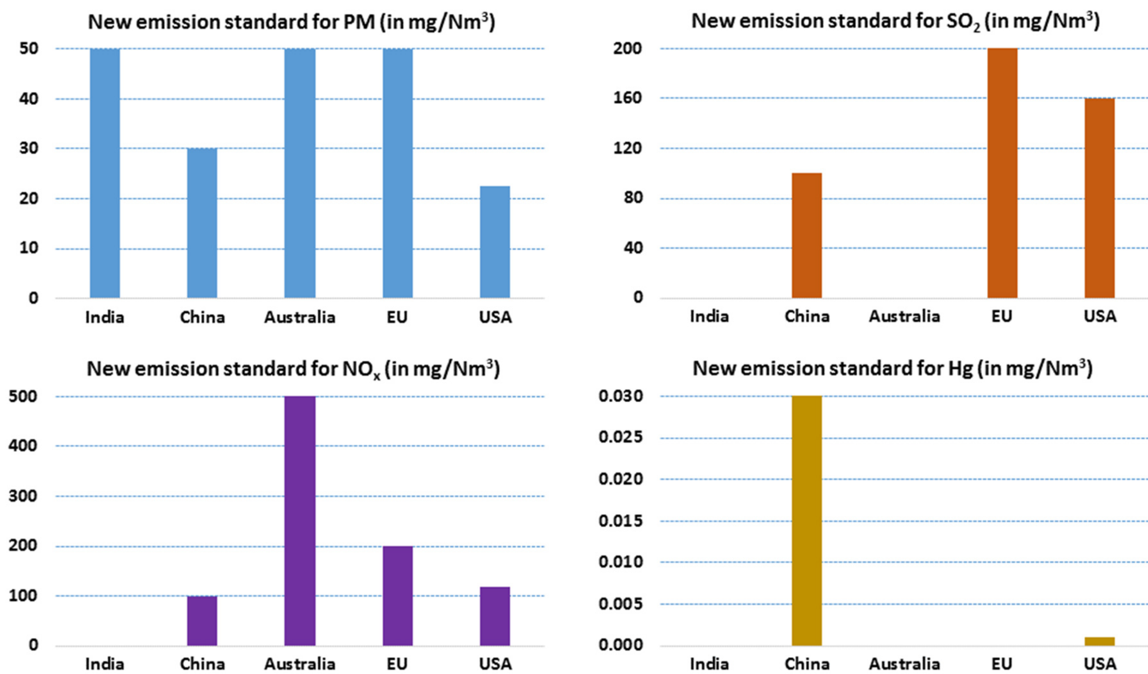
Table 2: Summary of new emissions standards (all in mg/Nm³) for the coal-fired Thermal Power Plants[10]

	PM	SO_2	NO_2	Mercury
India [a]	50	-	-	-
China [b]	30	100	100	0.03
Australia [b]	50	-	500	-
European Union [b]	50	200	200	-
USA [b]	22.5	160	117	0.001

Coal-fired power comes with significant costs to environment and human health. The water runoff from coal washeries carries pollution loads of heavy metals that contaminate ground water, rivers, and lakes - thus affecting aquatic flora and fauna. Fly-ash residue and pollutants settle on soil contaminating areas and are especially harmful to agricultural activities. Most importantly for human health, combustion of coal releases emissions of SO_2, NO_x, PM, CO, VOCs, and various trace metals like mercury, into the air through stacks that can disperse this pollution over large areas. To date, the environmental regulations lag behind those observed in the developed countries like the United States, the European Union, China, and Japan, with no control regulations for SO_2, NO_x, and Mercury (**Table 2**). Given the plans to greatly expand the contribution of coal to the Indian power sector, it is vital that decision makers understand the hidden costs of air pollution from coal fired TPPs.

[10] Sources for the data are (a) http://cpcb.nic.in/Industry_Specific_Standards.php and (b) http://www.airclim.org/acidnews/china-new-emission-standards-power-plants

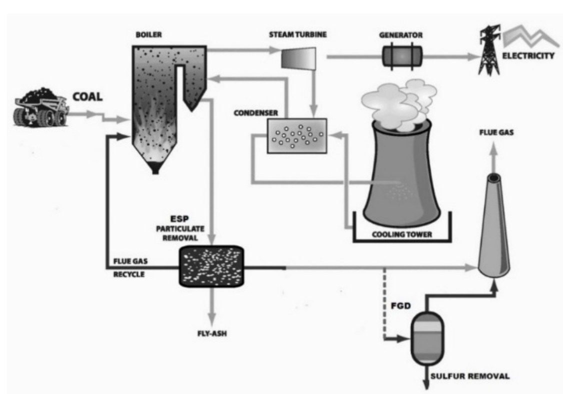
Figure 3: Summary of new emission standards for the coal-fired thermal power plants (zero listing = no standard)



For SO_2 and NO_x, there are no mandatory requirements to operate emission control equipment, except for specifications for stack heights, assuming that the emissions will be dispersed to farther distances and thus diluting the ambient concentrations. For example, MoEF requires all TPPs with generation capacity more than 500 MW to build a stack of 275m; those between 210 MW and 500 MW to build a stack of 220 m; and those with less than 210 MW to build a stack based on the estimated SO_2 emissions rate (Q in kg/hr) and a thumb rule of height = $14*(Q)^{0.3}$. The stack heights for old TPPs ranged between 150 m and 220 m. Some of the new installations and extensions are equipped with low-NOx burners, with little details on their operational performance.

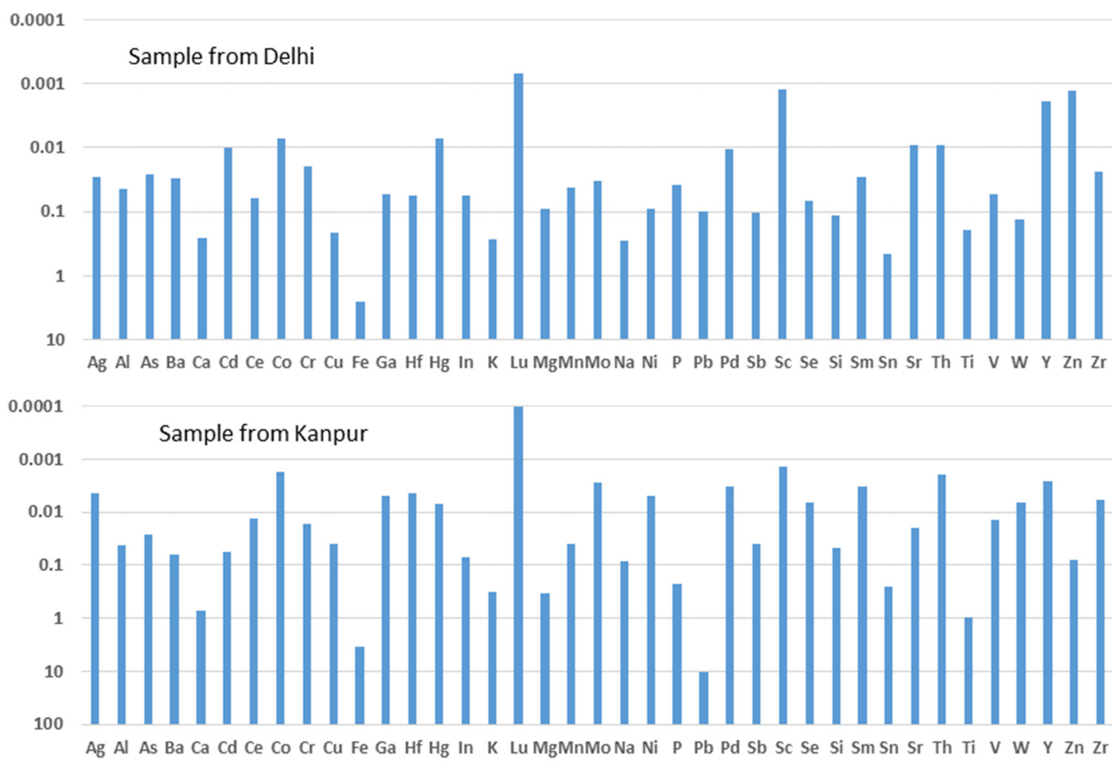
PM is the only pollutant for which controls are widely applied. The standards for PM polluion were revised in 2013 to 50 mg/Nm^3, which was standing at 150 mg/Nm^3 for the plants commissioned prior to 2013. A schematic of a coal-fired power plant is presented in **Figure 4** that shows flue gas from the boilers at high temperature and velocity passing through heat exchangers to recycle the residual energy. This then enters the

Figure 4: Simplified schematics of a coal-fired TPP



particulate control equipment (ESPs and cyclone bag filters) for removal of entrained ash. ESPs are installed in all coal-fired TPPs in India. As removal efficiencies at ESPs are higher for coarse particles, most of the PM dispersing from the top of the stack is in the size range of respirable PM. The PM in the flue gas also contains high concentrations of heavy metals such as arsenic, lead, cadmium, mercury, copper, and zinc, which not only contributes to potential health hazard than the bottom ash, but also increases the resistivity and reduces the ESPs collection efficiency to as low as 98%. A composite of the share of heavy metals in samples collected at the TPPs in Delhi and Kanpur is presented in **Figure 5**.

