4 POWER SECTOR

4.1 Coal-based thermal power plants

In India, more than 50% of the electricity demand is met through coal-based thermal power plants (TPPs) (Singh and Siddique, 2013; TERI, 2015). Large quantities of coal is burnt annually in the TPPs, which leads to the production of fly ash and bottom ash. Particulate matter emissions from coal-based TPPs are linked to high ash content (which ranges between 20% and 40%) in Indian coal. Sulphur content in Indian coal (generally < 0.6%), leads to emission of SO_2 from TPPs. Emissions from coal-fired power plants are function of the quality of fuel (ash content and sulphur content), the type of boilers, and the types of air pollution control devices used and their efficiency. In addition to coal, natural gas is also used in power plants in India.

The equations (Eq. 9 and Eq. 10) used for estimation of emissions from coal-based power plants are:

$$[E_{PM}]_c = \sum_{a=1}^{n} [P_c]_a \times Ac \times (1-fb_r) \times M \times (1-RE_a) \quad (9)$$

$$[E_{pg}]_c = \sum_{a=1}^{n} [P_c]_a \times EF_{pg} \times (1-RE_a) \quad (10)$$

where, E_{PM} is the emission of particulates; E_{pg} is the emission of gaseous pollutants; $[P_c]_a$ is annual coal consumption in plant a; A_c is ash content of coal; fb_r is the ratio of bottom ash to total ash; M = particulate mass fraction (0.4 for $PM_{2.5}$ to PM_{10} and 0.75 for PM_{10} to total particulates following Mahtta et al., 2016); RE is the efficiency (%) of installed emission control equipment; and EF_{pg} is the emission factor of the particular gaseous pollutant (p).

Coal consumption (Pc) in each power plant for the year 2016 was taken from the CEA database. As per the CEA data, the total coal consumed by power plants in India for the year 2016 was 557,854 Gg. However, the MARKAL estimates of coal consumption in power sector during the year was 473,290 Gg, while MoSPI (2018) reported it as 527,256 Gg. The CEA (2016) reports plant-wise actual coal consumptions during January to December. However, MoSPI (2018) provides the data of total coal supplied to the power plant during FY2016–17. In general, power plants maintain a coal stock for three months, this attributes to variation in actual coal consumptions in power plants than supplied coal during a particular period. Plant-wise ash content (Ac) data was also taken from the CEA database. Expert consultations were organized to understand the type of boilers and efficiencies of air pollution control devices used in power plants. Ratio of bottom to total ash was taken as 20% because 20% of the total ash generated during combustion of coal is bottom ash and the remaining is fly ash (F.Bassetti et al., 2015; FHWA, 1998). It was understood after consultation from experts that all the coal- based TPPs in India are equipped with electrostatic precipitators (ESPs) to control PM emissions in order to meet the emission norms prescribed by the CPCB. A literature review was carried out to understand the

efficiency of ESPs used by TPPs in India and based on that, ESP efficiencies for 40 units were adopted from Chandra (2008). For rest of the units, average efficiency of all ESPs used by different TPPs of that particular state was assumed. During 2016, there were only three power plants in India that have FGD (Wet flue gas desulphurization) units in operation to reduce SO_2 emissions. These power plants are: Trombay TPS, Udipi TPP and Jindal TPP—whose sulphur removal efficiency is 90%. NO_x emissions from coal-based power plants in India are not controlled.

Emission factors for gaseous pollutants namely, SO_2, NO_x, CO, NMVOCs and NH_3 were selected based on review of published literature and the selected emission factors are shown in Table 6.

Table 6 Emission factors for coal-based thermal power plants in India

Pollutant	Emission factor
SO_2 (kg/Mg)*	7.37
NO_x (kg/Mg)**	4.50
CO (kg/Mg)**	0.30
NH_3 (Mg/PJ) ***	0.01
NMVOCs (Mg/PJ) ***	15.00

Source: *Mahtta et al., 2016;** ARAI, 2010; ***GAINS Asia database

4.2 Gas-based power plants

The equation (Eq. 11) used for estimation of emissions from gas-based power plant is:

$$[E_p]_g = \sum_{a=1}^{n} [P_g]_a \times EF_p \times (1-RE_a) \quad (10)$$

where, Ep is the emission of particular pollutant (p); [Pg]a is the annual gas consumption in power plant a; and EFp = Emission factor of the particular pollutant (p). Gas consumption (Pg) in each power plant for the base year was taken from the CEA database. The quantity of gas consumed for power generation in India for the year 2016 was about 11,067 MMSCM.

Fuel-specific emission factors (EFpg and EFp) of different pollutants were selected based on review of published literature. All the gas-based power plants in India are using selective catalytic reduction (SCR) for NO_x emissions reduction whose efficiency is about 85%. The selected emission factors for gas-fired TPPs in India are shown in Table 7.

Table 7 Emission factors for gas-based power plants

Pollutants	Emission factor	Pollutants	Emission factor
PM_{10} (kg / 10^6 m^3)	121.60	NMVOC (kg/ 10^6 m^3)	0.091
$PM_{2.5}$ (kg / 10^6 m^3)	121.60	NH_3 (Mg/PJ)	0.01
SO_2 (kg / 10^6 m^3)	9.60	HC (Mg/PJ)	1.00
NO_x (kg / 10^6 m^3)	4480.00	CO (kg / 10^6 m^3)	1344.00

Source: *ARAI, 2010; **GAINS Asia Database

4.3 Emission inventory of the power plant

PM_{10} emissions for the year 2016 are estimated to be about 572.5 Gg from coal-based power plants in India, out of which around 229 Gg are $PM_{2.5}$ (*Table 8*). For the same year, the estimated emissions of SO_2, NO_x, CO, and NMOVCs from coal-based TPPs in India are 5437, 2509, 167, and 80 Gg, respectively. However, NH_3 emissions from coal- based TPPs in India were estimated to be small (0.05 Gg).

Table 8 Emissions from coal-based power plants during 2016

Pollutants	Emissions (Gg)
PM_{10}	572
$PM_{2.5}$	229
SO_2	5437
NO_x	2509
CO	167
NMVOC	80
NH_3	0.05

The estimated emissions from gas-based thermal power plants in India are shown in *Table 9*. Emissions from both coal- and gas-based power plants were spatially distributed in 36 km × 36 km map based on actual coordinates of the thermal power plant.

Table 9 Emissions from gas-based thermal power plants during 2016

Pollutants	Emissions (Gg)
PM_{10}	1.35
$PM_{2.5}$	1.35
SO_2	0.11
NO_x	7.44
CO	14.87
NMVOC	0.001
NH_3	0.005