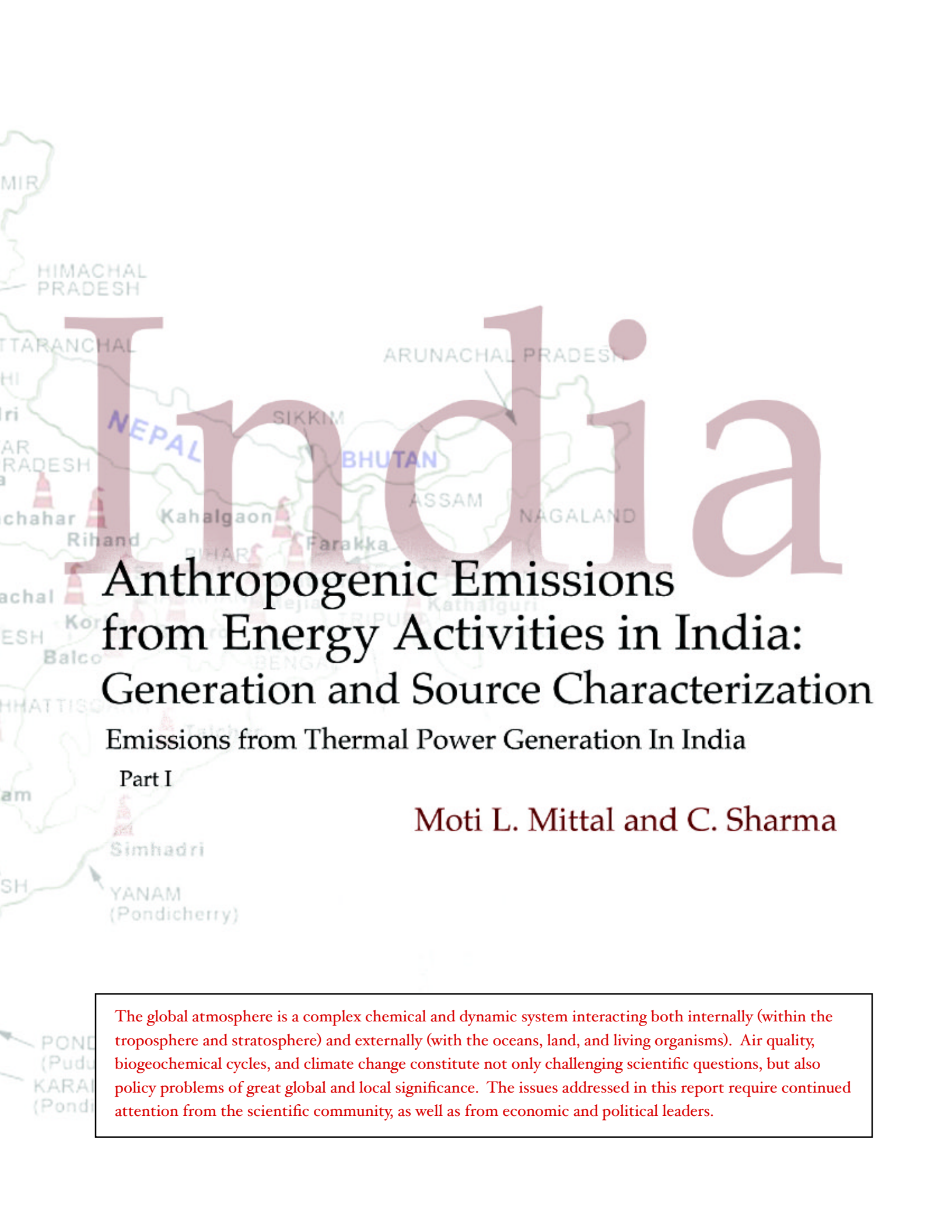




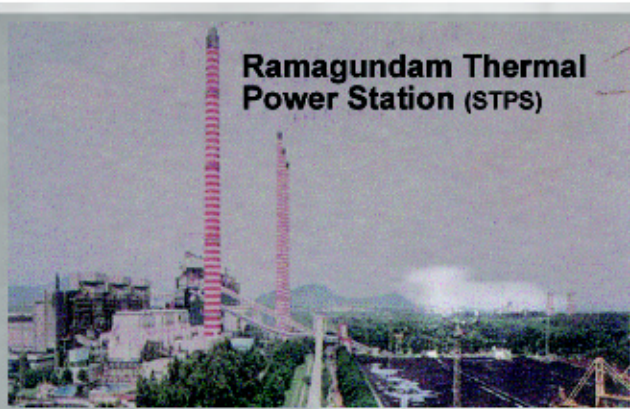
Anthropogenic Emissions from Energy Activities in India: Generation and Source Characterization

Emissions from Thermal Power Generation In India

Part I

Moti L. Mittal and C. Sharma

The global atmosphere is a complex chemical and dynamic system interacting both internally (within the troposphere and stratosphere) and externally (with the oceans, land, and living organisms). Air quality, biogeochemical cycles, and climate change constitute not only challenging scientific questions, but also policy problems of great global and local significance. The issues addressed in this report require continued attention from the scientific community, as well as from economic and political leaders.