Figure 5: Source profile of the heavy metals in a particulate sample collected from a power plant in Delhi and Kanpur (CPCB, 2010)[11]



Besides flue gas PM emissions, fugitive dust from coal-handling plants and ash ponds (after the disposal from the plants) is a problem. According to the Central Electrical Authority, after the combustion and application of control equipment, ash collection at the TPPs ranged 70-80% of the total ash in the coal. It is assumed that the remaining particulates is dispersed from the stacks. An amendment notification from MoEF mandates that 100% of ash utilisation within four years of generation; at least 25% of ash utilisation in all brick kilns within 100km radius of TPPs; and all building construction within 100km for any coal-fired TPP to use 100% ash based bricks, blocks,

[11] These samples from the coal-fired TPPs in Delhi and Kanpur were collected and analysed as part of the particulate pollution source apportionment study in six cities, commissioned by the Ministry of Environment and Forests, and executed by the Central Pollution Control Board (2010). Details of the program and results are available @ http://cpcb.nic.in/Source_Apportionment_Studies.php

and tiles[12]. To date, percentage of ash utilised in the construction industry is low - approximately 13% used for brick manufacturing and other construction activities.

For 2011-12, a study was conducted to assess the impact of the coal-fired TPPs in India on the ambient air quality and health[13]. In this study, we isolated the emissions from the coal-fired TPPs and estimated a premature mortality rate of 80,000 to 115,000 due to their contribution to the ambient $PM_{2.5}$ concentrations. This number does not include the impacts of the water run-off and soil contamination due to the release of heavy metals. Combined with a strong demand for reliable electricity and consistent shortage in supply, it is doubtful that pollution will be controlled absent strong regulation for the operational 111 coal-fired TPPs.

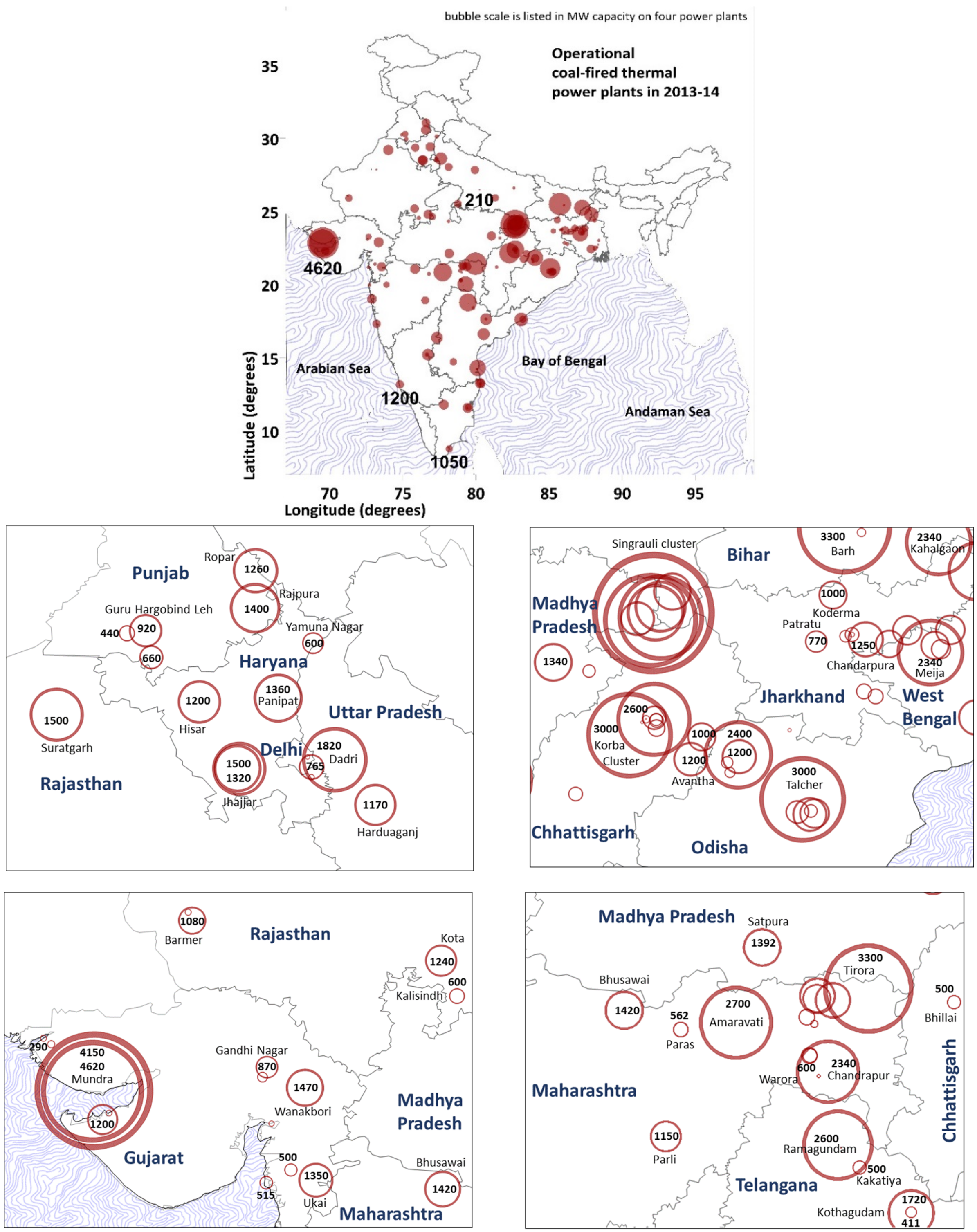
The coal-fired TPPs operational in 2014 are presented in **Figure 6**. With so many TPPs commissioned in clusters, it is not easy to present them all in one figure without overlaps. Also presented in **Figure 6** are inlays for four of major clusters.

- The North India cluster is centered around the National Capital Region of Delhi (with a combined population of 22 million), with large TPPs supporting its electricity demand are located within 100km. Two large TPPs are in Jhajjar (Indira Gandhi TPP and Mahatma Gandhi TPP), one large power plant in Dadri (closet to the city) with a combination of gas and coal, one in Hisar (Rajiv Gandhi TPP); and some smaller TPPs operating on coal, oil, and gas. The remaining cluster consists of five TPPs supporting the needs in Punjab and one 1500MW TPP in Suratgrah (Rajasthan)
- The Central India cluster around the coal mines of Chhattisgarh, Odisha, Jharkhand, and West Bengal, are the largest in the country. The Korba cluster and the Singrauli cluster have a combined generation capacity of more than 5000MW and 10000MW respectively; with the plants signing MoUs to supply electricity to the neighbouring states
- The Kutch region, with its access to the largest ports, hosts the largest operational TPPs in the country. The Mundra cluster (state: Gujarat) has a combined generation capacity of 9620 MW between two privately run TPPs located within 5km of each other.
- The Western Maharashtra region (Amravati, Tiroda, Parli, Warora, Chandarpur, and Bhusawai) and Telangana (Ramagundam and Kothagudam) are also hub to large TPPs nearest to the coal mines

[12] Press Information Bureau of India notifications #51345 July/31/2009 and #106550 on July/14/2014; and one notification from the archives (2003) "Use of fly ash made mandatory" @ http://pib.nic.in/archieve/lreleng/lyr2003/rjan2003/01012003/r010120033.html

[13] Press Information Bureau of India notification # 98090 on August/13/2013 and a press release in the New York times @ http://india.blogs.nytimes.com/2013/03/22/indias-coal-power-plants-kill-tens-of-thousands-every-year-study-says

Figure 6: Installed capacity of the coal-fired thermal power plants in India. The largest circle is 4620MW. Note that many of these circles are overlapping due their close proximity to other TPPs, which is displayed in the inlays of the largest clusters in 2014



The main conclusions of 2011-12 study are the following

- To date, the pollution standards exist only for ambient air quality and not for individual TPPs, which compromises the efforts to control any pollution. Only after standards are regulated at the plant level, can we proceed to the next steps of monitoring and enforcing, and reduce the impact of emissions from coal-fired TPPs
- Going forward, coal-fired TPPs should be subjected to tighter emission standards, similar to those found in emerging economies (like China) and developed economies (like EU, Australia, and USA). For example, a mandate for installation of FGD systems for the existing 111 coal-fired TPPs could reduce the $PM_{2.5}$ concentrations significantly, by eliminating the formation of secondary sulphates and nitrates, and some additional benefits to the primary particulates. For 2011-12, if FGD was operational at all the plants, we estimate that 42,500 premature deaths (~55% of the estimated total for that period)
- The efficiency improvement of existing older TPPs, irrespective of the boiler size, should become a starting point for reducing overall coal consumption and associated atmospheric emissions
- The stack emissions can be monitored relatively easily as compared to non-point sources (such as vehicles, garbage burning, domestic burning, and fugitive dust). While, the larger TPPs are now equipped with continuous stack monitors, this information is not open to public, either for analysis or for scrutiny of the emission loads. This adds to the uncertainty of similar studies. Besides strengthening standards, newer policies are required for dissemination of information from the coal-fired TPPs
- The environmental impact assessment procedures need to be revised, in order to include the health and environment damages due to long-range transport of pollution from the stacks, as high as 275m, and travelling the distances of more than 300km in less than 24 hours. Currently, the procedure require assessment for an area of 10km radius from the plants

3. FUTURE COAL-FIRED POWER PLANTS in INDIA

The power sector in India, has an installed capacity of 250GW (as of June, 2014); with 148 GW coming from coal[14]. In India, the supply of electricity lags behind the demand. According to the Central Electricity Authority, in 2010-11, of the 122 GW peak demand, only 110 GW was supplied – which amounted to a shortfall of 10%. A third of the population that lives in rural India does not have access to electricity. Even those with access in urban India have to endure frequent power cuts and load shedding, which results in use of in-situ diesel generator sets.

Box 2: India pledges 24-hour electricity to all by 2019

The Indian government estimates that it will need to spend around $250bn over the next five years in order to connect the entire nation to the grid. The country's energy minister, Piyush Goyal, said $100bn of the new investment would be in renewables and $50bn in transmission, with the rest in other areas. "We can see a situation where we will have power for all businesses, all homes, all offices right through the length and breadth of India," Mr Goyal said.

The minister re-affirmed that output would be increased through improving the overall power mix. This includes greater use of renewables such as wind and solar, and a doubling of state-run Coal India's mine output to 1 billion tonnes a year in the next five years to provide fuel for big new coal-fired TPPs starved of coal.

India currently has 2.9 GW of solar electricity capacity and the government is ambitiously targeting a raise in that to 20 GW by 2022, with a new solar target of 100 GW within the next eight years.

The FT reports that the government is however reluctant to invest to the same extent in nuclear power, without further analysis. Yet India's existing long-term energy strategy also calls for adding up to 26 GW of nuclear power to help meet its electricity deficit, and companies from around the world, including Areva and Rosatom, as well as Japanese engineering giants are all hoping for a share.

As it stands 53 million homes on the subcontinent are without power, with much reliance on diesel generators to produce electricity during lengthy power cuts. In the summer of 2012, the grid in northern India collapsed, leaving hundreds of millions of Indians without electricity for up to three days in the worst outage in history.

Power Engineering, November 2014
@ http://www.powerengineeringint.com/articles/2014/11/india-pledges-24-hour-electricity-to-all-by-2019.html

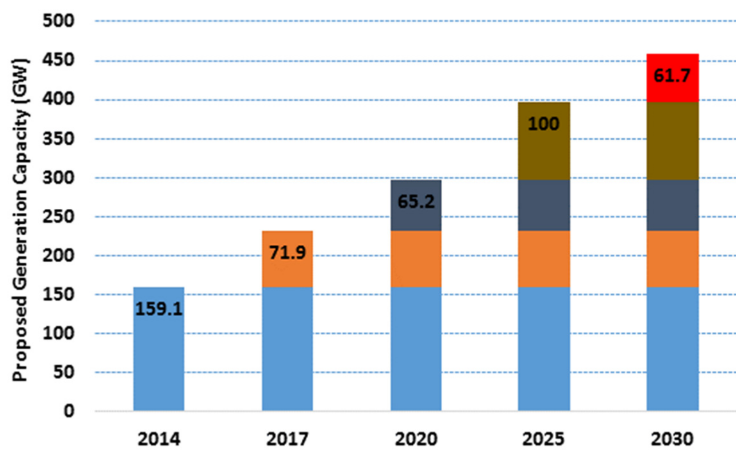
An analysis by McKinsey[15] claims that India's demand for electricity may cross 300 GW, earlier than most estimates. To explain their estimates, they point to four reasons:

- India's manufacturing sector is likely to grow faster than in the past
- Domestic demand will increase more rapidly as the quality of life for more Indians improve
- About 125,000 villages are likely to get connected to India's electricity grid
- Blackouts and load shedding artificially suppresses demand; this demand will be sought as revenue potential by power distribution companies

[14] Central Electrical Authority, Monthly report, June 30th, 2014 @ http://cea.nic.in/reports/monthly/inst_capacity/jun14.pdf
[15] "Powering India – The road to 2017", McKinsey (2008) – Link @ http://en.wikipedia.org/wiki/Electricity_sector_in_India

In 2011, Prayas Energy Group (Pune, India) listed that ~700 GW of power generation from coal, is in the pipeline, with the environmental clearances and project preparations at various stages; if come online will certainly meet the necessary demand for electricity in the industrial and domestic sector through 2030[16]. However, what is the impact of these future coal-fired TPPs on the ambient air quality and human health, given the lack of regulations in place to control the pollutants like PM, SO_2, NO_x, CO, and GHGs?

Figure 7: Proposed expansions for the coal-fired TPPs in India



The database of TPPs under construction, under advanced development, planning, and under consideration are binned for operations between 2014 to 2030; with their likeliness of being operational in 2017-18, 2020-21, 2025, and 2030. The temporal distribution of the TPPs is currently speculative based on the project documents and their project status. This status is dependent on resource, financial, and environmental viability for each plant. The plants with less probability of securing either of the required clearances are not included in the assessment. Having excluded these, the likely installed capacity at the end of 2014 is 159.1 GW and the estimated installed generation capacity for the years 2017, 2020, 2025, and 2030 are 231 GW, 296 GW, 396 GW, and 458 GW, respectively; with new capacity of ~300GW between 2014 and 2030. This is less than ~700 GW of generation capacity anticipated by Prayas (Pune, India), as a result of cancellations and withdrawals due to lack of either resource, financial, and environmental clearances. The future TPPs presented in **Figure 8** for 2017-18, 2020-21, 2025, and 2030 are not all established as new plants. Some of these are extensions at the existing TPPs. The circles in **Figure 8** are overlapping with the existing and the new TPPs.

[16] Prayas Energy Group (Pune, India) "Thermal TPPs on the Anvil – Implications and Need for Rationalisation" @ http://www.prayaspune.org/peg/publications/item/164-thermal-power-plants-on-the-anvil-implications-and-need-for-rationalisation.html

Figure 8: Proposed locations of the coal-fired TPPs in India through 2030. The brown circles represent the TPPs operational in 2014 (details in Figure 6) and the second colour in each map represents all the new plants and expansions expected after 2014 and likely to be operational in the representative year. The largest circle is 4620MW. Note that many of these circles are overlapping due their close proximity to other TPPs