Ramagundam Thermal Power Station (STPS)



Talcher Thermal Power Station (STPS)



Chandrapur Thermal Power Station (STPS)



Faridabad Thermal Power Station

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Environmental Impact of Emissions from Thermal Power Generation In India

Introduction

India is the world's fourth largest economy and has a fast growing energy market. India's current power capacity is approximately 8.3% short of demand with peak load shortages of 13%, whereas in 1996-97, power capacity was 11.5% short of demand with peak load shortage of 18%¹. Coal and petroleum are the primary sources of energy. High ash content in Indian coal and inefficient combustion technologies contribute to India's emission of air particulate matter and other trace gases, including gases that contribute to climate change. The USAID/India's Office of Environment, Energy & Enterprise promotes clean energy development through efficient energy use and pollution reduction. This organization has sponsored the project, *Anthropogenic Emissions from Energy Activities in India* to assess the emissions of greenhouse and other trace atmospheric gases from energy activities in India.

This analysis aims to look at India's present and projected inventory of emissions, study the transport and distribution patterns of emitted pollutants, and develop a long-term air quality database covering the country's various geographical areas. Part I gives estimates of emissions of greenhouse and other trace gases including suspended particulate matter and soot carbon from India's coal-based thermal power plants. The emission estimates are made for each power plant based on power generation per day and the coal used per unit generation of power, based on the information provided in various public documents².

This portion of the study is now complete and this report summarizes the results. It is meant to be used as a quick reference for policy makers, researchers, and practitioners interested in the links between energy use and air emissions in India. Part II of the research deals with the emissions from the vehicular transport using petroleum fuels. This study is currently in progress. The next phase of the project will involve the transport and distribution patterns of emitted pollutants and the development of a long-term air quality database for the Indian region.

Energy Use in India

India's population, second largest in the world, grows at a rate of about 2% per year³ and has grown from 300 million in 1947 to more than a billion today. Rising population and changes in lifestyles consistent with rapid economic growth have accelerated the energy demand. Energy consumption in India has grown 7,000% from 1950 to 1998. The present annual growth rate of electric power consumption in India is 4%². Per capita electric consumption in India in the year 1997 was 427.8 kilowatt-hr (KWH), compared to 12,307 KWH in the United States and 804.8 KWH for China⁴. To ensure 'Power on Demand,' India will require an additional generating capacity of 100,000 MW by the year 2012.

Fossil fuels are the main source of energy and also, unfortunately, of pollutants, greenhouse gases, and other trace atmospheric varieties of gases. Coal is the primary fuel in thermal power plants; gasoline and diesel are the primary fuels for automobiles. There is also limited use of natural gas in these energy activities.

¹ Ministry of Power, Government of India, Annual Report 2001-02 (www.powermin.nic.in)

² Coal Stocks position of Thermal Power Stations: CEA No.1/2/1998-OMD and Daily generation report-State Electricity Board wise (www.cea.nic.in/data/opt2-daily_coal.htm and www.cea.nic.in/data/opt2_seb.htm)

³ World Development Indicators – annual report of the World Bank on development indicators (www.worldbank.org/data/wdi2000/pdfs/tab3-7.pdf, [tab3-8.pdf](http://www.worldbank.org/data/wdi2000/pdfs/tab3-8.pdf), and [/countrydata/aag/ind-aag.pdf](http://www.worldbank.org/data/wdi2000/pdfs/countrydata/aag/ind-aag.pdf))

⁴ International Energy Annual (www.eia.doe.gov)

Thermal Power in India

According to the National Thermal Power Corporation, coal is used for approximately 62.3% of India's electric power generation; oil and gas account for 10.2%; hydropower contribute 24.1%; nuclear, wind, and other power generation methods contribute to the remaining 3.4% of the power generated. Thermal power generation in India grew from 178,713 Giga Watt Hours (GWH) in 1990-91 to 386,226 GWH in 1999-2000. However, the shortfall between peak demand and available power came down only from 18.3% in 1995-96 to 11.6% in 2000-01. The shortfall for base power came down from 9.2% in 1995-96 to 7.5% in 2000-01. Figure 4 shows the state wise distribution of the installed generating capacity of 93249 MW as on March 31, 1998. India estimates that 100,000 MW of fresh capacity (over and above present installed capacity) will have to be installed over the next 12 years to meet its future power need to support economic rate of growth of about 6% per year.