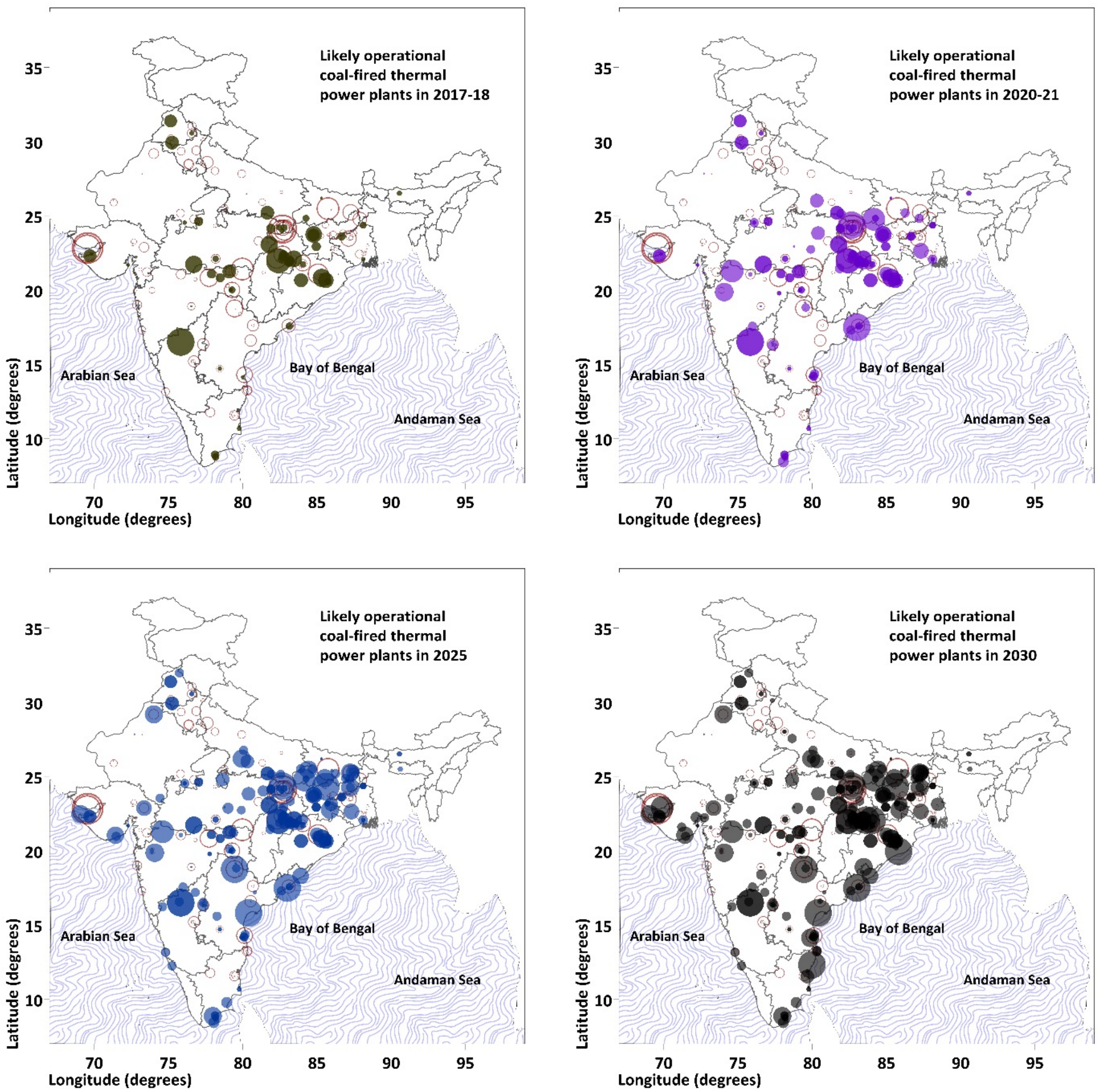


Table 3: Estimated energy consumption and emissions for the coal-fired TPPs operational in 2014							
	GW	Coal	$PM_{2.5}$	SO_2	NO_x	CO	CO_2
		mil.tons	ktons	ktons	ktons	ktons	mil.tons
Andhra Pradesh	8.9	35	21	172	160	129	85
Bihar	6.2	25	30	120	107	89	59
Chhattisgarh	11.1	46	57	223	250	166	110
Delhi	0.8	4	12	17	23	13	9
Gujarat	15.9	63	107	309	275	231	152
Haryana	6.0	25	15	124	165	92	61
Jharkhand	6.2	27	28	129	172	97	64
Karnataka	5.5	23	32	93	151	85	56
Madhya Pradesh	12.4	51	30	250	281	186	123
Maharashtra	21.3	87	78	373	449	316	209
Odisha	11.0	47	36	229	305	171	113
Punjab	4.7	20	11	95	117	71	47
Rajasthan	7.4	30	62	148	167	111	73
Tamilnadu	9.1	39	40	189	252	141	93
Telangana	5.3	22	17	110	146	82	54
Uttar Pradesh	15.3	65	64	317	423	237	156
West Bengal	11.9	51	56	247	330	185	122
Grand Total	**159.1**	**660**	**695**	**3,147**	**3,774**	**2,402**	**1,584**

Table 4: Estimated energy consumption and emissions for the coal-fired TPPs operational in 2030							
Year	GW	Coal	$PM_{2.5}$	SO_2	NO_x	CO	CO_2
		mil.tons	ktons	ktons	ktons	ktons	mil.tons
Andhra Pradesh	37.1	141	94	687	514	513	338
Assam	1.3	5	3	25	34	19	12
Bihar	30.2	117	83	572	560	427	282
Chhattisgarh	50.1	200	149	973	1,008	726	479
Delhi	0.8	4	12	17	23	13	9
Gujarat	37.7	143	173	699	557	522	344
Haryana	6.6	28	16	135	170	101	67
Jharkhand	29.4	113	93	553	511	412	272
Karnataka	18.9	73	61	319	317	267	176
Kerala	1.3	5	3	23	11	17	11
Madhya Pradesh	34.6	138	87	673	653	502	331
Maharashtra	42.4	171	144	764	860	622	410
Meghalaya	0.8	3	2	15	20	11	7
Odisha	44.3	173	151	682	810	631	416
Punjab	11.0	44	26	217	228	162	107
Rajasthan	14.9	58	101	282	235	210	139
Tamilnadu	26.9	104	92	453	461	379	250
Telangana	10.0	39	35	192	197	143	95
Uttar Pradesh	36.3	143	110	699	715	522	344
West Bengal	23.2	96	82	467	558	349	230
Grand Total	**457.9**	**1,799**	**1,514**	**8,447**	**8,440**	**6,547**	**4,318**

The energy and emissions outlook through 2030 is

- The total installed capacity is expected to increase three times from 159 GW in 2014 to 450 GW in 2030; under the proposed and active list of power plant projects
- Largest (three fold) expansions are expected in the states of Andhra Pradesh, Odisha, Chhattisgarh, Bihar, and Jharkhand, all of which have coal reserves. A two fold expansion is expected in the states of Karnataka, Madhya Pradesh, Maharashtra, Punjab, Tamilnadu, and Uttar Pradesh
- The total coal consumption is estimated to increase 2-3 times from 660 million tons/year to 1800 million tons/year; accordingly the CO_2 emissions from 1,590 million tons/year to 4,320 million tons/year
- The PM, SO_2, and NO_x emissions will at least double in the same period. The improvement in the rate of increase in the emissions is primarily due to the introduction of supercritical- and ultra- TPPs in the future, which tend to utilise less coal per MWh of electricity generated. With no emission regulations in place for SO_2 and NO_x, these are assumed uncontrolled and allowed to release at the elevated stacks for dispersion

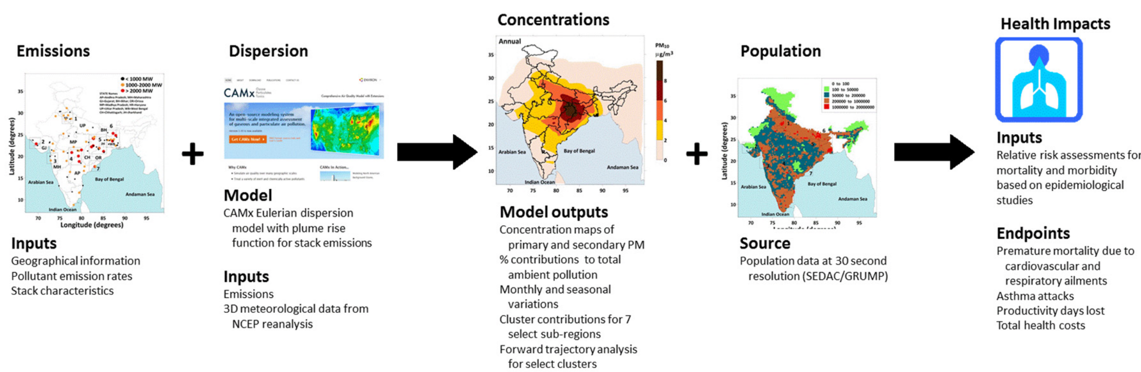
Table 5: Anticipated percent increase in the installed capacity compared to 2014 by state

	2014 (GW)	2017	2020	2025	2030
Andhra Pradesh	8.9	25%	153%	243%	319%
Assam		100%	100%	100%	100%
Bihar	6.2	23%	97%	352%	390%
Chhattisgarh	11.1	131%	201%	314%	351%
Delhi	0.8				
Gujarat	15.9	20%	20%	80%	137%
Haryana	6.0				11%
Jharkhand	6.2	92%	113%	349%	370%
Karnataka	5.5	73%	110%	230%	245%
Kerala				100%	100%
Madhya Pradesh	12.4	72%	142%	168%	178%
Maharashtra	21.3	30%	76%	92%	99%
Meghalaya				100%	100%
Odisha	11.0	82%	147%	173%	301%
Punjab	4.7	97%	97%	125%	136%
Rajasthan	7.4	26%	47%	102%	102%
Tamilnadu	9.1	36%	54%	100%	195%
Telangana	5.3			87%	89%
Uttar Pradesh	15.3	19%	41%	88%	137%
West Bengal	11.9	23%	74%	74%	94%
Grand Total	**159.1**	**45%**	**86%**	**149%**	**188%**

What are the anticipated changes in the contribution of coal-fired TPPs to ambient pollution?

Following the methodologies utilised in the previous assessments, the emissions from the future coal-fired TPPs through 2030 are also assessed for their impacts on the human health, due to the outdoor air pollution from the primary and secondary $PM_{2.5}$ pollution.

Figure 9: Pollution and health impact assessment schematics employed in this study



The atmospheric dispersion modeling of the emissions from all the coal-fired TPPs was conducted, following the above schematic and using the ENVIRON - Comprehensive Air Quality Model with Extensions (CAMx), an Eulerian photochemical dispersion model, suitable for integrated assessments of gaseous and particulate air pollution. The model formulation, advection and scavenging schematics, chemical solvers, and gas-to-aerosol conversion mechanisms[17].

The most important advantage of CAMx is the use of 3D meteorology and independently control plume rise and emission release point for each power plant, according to the stability profile at the plants location. The meteorological data (3D wind, temperature, pressure, relative humidity, and precipitation fields) is derived from the National Center for Environmental Prediction[18], a global reanalysis database and processed through WRF 3.5.1 meteorological model at 1 hour temporal resolution[19]. The horizontal resolution of the analysis is 0.25° grid (approximately 25km x 25km grids). The vertical resolution of the model extends to 10.5km stretched over 28 layers, with the lowest layer designated at 30m and 15 layers within 1km to advance vertical advection closer to the ground level.

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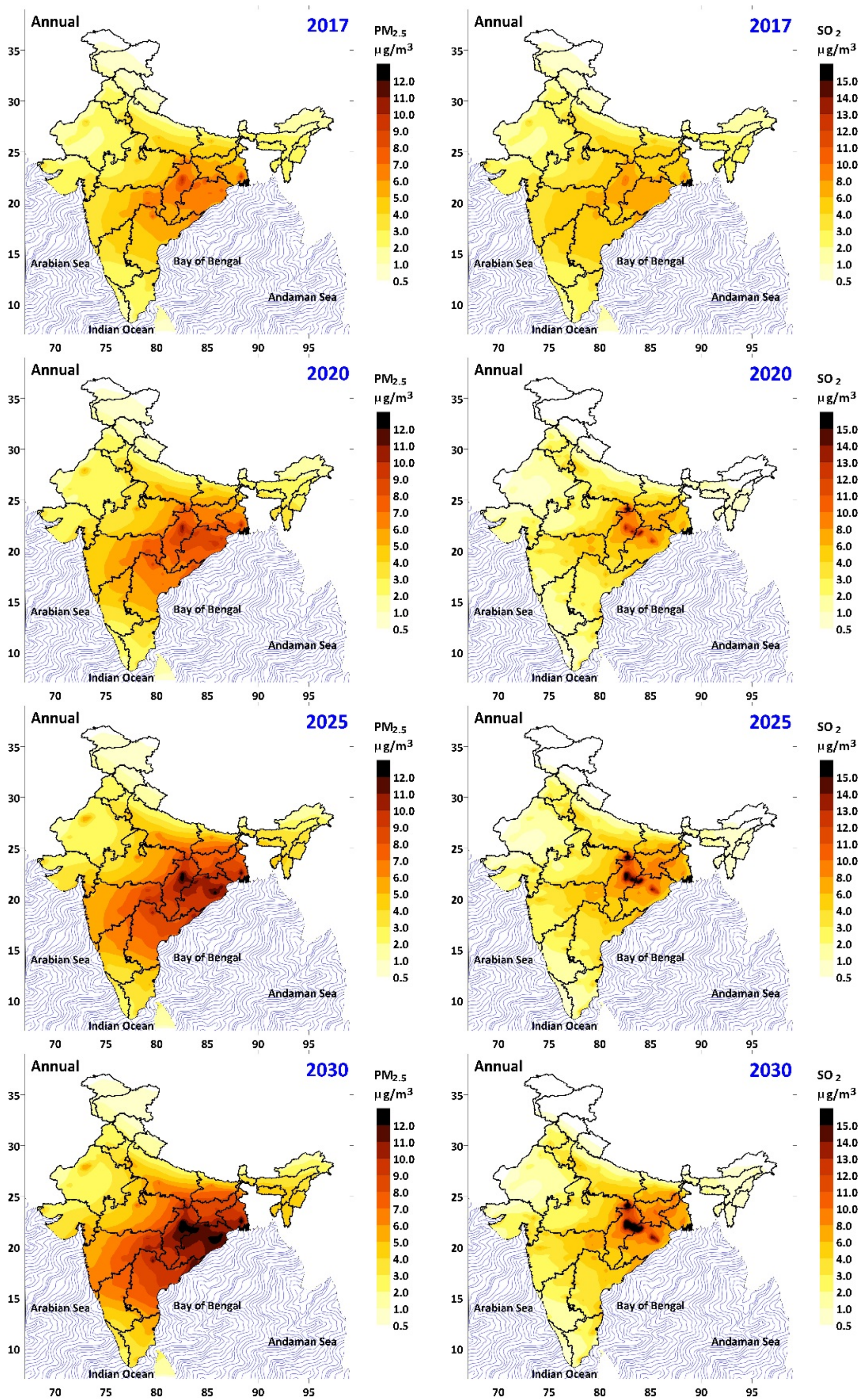
[17] The model utilises full gas phase chemistry with 217 reactions and 114 species; with two mode coarse/fine PM fractions including gas to aerosol conversions, for SO_2 to sulphates, NO_x to nitrates, and VOCs to secondary organic aerosols (SOA). The removal processes include dry deposition schemes using an updated approach with 26 landuse patterns and wet deposition due to predominant meteorological conditions. More details on the model architecture, manual, and operational instructions are available @ http://www.camx.com.

[18] NCEP operational meteorological fields are available @ http://rda.ucar.edu/datasets/ds083.2/index.html

[19] The Weather Research and Forecasting (WRF) model is a state-of-the-art meteorological modeling system to generate CAMx dispersion model ready data for chemical transport modeling at multiple scales. More details on the model architecture, manual, and operational instructions are available @ http://wrf-model.org/index.php

Figure 10: Modelled annual average $PM_{2.5}$ and SO_2 concentrations ($\mu g/m^3$) from the coal-fired TPPs in India



While the impact of the emissions from the TPPS are felt within 300km of the stacks, under windy conditions their influence can be tracked to distances as far as 500km from the source region. Major cities in the Korba region are Ranchi, Jamshedpur, Rourkela, Jabalpur, Nagpur, and Raipur (capital of Chhattisgarh); Major cities in the Mundra region are Jamnagar (major industrial port), Rajkot, and Ahmedabad (300km away, with two TPPs of 1000MW in the city); The city of Delhi with large TPPs within 100km of radius; experience the impact of the emissions from the coal-fired TPPs, though most of these cities do not host one in their administrative boundaries. The phenomenon of long range transport of these emissions released at stacks as high as 275m was illustrated in the form of 24hr forward trajectories, which is currently not accounted in the environmental impact assessments. The collective impact of the TPPs over each state is presented in **Table 6**, as population weighted concentrations, which is indicative of the pollution load observed in each state, irrespective of the size of the installed capacity in that state.