The total installed capacity for electric power generation during the year 1997-98 for which this study is carried out was 89166.87 MW, consisting of 64150.78 MW of thermal power. Thermal (coal, gas, and oil) power generation in this period was 300,730 GWH and the total electricity generation exceeded 460,000 GWH by all of the prime sources (Steam, Gas, Diesel, Wind, Nuclear, and Hydro)⁵. This includes electricity generation by utilities and captive plants (electricity generation by other industries for their own use). Captive plants generate approximately 10% of the electricity. Public utilities primarily use steam in the generation of power.

India is the third-largest producer of coal, but Indian coal is of poor quality with high ash content (35-50%) and low calorific value (gross heat of combustion). A major portion of the ash is inherent in the coal, aggravating the difficulty in removing it.

To illustrate this point, comparisons of coal samples used at an Indian coal-fired power plant (Chandrapur) with that of Ohio (USA) coal are given in Table 1. The calorific value of Ohio coal is almost twice that of Chandrapur coal. To generate the same amount of steam (for electricity), the amount of Indian coal required is almost twice as that of Ohio coal.

Table 1: Comparison (Ultimate analysis) of Chandrapur and Ohio coal

		Chandrapur (India)	Ohio (USA)
1	Fixed carbon	27.50%	44.0%
2	Total carbon	37.69%	64.2%
3	Hydrogen	2.66%	5.0%
4	Nitrogen	1.07%	1.3%
5	Oxygen (difference)	5.78%	11.8%
6	Sulfur	0.80%	1.8%
7	Ash	47.00%	16.0%
8	Total moisture	5.00%	2.8%
9	Gross calorific value Kcal/Kg	3700	6378
10	Coal per unit of electricity (Kg/KWH)	0.77	0.36

⁵ Annual report of the Ministry of Power for the year 1997-98 (www.powermin.nic.in/ar97-98.pdf)

According to the Central Electricity Authority of India, as of March 31, 1998, 83 coal fired plants were in operation in India. These plants generated almost 60% of total generated power for the nation. Appendix-A gives a listing of the thermal power plants along with power and coal usage statistics.

Coal consumption by various plants in the country during the year 1997-98 was almost 252 million metric tons. The consumption of fuels such as furnace oil decreased by more than 32.5%, while the consumption of lignite coal, low-sulfur heavy stock (LSHS), high sulfur heavy stock (HHS), and diesel oil increased by 7.54%, 31.91% and 33.9%, respectively. Decreased use of furnace oil during last three years has decreased the emissions to some extent.

Emissions from Thermal Power Plants

The main emissions from coal combustion at thermal power plants are Carbon dioxide (CO₂), Nitrogen oxides (NO_x), Sulfur oxides (SO_x), Chlorofluorocarbons (CFCs), and air-borne inorganic particles such as fly ash, carbonaceous material (soot), suspended particulate matter (SPM) and other trace gas species. Carbon dioxide, nitrous oxide, and chlorofluorocarbons are greenhouse gases. Evidence accumulated by the Inter-governmental Panel on Climate Change (IPCC) suggests that emission of these greenhouse gases might be responsible for climate change, a global concern. Possible consequences projected by IPCC include:

- a rise in sea levels
- a more vigorous hydrological cycle that may increase the severity of floods and droughts and may cause more extreme climatic events; and
- ecological change that could threaten agricultural productivity

Oxides of nitrogen and sulfur, also play an important role in atmospheric chemistry and are largely responsible for atmospheric acidity. Particulates and black carbon (soot) are of concern in the radiative⁶ forcing of the earth. They also have a significant negative impact on human health causing lung tissue irritation and are linked to cancer and other serious diseases.

In this study, CO₂, SO₂, nitric oxide (NO), SPM, and soot emissions from each of the thermal (coal-fired) power plants in India have been computed using basic principles of combustion. This is one of the many available methods for emissions inventory. These methods are based on guidelines published by IPCC⁷. The present calculations are based on publicly available data², such as chemical composition of the coal used in the power plants, coal used per unit of power, excess air used during combustion, and the power generation from each plant. Emissions from combustion of the supplementary fuels such as high-speed diesel (HSD) and furnace oil used in small quantities (<1%) are not counted in the present calculations.

During the year 1997-98, 336 billion KWH of electricity was generated from these power plants. Table 2 gives the GHGs emissions from the power plants at a national as well as regional level for the year 1997-98. The division of the region is as defined by the power sector.

⁶ Radiative forcing is defined as a change in the average net radiation. It is based on global balance between incoming solar energy and outgoing terrestrial radiative energy that is emitted to space.