Table 6: Modelled state average $PM_{2.5}$ concentrations (indicative of the pollution load) due to the emissions from the coal-fired TPPs

	2017	2020	2025	2030
Andhra Pradesh	4.9 ± 0.9 (8.5)	6.1 ± 1.1 (9.8)	7.5 ± 1.3 (11.6)	8.4 ± 1.5 (13)
Arunachal Pradesh	1.6 ± 0.3 (2.0)	2.0 ± 0.4 (2.4)	2.5 ± 0.5 (3.0)	2.9 ± 0.6 (3.5)
Assam	2.1 ± 0.3 (2.6)	2.6 ± 0.4 (3.2)	3.3 ± 0.5 (4.1)	3.8 ± 0.6 (4.6)
Bihar	3.7 ± 1 (6.0)	4.3 ± 1.2 (6.5)	5.5 ± 1.7 (7.7)	6.1 ± 1.9 (8.8)
Chhattisgarh	6.6 ± 0.9 (12.7)	8.0 ± 1.0 (14.0)	9.6 ± 1.1 (16.0)	10.6 ± 1.2 (16.9)
Delhi	4.1 ± 1 (5.8)	4.3 ± 1.0 (6.0)	4.7 ± 1.0 (6.4)	5.0 ± 1.0 (6.8)
Goa	3.6 ± 0.1 (3.8)	4.4 ± 0.1 (4.6)	5.4 ± 0.1 (5.6)	6.0 ± 0.1 (6.2)
Gujarat	3 ± 0.7 (5.7)	3.3 ± 0.8 (6.2)	3.9 ± 0.9 (7.0)	4.2 ± 1 (7.5)
Haryana	3.3 ± 0.7 (5.8)	3.5 ± 0.7 (6.0)	3.9 ± 0.8 (6.4)	4.2 ± 0.8 (6.8)
Himachal Pradesh	1.4 ± 0.4 (2.1)	1.5 ± 0.4 (2.2)	1.8 ± 0.5 (2.5)	1.9 ± 0.6 (2.7)
Jammu & Kashmir	0.9 ± 0.2 (1.4)	1.0 ± 0.3 (1.5)	1.2 ± 0.3 (1.8)	1.2 ± 0.3 (1.9)
Jharkhand	5.2 ± 0.7 (10.1)	6.2 ± 0.9 (11.5)	8.0 ± 0.9 (13.3)	8.8 ± 0.9 (14.3)
Karnataka	3.3 ± 0.8 (5.5)	4.1 ± 1.0 (6.4)	5.1 ± 1.2 (7.5)	5.7 ± 1.3 (8.2)
Kerala	1.9 ± 0.2 (2.6)	2.3 ± 0.3 (3.2)	2.9 ± 0.4 (4.0)	3.3 ± 0.4 (4.5)
Madhya Pradesh	3.7 ± 0.9 (8.2)	4.4 ± 1.2 (8.7)	5.2 ± 1.4 (10.0)	5.6 ± 1.5 (10.8)
Maharashtra	4.4 ± 0.9 (9.3)	5.2 ± 1.1 (10.6)	6.3 ± 1.3 (12.1)	6.8 ± 1.4 (12.9)
Manipur	2.4 ± 0.1 (2.6)	2.9 ± 0.1 (3.2)	3.7 ± 0.2 (4)	4.1 ± 0.2 (4.5)
Meghalaya	2.4 ± 0.1 (2.8)	2.9 ± 0.1 (3.3)	3.8 ± 0.2 (4.4)	4.3 ± 0.2 (5.0)
Mizoram	2.5 ± 0.1 (2.6)	3.1 ± 0.1 (3.2)	3.9 ± 0.1 (4)	4.4 ± 0.1 (4.5)
Nagaland	2.1 ± 0.1 (2.4)	2.6 ± 0.2 (2.9)	3.2 ± 0.2 (3.7)	3.7 ± 0.2 (4.2)
Odisha	6.4 ± 0.6 (10.1)	8.1 ± 0.7 (11.5)	10.1 ± 0.9 (13.6)	11.2 ± 0.9 (15.0)
Punjab	1.9 ± 0.3 (2.7)	2.1 ± 0.3 (2.8)	2.4 ± 0.4 (3.2)	2.6 ± 0.4 (3.4)
Rajasthan	2.4 ± 0.6 (6.3)	2.7 ± 0.7 (7.6)	3.1 ± 0.8 (8.1)	3.3 ± 0.8 (8.2)
Sikkim	1.4 ± 0.3 (1.6)	1.7 ± 0.4 (1.9)	2.1 ± 0.5 (2.4)	2.3 ± 0.6 (2.6)
Tamilnadu	2.6 ± 0.5 (5.2)	3.1 ± 0.7 (5.6)	3.9 ± 0.8 (6.3)	4.4 ± 0.9 (6.8)
Tripura	2.6 ± 0.1 (2.8)	3.2 ± 0.1 (3.4)	4.2 ± 0.1 (4.4)	4.7 ± 0.2 (5.0)
Uttar Pradesh	3.2 ± 1.1 (7.4)	3.6 ± 1.4 (8.6)	4.3 ± 1.6 (10.0)	4.7 ± 1.8 (10.8)
Uttarakhand	1.4 ± 0.3 (1.8)	1.6 ± 0.4 (2.0)	1.9 ± 0.4 (2.3)	2.0 ± 0.5 (2.5)
West Bengal	6.0 ± 1.6 (12.9)	7.1 ± 1.9 (14.1)	8.8 ± 2.3 (16.0)	9.7 ± 2.6 (17.0)

The concentrations are in $\mu g/m^3$ and the data represents - population weighted state average concentration ± standard deviation of concentrations for all grids covering the state and (in the brackets - maximum concentration among the grids covering the state) The model grid size is 0.25 degrees (~25km x 25km). Because of this spatial coverage, these numbers cannot be directly compared to the data from the monitoring stations, which only represent their immediate vicinity.

What are the anticipated health impacts of the coal-fired TPPs?

Of all the pollutants, the public health concerns are focused on PM, which contributes to a host of respiratory and cardiopulmonary ailments. Using the established dose-response functions from the GBD assessments[20], health impacts of the emissions from the coal-fired TPPs in India, as binned for the years 2017-18, 2020-21, 2025, and 2030 were estimated, utilising the modeled $PM_{2.5}$ concentrations and gridded population are presented in **Table 7**. The total premature mortality due to the emissions from coal-fired TPPs is expected to grow 2-3 times reaching 186,500 to 229,500 annually in 2030 and the asthma cases associated with coal-fired TPP emissions will grow to 42.7 million by 2030.

Table 7: Anticipated health impacts due to ambient $PM_{2.5}$ pollution from the proposed coal-fired TPPs in India

	Premature mortality	Asthma attacks
Year 2017-18	112,500 – 126,000	23.4 million
Year 2020-21	132,500 – 153,500	28.4 million
Year 2025	164,000 – 197,500	36.7 million
Year 2030	186,500 – 229,500	42.7 million

Air pollution knows neither political nor administrative boundaries. The emissions from the high stacks also find their way into the states with limited generation capacity or no generation capacity, which is evident from the extracts of the health burden assessments at the state level in **Table 8**. The most populated states of Maharashtra, Uttar Pradesh, Bihar, Andhra Pradesh, (including Telangana), Odisha, Madhya Pradesh, and West Bengal, which also harbour the largest clusters of the power plants are listed with the most number of premature deaths associated with the emissions from coal-fired TPPs. The northeastern states experience the effects of long-range transport.

Table 8: Estimated health impacts by state due to $PM_{2.5}$ pollution from the coal-fired TPPs in India

	2017	2020	2025	2030
Andhra Pradesh	9,870	12,170	15,170	17,510
Arunachal Pradesh	70	90	110	130
Assam	1,780	2,160	2,800	3,300
Bihar	9,450	11,070	14,410	16,410
Chhattisgarh	3,870	4,610	5,600	6,340
Delhi	1,520	1,640	1,880	2,090
Goa	120	140	180	200
Gujarat	4,300	4,880	5,890	6,690
Haryana	2,080	2,260	2,630	2,940
Himachal Pradesh	280	300	370	410
Jammu & Kashmir	360	400	480	530
Jharkhand	4,120	4,940	6,340	7,190
Karnataka	5,170	6,340	7,940	9,160
Kerala	1,660	2,000	2,530	2,980
Madhya Pradesh	6,790	7,970	9,700	10,940
Maharashtra	11,580	13,860	16,870	19,010
Manipur	180	220	280	330
Meghalaya	190	230	300	350
Mizoram	70	90	110	130
Nagaland	130	160	200	230
Odisha	6,100	7,560	9,380	10,740
Punjab	1,470	1,600	1,920	2,140
Rajasthan	4,340	4,860	5,800	6,510
Sikkim	30	30	40	50
Tamilnadu	5,080	6,110	7,650	9,020
Tripura	200	240	320	370
Uttar Pradesh	16,470	18,740	22,870	26,000
Uttarakhand	390	440	540	610
West Bengal	12,360	14,470	18,060	20,440

[20] The methodologies, a compilation of air pollution and health related studies worldwide, the dose-response functions and linked parameterisation to conduct health impact analysis, and the results of the global burden of disease assessments for 1990-2010 are presented by the Institute for Health Metrics and Evaluation (IHME) @ https://www.healthdata.org

4. ROLE of FLUE GAS DESULPHURISATION

Even with 55% of the installed coal-based generation capacity, there is a conspicuous lack of regulations for SO_2 emissions, which does not mandate the TPPs to operate any control equipment. Only four coal-fired TPPs in India operate flue gas desulphurization (FGD) units and among those to be commissioned through 2030, only 7 TPPs are listed to have FGD. The ones currently operating a FGD are (a) Tata power in Trombay (in Mumbai) (b) BSES/Reliance at Dahanu (western Maharashtra) (c) Jindal (JSW) TPP at Ratnagiri (southwestern Maharashtra) and (d) Udupi TPP (coastal Karnataka). At the remaining coal-fired TPPs, the emissions are dispersed from the stack.