⁷ Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, Edited by JT Houghton et al., IPCC/OECD/IEA, UK Meteorological Office, Bracknell

Table 2: Region wise and national emissions

Region		CO ₂	SO ₂	NO	C(Soot)	SPM	TPD = Tons per day gm/KWH = Grams per unit of electricity ⊗ SO₂ emissions in Western and Southern regions are high due to higher sulfur content in lignite and Chandrapur coal, and in Eastern region due to low efficiency.
Northern	TPD	280,455.00	1,756.00	2,182.00	17.00	622.00	
	gm/KWH	990.00	6.20	7.70	0.06	2.20	
Western	TPD	376,080.00	2,852.00	2,765.00	23.00	793.00	
	gm/KWH	956.00	7.25 ⊗	7.00	0.06	2.00	
Southern	TPD	214,030.00	1,587.00	1,600.00	13.00	576.00	
	gm/KWH	1,001.00	7.40 ⊗	7.50	0.06	2.70	
Eastern	TPD	209,700.00	1,388.00	1,330.00	13.00	530.00	
	gm/KWH	1,050.70	7.00 ⊗	6.60	0.06	2.60	
North-eastern	TPD	1,175.00	8.00	9.60	0.07	2.20	
	gm/KWH	877.00	5.80	7.20	0.05	1.70	
Country Total	TPD	1,081,440.00	7,592.00	7,887.00	67.00	2,524.00	
	gm/KWH	991.00	6.96	7.20	0.06	2.30	

Carbon dioxide emissions

Utilities burn mostly coal with approximately 10–30% excess air. The total coal-carbon obtained from analysis is converted to CO₂ after the reaction (combustion) is complete. Total CO₂ emissions for the year 1997 from all the power plants in India are estimated at 333 million tons, while the average CO₂ emission per unit of electricity is estimated at 991 gm/KWH. In USA, total CO₂ emissions for the year 1995 from the electric utilities using coal are estimated as 1590 million tons⁸, while CO₂ emission per unit of electricity is estimated at 962 gm/KWH in the year 1995 and 917 gm/KWH in the year 1998.

Technological improvements in efficient combustion of coal can lead to greater production of electricity per unit of coal that will effectively reduce CO₂ emission per unit of electricity. Although the current per capita CO₂ emission in India is only one quarter of the world average and about twenty times less than United State's averages, the growth rate of emissions is very high. India's low per capita emission is compensated for by its one billion population, making it the sixth largest greenhouse gas emitter in the world. High population, a growing economy, and inefficiencies in the energy sector means India is likely to emit ever increasing amounts of greenhouse gases, such as CO₂ and other air pollutants unless appropriate measures are taken.

Sulfur dioxide emissions

The sulfur content in Indian coal is low compared to United States coal. Acid rain due to sulfur dioxide emissions is presently not monitored, but is projected to become a problem under business as usual projections. A recent study by Boudry, et.al⁹. shows India exceeding critical thresholds of acidification by the year 2020. Increasing coal use or blending Indian coal with imported coal of higher calorific value (further increasing electricity production) needs to be carefully addressed through viable technological options. At present, there are no controls for sulfur dioxide emissions in India. Average SO₂ emission per unit of electricity is estimated at 7.6 (gm/KWH). Total SO₂ emissions are estimated to be 2.3 million tons for the year 1997. This compares to 10 million tons yearly and 6 (gm/KWH) per unit of electricity in USA for the year 1995⁷.

⁸ Electric Power Annual 1995, Volume 2. Energy Information Administration, Department of Energy, Washington D.C. DOE/EIA-0348(95)/2. December 1996

⁹ Energy Policy, April 2002

Emissions of oxides of nitrogen

Oxidation of nitric oxide (NO) discharged in combustion products forms nitrogen dioxide (NO₂) in the atmosphere. These oxides of nitrogen form photochemical smog. Oxidation of atmospheric nitrogen during combustion of the fuel forms NO. Chemically bound nitrogen within the fuel has a very small contribution to NO formation. NO formation largely depends on the excess air used during combustion and the gas temperature in the boiler, besides other factors, such as type of boiler and burner, air introduced in boiler, etc. The present estimations are based on temperature and excess air considerations only. An average temperature of 1700 K is used for these calculations. Excess air varies 10% to 30% in the plants. NO emissions per unit of electricity are estimated as 4.8 gm/KWH. This compares to a US average⁷ 3.5 gm/KWH for the year 1995. Total NO emissions are estimated to be 5.3 million tons for the year 1997. NO_x emissions in USA from electric utilities using coal for 1995 are estimated as 6 million tons.

Nitrogen oxides are important chemical species in the atmosphere since they contribute to its acidity; they also act as precursor gases for the formation of tropospheric ozone. Tropospheric ozone is a greenhouse gas responsible for global warming and is also known to have an adverse affect on plants.