Box 3: Sulphur Emission Control Systems

The sulphur emission control systems could range from in furnace control via limestone injection, wet scrubbing of flue gas, to capturing SO_2 in the flue gas through industrial processes.

Limestone Injection - is an in-furnace process, where the crushed coal and limestone are passed together into the boiler as a fluidized mixture with hot air. The sulphur from combustion gases then combines with the limestone to form a solid compound, rather than being released as SO_2 in the flue gas. This is a low capital cost, low feed rate, and low operating cost technology with, co-benefits of mercury control and capture, during the coal burning process. This technology achieves emission reduction rates of 50-60%, making it an attractive option. These technologies require a high sorbent-to-sulphur ratio to achieve sufficient reduction rates and consequently, also produce large amounts of waste material (solids other than ash from the boilers), the disposal of which faces increasing difficulties.

Wet Flue Gas Desulphurization - is the most commonly used process with typical sulphur removal rates of 90% at moderate costs. This method includes application of wet limestone scrubbing or a spray dryer process on the flue gas, after the combustion, to form gypsum as a by-product. A wet FGD flue gas treatment system is usually located after removal of PM via an electrostatic precipitator (ESP) and the cleaned gas is discharged to the stack for further dispersion. Gypsum can be used, for producing building material.

High Efficiency Regeneration - process is a relatively expensive compared to the other two processes and produces SO_2 rich gas (~97%) which can be used as raw input in chemical industry to produce sulphuric acid or even elementary sulphur. Caustic soda (sodium hydroxide) is used as sorbent, which is regenerated to keep the sorbent losses to the minimum. Typical sulphur removal rate of more than 98% is possible, along with tons of commercial by-products.

In India, only three coal-fired TPPs in Maharashtra and one in Karnataka operate FGD systems. According to the Ministry of Environments and Forests, installation of FGD is in process at NTPC Bongaigaon (Assam), NTPC Vindhyachal stage-V (Uttar Pradesh), and Adani Power Mundra Ph-III (Gujarat) (PIB, 2012).

The Trombay TPP (TTPP) (in Mumbai) uses sea water's natural alkalinity to scrub SO_2 from the flue gas. After neutralisation with sea water from the cooling water heat exchanger, the effluent is discharged into the sea. The removal efficiency is estimated at 85-90%. Because of the use of sea water for scrubbing (and no additional sorbent), the designing and operations are performed at the low cost. A disadvantage, however, is that the pollution is discharged into the sea, which in the long run leads to marine contamination.

The Dahanu TPP (DTPP), started its commercial operation in 1996. As part of their consent and environmental clearance conditions, they were required to install a FGD system for environmental safety and protection and for the well-being of the people of Dahanu. However, the FGD was only installed after an order dated 12th May 1999 was passed by the Bombay High Court. This 2x250 MW plant uses 80% local coal from the Korba mining areas (Chhattisgarh) and remaining 20% imported from Indonesia and South Africa. DTPP also utilises sea water for scrubbing and cooling in its FGD plant.

The 2x600 MW Udupi TPP (UTPP) (near Mangalore, on the west coast), started its commercial operations in 2010 and operates limestone injection and gypsum production system, to control SO_2 emissions. This FGD technology is a zero discharge system utilising all wastewater in the system, thus reducing the need for fresh water and eliminating waste disposal costs.

According to Prayas Energy Group[21], only 7 plants with a total of 5448 MW capacity, or just 3.2% of the total coal-fired thermal power capacity that has been granted environmental clearance, have a provision for installing and operating a FGD. With no mandatory requirements, in all the proposed TPPs, the only condition stipulated is that space must be provided for the installation of a FGD plant, if required in the future.

So, if FGDs are in fact mandated for all the future TPPs in India, what can we expect?

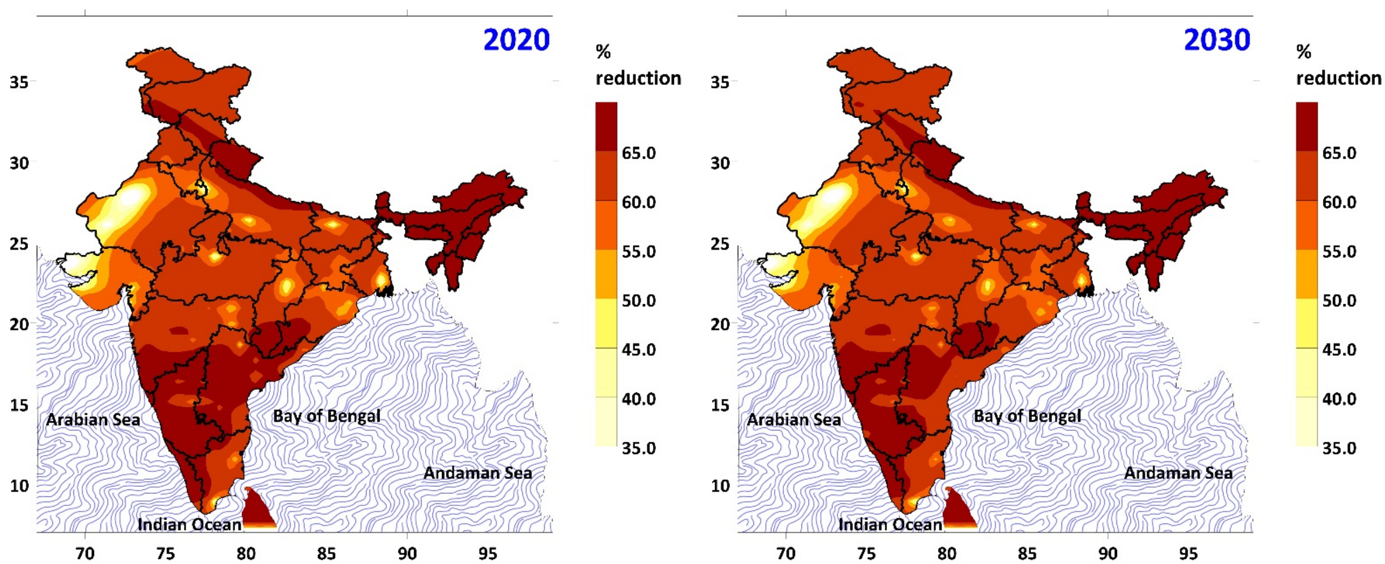
An immediate benefit is for the human health. The share of the secondary sulphates contributing to the ambient $PM_{2.5}$ ranges up to 40% and can be as high as the 60% for the denser clusters. By controlling sulphur emissions either during the combustion, which can achieve up to 60% removal or post combustion, which can achieve up to 98% removal, the overall health impacts due to the coal-fired TPPs can be reduced accordingly.

For example, for 2011, the health impacts calculated for the modeled $PM_{2.5}$ pollution from the coal fired TPPs, ranged between 80,000 and 115,000 per year. With application of FGD systems for all these TPPs, this could have been reduced by at least 26,000 (for 60% removal efficiency) or 38,000 (for 95% removal efficiency). Even a conservative value of INR 2,000,000 (approximately USD 40,000) per life lost, based on the average life insurance policy's issued in India, the estimated benefits range between INR 5,100 to 7,600 crores (approximately USD 0.9 to 1.3 billion) annually, enough to justify the costs of implementing and operating a FGD at every existing coal-fired power plant. For the operational coal-fired TPPs and the proposed coal-fired TPPs, the benefits of operating a FGD are at large, and only require a mandate from the Ministry of Environment, Forests, and Climate Change, to reduce this burden.

[21] Prayas Energy Group (Pune, India) "Thermal TPPs on the Anvil – Implications and Need for Rationalisation" @ http://www.prayaspune.org/peg/publications/item/164-thermal-power-plants-on-the-anvil-implications-and-need-for-rationalisation.html

Table 9: Anticipated health impacts of planned coal-fired TPPs and likely number of lives saved by operating a flue gas desulphurization unit at all the coal-fired TPPs in India			
	Premature mortality under no FGD	**Lives saved under 60%- and 95%- FGD efficiency**	**Monetary benefits under FGD (crores)**
Year 2017	112,500 – 126,000	39,000 – 63,000	7,800 – 12,600
Year 2020	132,500 – 153,500	45,000 – 74,000	9,000 – 14,800
Year 2025	164,000 – 197,500	54,500 – 90,500	10,900 – 18,100
Year 2030	186,500 – 229,500	61,000 – 101,500	12,200 – 20,300

Figure 11: Percentage change in the $PM_{2.5}$ concentrations upon implementation of FGD (with 95% efficiency) in all the proposed TPPs



The co-benefits of a FGD system extend to other pollutants. For example, in the wet FGD process, the particulate matter is also trapped in the sorbents, resulting in further removal of the PM emissions. The FGD system is applied after the flue gas passes through an ESP, which is known to deliver up to 99% PM removal efficiency, which is further improved when the flue gas passes through a post-combustion FGD system. Given the volume of the coal consumed in India and the ash content, even a fraction of improvement in the PM removal efficiency will result in large benefits for ambient PM concentrations and health impacts.

5. IN RETROSPECT

To meet the growing electricity demand in India's urban and rural regions, the expansion of the coal-fired TPPs is the most likely scenario, which also leads to an array of health impacts. There is growing evidence in the scientific community on the health impacts associated with the air pollution from the coal-fired TPPs, reviewed and published as part of the GBD assessments. The technology improvements worldwide are also showing ways to make the electricity generation cleaner and safer for the environment. Keeping that in perspective, the conclusions of this study are the following

Benefits of mandating FGD for the existing and the newly commissioned coal-fired TPPs is obvious. This is not only to reduce the emission loads at the plants for SO_2 and NO_x, but also to arrest the formation of the secondary sulphates and secondary nitrates at the regional level, which form due to atmospheric chemical reactions downwind of the source regions; and further add to the overall health impacts. A conservative estimate, in terms of lives saved, of operating a FGD, at all the plants through 2030 is upwards of 50%.

To date, the pollution standards for SO_2 and NO_x emissions exist only for ambient air quality, measured at select locations in major cities, and not for individual TPPs. The same cities also implemented interventions to reduce the SO_2 emissions, such as low-sulfur diesel and relocation of the heavy industries, which resulted in the reduction of the SO_2 ambient concentrations in the cities, as measured at the select monitoring locations. This tends to give a false impression that the SO_2 emissions and the SO_2 ambient concentrations are dropping across the country. Solution to this issue is a two step process (a) emission standards need to be regulated at the TPPs, which can lead to implementation of any form of the FGDs discussed in this report and (b) only after the standards are regulated at the plant level, can we proceed to the next steps of monitoring and enforcing, and reduce the impact of emissions from coal-fired TPPs.

The environmental impact assessment procedures are archaic and need to be revised, in order to include the health and environment damages due to long-range transport of pollution from the coal-fired TPP stacks, as high as 275m. Currently, the procedure requires assessment for an area of 10km radius from the plants. Given the stack height, stack diameter, exit temperature, and exit velocity of the flue gas at most of these TPPs, these emissions tend to travel farther, more than 300km in less than 24 hours, which means that the stipulated 10km radius does not capture the true nature of the impact of the TPPs on environment and health.

The newly commissioned TPPs and the proposed TPPs are expected to operate at higher performance levels, than those observed in the past, and thus reducing the coal consumption levels per MWh. The efficiency improvement of the older TPPs, irrespective of the boiler size, should become a starting point for reducing overall coal consumption and associated atmospheric emissions.

The stack emissions can be monitored relatively easily as compared to non-point sources (such as vehicles, garbage burning, domestic burning, and fugitive dust). While, the larger TPPs are now required to operate continuous stack monitors, this information is not open to public, either for analysis or for scrutiny of the emission loads. This adds to the uncertainty of similar studies. Besides strengthening standards, new policies are required for dissemination of information from the coal-fired TPPs. The Central Pollution Control Board operates and maintains website to collate and disseminate the information from the continuous monitorng stations in the cities. A similar platform or the same platform should be utilised to collate and disseminate information from the coal-fired TPPs in real time.

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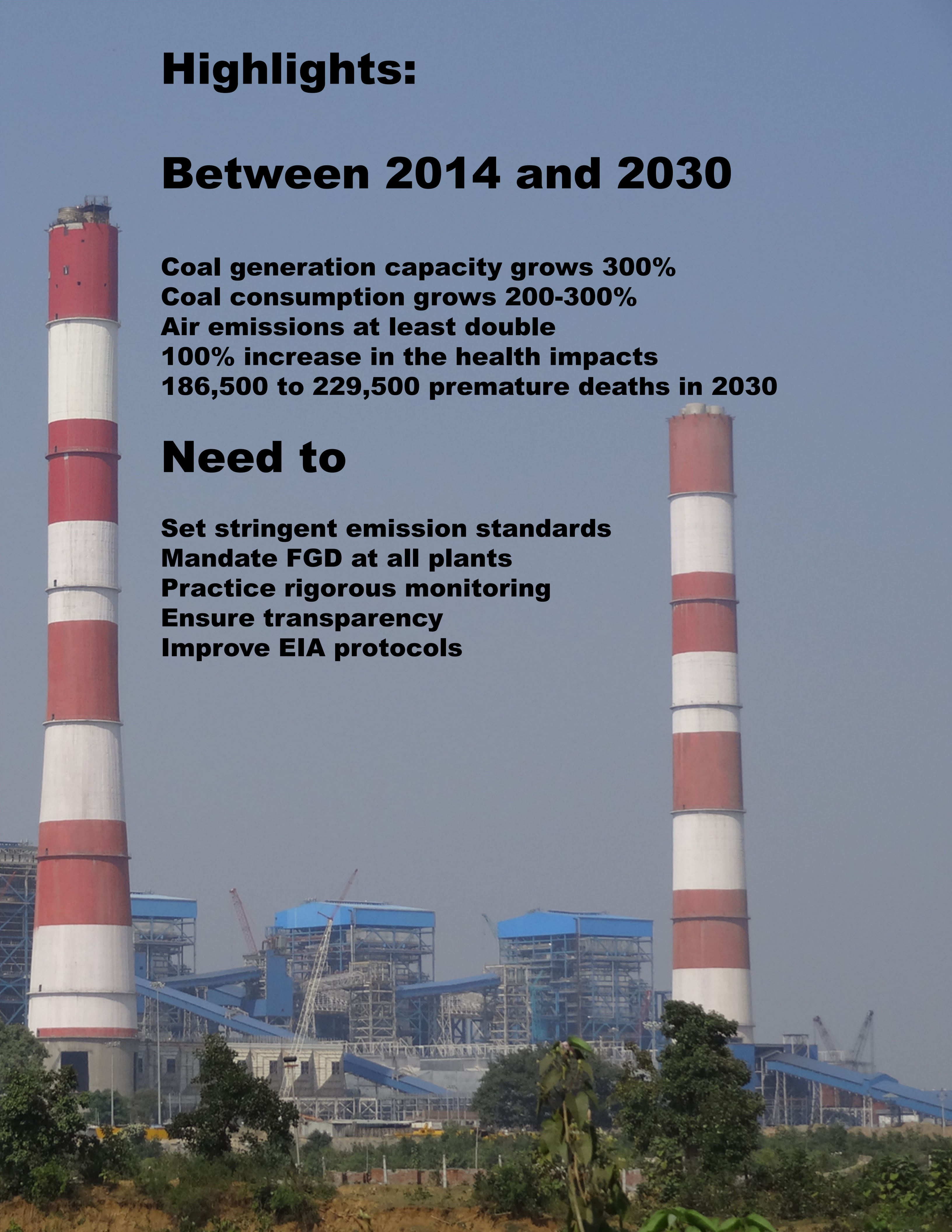

Highlights:

Between 2014 and 2030

Coal generation capacity grows 300%
Coal consumption grows 200-300%
Air emissions at least double
100% increase in the health impacts
186,500 to 229,500 premature deaths in 2030

Need to

Set stringent emission standards
Mandate FGD at all plants
Practice rigorous monitoring
Ensure transparency
Improve EIA protocols

Conservation
ACTION TRUST

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