Particulate Matter:

Carbonaceous material (soot) and suspended particulate matter (SPM)

Incomplete and/or inefficient combustion processes of fossil fuel generate carbonaceous material, known as soot. Soot is formed under fuel-rich conditions, the carbon particles formed agglomerating to form a chain-like structure. Soot analysis ranges from C₈H to C₁₂H and soot particles are essentially sub-micronic (i.e. less than one micron). Present calculations estimate emission of soot particles as 0.02 million tons for the year 1997 and 0.061 gm/KWH per unit of electricity from Indian thermal power plants.

A recently conducted Indian Ocean Experiment (INDOEX) suggests that the presence of soot carbon in the atmosphere over the northern Indian Ocean hinders its natural heating processes by about 15%. Enhancement of boundary layer heating can significantly influence regional hydrological cycles and climate. Soot emissions in India have not been studied thoroughly so far; these are the first estimates of soot emission from Indian thermal power plants. Appropriate technological intervention to prevent soot carbon formation may possibly not only reduce the chances of soot escaping into the atmosphere (where it can potentially change the radiation balance), but can also lead to further increases in electricity production.

The size of airborne SPM could be from sub-micron to as big as about 25 micron. SPM emissions are estimated as 2.3 gm/KWH per unit of electricity and 0.8 million tons for the year 1997. The detrimental impacts of Suspended Particulate Matter (SPM) on human health in India are a matter of great concern. SPM estimates are based on the assumption that all the plants are fitted with electrostatic precipitators which work at 99% efficiency.

These emission estimates are based on theoretical calculations, as mentioned earlier. Real conditions may differ from the ideal (theoretical) conditions. At present, controls for SO₂ or NO_x are not in use in India. These estimates, which do not account for controls, provide a basis for further work.

Electric Power generation and emission trends

Electric power generation from coal-fired power plants in India is continuously increasing. Based on the data from the Central Electricity Authority¹⁰, emissions per unit of electricity and annual emissions are estimated. Emissions per unit of electricity from these plants are decreasing, while the total annual power generation and emissions are increasing. Figure 1 gives the trend in emissions (per unit of electricity) and Figure 2 shows the power generation and emissions for the period 1994-95 to 1997-98.

Figure 1: Trends in emissions (kg/KWH) for 1994-95 to 1997-98

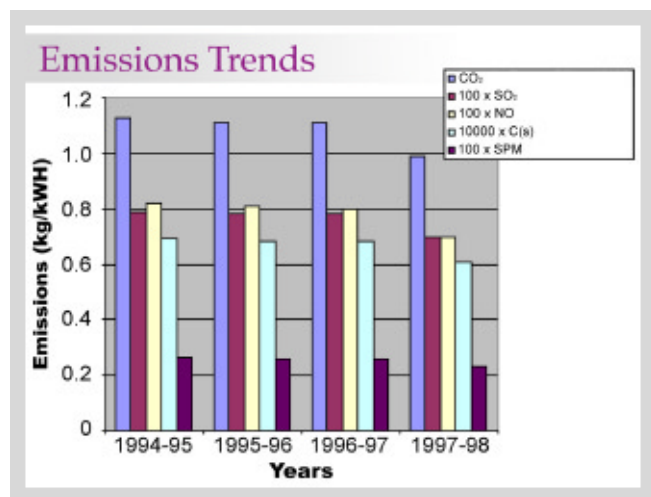
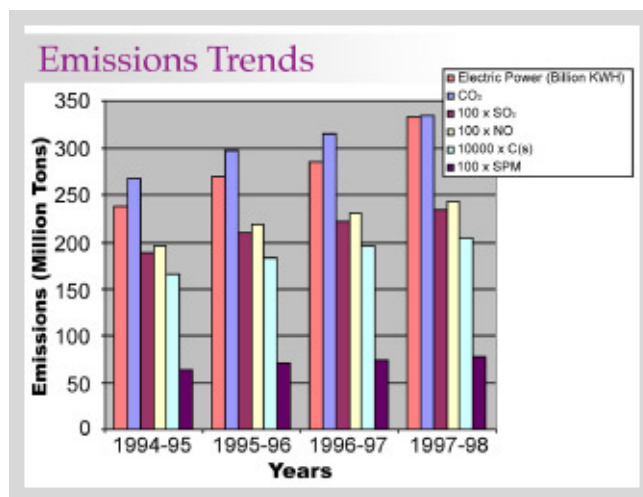


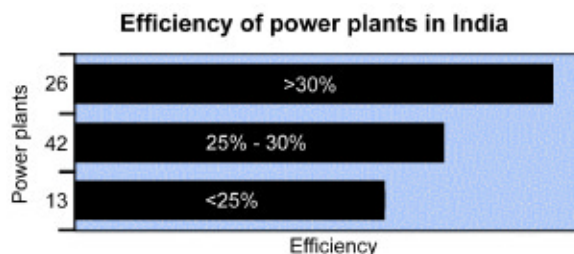
Figure 2: Yearly electric power generation and emissions during 1994-95 to 1997-98



Next Steps and Recommendations

1. This study provides a viable methodology for inventory process from energy activities in India. The emission estimates are based on a theoretical ideal and the input data available from the published information. Currently, the methodology used in this study is most suitable for the conditions in India. The results provide a valuable benchmark and should be followed with efforts to increase the accuracy with more realistic input information and measurement verification/validation.
2. As found out from the calculation carried for this study, most power plants in India are running at an efficiency rate of 20-30%, compared to the efficiency rates of 35-38% in the US. Figure 3 gives an estimate of efficiency ranges of power plants in India.

Figure 3: Efficiency of power plants in India



The reason for inefficient combustion should be probed and corrective measures may be taken to modernize India's plants. These actions will reduce national emissions as well as increase electricity production.

¹⁰ Performance Review of Thermal Power Stations, Central Electricity Authority, New Delhi -11006

- It is estimated that a 1% to 2% increase in heat rate improvements¹¹ leading to efficiency improvement will result in a 1% to 2% decrease in emissions per unit of electricity. This translates to reduction of 3.967 to 7.934 million tons of CO₂, 0.027 to 0.054 million tons of SO₂, 1967 to 3934 tons of NO, 245 to 490 tons of soot, and 9681 to 19,362 tons of SPM per year. The reason for inefficient combustion should continue to be probed and corrective measures (e.g. Heat rate improvement Guidelines for Indian Power Plants, USAID/TVA/NTPC, June 2000) taken to modernize India's Power plants. Continued promotion of activities like USAID's Greenhouse Gas Pollution Prevention program in association with the U.S. Department of Energy and NTPC's Center of Power Efficiency and Environmental Protection show tremendous potential to reduce national emissions as well as increase electricity production.
- For example, Dahanu Power Plant of BSES in Maharashtra uses Dipka coal after beneficiation. Table 3 gives the elemental analysis of Dipka Raw Coal before and after beneficiation.

Table 3: Ultimate analysis of Dipka Raw coal

Ultimate Analysis	As received	After beneficiation
Hydrogen	3.73%	4.25%
Carbon	42.39%	48.32%
Nitrogen	0.82%	0.93%
Sulfur	0.39%	0.44%
Oxygen	14.21%	16.20%
Ash	38.46%	30.00%
Heating value (Net calorific value)	4137.7 kcal/kg	4710 kcal/kg

After coal beneficiation, coal usage per unit of electricity at Dahanu plant will reduce to 0.54 from 0.62 (kg/KWH). This will increase the efficiency and reduce the emissions. CO₂ emissions will reduce from 848 gm/KWH to 842 gm/KWH along with the reduction in SPM emissions.

- Efficiency gains of about 1% by using beneficiation coal by the power plants over and above the efficiency gained by heat-rate improvement can further reduce the GHG emissions from the power plants in India¹².
3. Regulations for NO_x and SO₂ emissions along with technologies for their control should be considered.
 4. Dispersion and transport of emitted pollutants over the entire Indian region need to be mapped to better understand the impact on the climate, as well as on human, animal, plant, and ecological systems.
 5. Further research is needed on population exposure to these polluting gases. Effects of pollutants and power plant density should be studied.

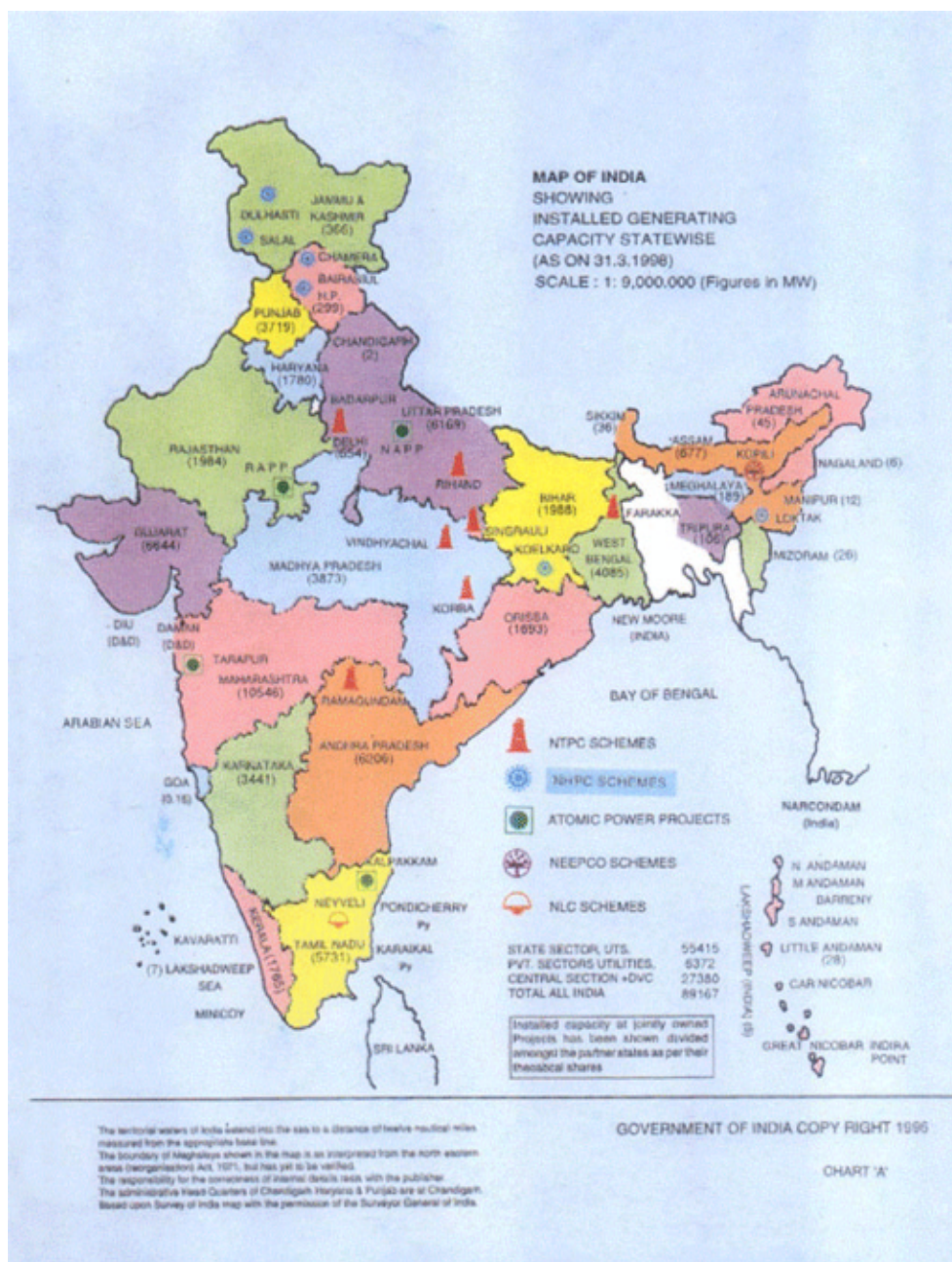
¹¹ Heat Rate improvement Guidelines for Indian Power Plants - USAID/TVA/NTPC, June 2000

¹² The Government of India is taking steps to control the emissions of pollutants from thermal power plants. In order to minimize fly ash generation, the ministry of environment and forest recommended the use of beneficiated coal in power plants. A Gazette notification has been promulgated under EPA, 1986 on use of beneficiated/blended coal containing ash not more than 34% with effect from June 2001 for thermal power plants located 1,000 km from pithead and also those located in urban areas/sensitive areas/critically polluted areas, irrespective of their distance from pithead. This application will certainly improve the plant efficiency.

Some of these recommendations/suggestions need further studies. Dispersion and transport of emitted pollutants from energy activities over the entire Indian region and population exposure to these polluting gases will be part of the next phase of the project. Analyses of detailed air characteristics and the associated meteorological parameters, will help to understand and illustrate the full impacts of emissions of greenhouse gases and other pollutants on human health and climate in India.

To learn more about emissions in India, please visit www.osc.edu/perm/emissions or contact Moti Mittal, Director, Program for Computational Reactive Mechanics, at moti@osc.edu.

**Figure 4: Installed generating capacity state wise; Annual report (1997-98)
Ministry of Power (www.powermin.nic.in/arep10f.htm)**



Appendix-A

Power and coal usage statistics at the thermal power plants in India for 1997-98

Sr. No.	Power Station	Installed Capacity (MW/day)	Generation (MW/day)	Coal Usage (kg/KWH)	Million KWH/day (MU) TM	CO ₂ Emissions (kg/KWH)
1R	BADARPUR	705	502	0.81	14.87	1.076
2R	I.P. STATION	277.5	136	0.86	2.96	1.143
3R	RAJGHAT	135	62	0.83	1.93	1.103
4R	FARIDABAD	165	131	0.97	2.96	1.289
5R	PANIPAT	650	362	0.82	9.74	1.090
6R	BHATINDA	440	300	0.73	6.83	0.970
7R	LEHRA	420	425	0.73	9.96	0.970
8R	ROPAR	1260	840	0.70	22.67	0.930
9R	KOTA	850	856	0.75	20.40	0.997
10R	SURATGARH #	500	516	0.73	11.85	0.970
11P	ANPARA	1630	1630	0.70	37.71	0.930
12R	HARDUAGANG	385	135	1.02	3.07	1.355
13R	DADRI	840	653	0.65	18.9	0.864
14R	OBRA	1442	1014	0.88	21.30	1.170
15R	PANKI	274	165	0.9	3.56	1.196
16R	PARICHA	220	80	0.88	1.75	1.170
17P	RIHAND	1000	960	0.66	24.09	0.877
18P	SINGRAULI	2000	1545	0.61	44.06	0.811
19R	TANDA	330	195	0.96	4.9	1.276
20R	UNCHAHAR	840	826	0.74	19.66	0.983
21P	KUTCH @	215	166	0.73	3.65	1.389
22R	SABARMATI #	330	326	0.73	6.6	0.970
23R	DHURVARAN	534	348	0.73	8.23	0.970
24R	GANDHI NAGAR	870	722	0.60	17.09	0.797
25R	SIKKA	240	225	0.67	4.99	0.890
26R	UKAI	850	775	0.72	16.74	0.957
27R	WANAKBORI	1470	1048	0.67	25.14	0.890
28R	BHUSAWAL	478	445	0.79	10.80	1.050
29R	CHANDRAPUR	2340	1705	0.79	44.39	1.050
30R	DAHANU	500	412	0.62	10.77	0.824
31R	KHAPER KHEDA	840	630	0.76	14.84	1.010
32R	KORADI	1080	662	0.84	17.03	1.116
33R	NASIK	910	810	0.74	17.6	0.983
34R	PARAS	58	29	0.82	0.96	1.090
35R	TROMBAY	1150	658	0.73	15.61	0.970
36R	PARLI	690	625	0.80	14.73	1.063
37P	AMARKANTAK	290	201	0.72	4.7	0.957
38R	SANJAY GANDHI	840	770	0.72	17.19	0.957
39P	KORBA II & III	400	315	0.97	7.29	1.289
40P	KORBA WEST	840	630	0.68	14.48	0.904
41P	KORBA - STPS	2100	2153	0.68	50.14	0.904
42R	SATPURA	1143	845	0.88	19.22	1.170
43P	VINDHYACHAL	2260	2204	0.65	51.13	0.864
44R	KOTHAGUDEM	1170	1004	1.08	22.39	1.435
45R	RAYALSEEMA	420	432	0.78	10.08	1.037
46R	NELLORE	30	23	1.21	0.45	1.608

Appendix-A continued

Sr. No.	Power Station	Installed Capacity (MW/day)	Generation (MW/day)	Coal Usage (kg/KWH)	Million KWH/day (MU) TM	CO ₂ Emissions (kg/KWH)
47R	RAMAGUNDAM	63	58	0.73	1.45	0.970
48P	RGUNDAM - STPS	2100	2160	0.63	50.65	0.837
49R	VIJAYAWADA	1260	1281	0.73	30.41	0.970
50I	ENNORE	450	157	0.94	3.75	1.249
51I	METTUR	840	860	0.75	20.33	0.997
52P	NEYVELLI @	600	550	0.76	12.77	1.349
53I	NORTH MADRAS	630	646	0.76	15.2	1.010
54I	TUTICORIN	1050	1070	0.74	25.13	0.983
55R	RAICHUR	1260	850	0.76	21.2	1.010
56R	BARAUNI	310	40	1.06	1.25	1.409
57R	MUZAFFARPUR	220	65	1.09	1.5	1.449
58R	PATRATU	770	274	0.96	5.23	1.276
59R	TENUGHAT	420	200	0.87	4.8	1.156
60P	KAHALGAON	840	745	0.84	17.7	1.116
61R	BOKARO A & B	805	260	0.80	5.70	1.063
62R	CHANDRAPURA	750	100	0.79	3.39	1.050
63R	MEJIA	630	475	0.70	9.9	0.930
64R	DURGAPUR - DVC	350	300	0.62	7.2	0.824
65R	BANDEL	530	150	0.59	4.87	0.784
66R	CALCUTTA	190	141	0.89	3.07	1.183
67R	NEW COSSIPORE	130	50.6	0.89	2.11	1.183
68R	S.GEN STATION	135	136	0.62	3.26	0.824
69R	DURGAPUR - DPL	390	93	0.74	4.39	0.983
70R	KOLAGHAT	1260	1210	0.73	29.0	0.970
71R	BAKRESHWAR *	630	383	0.77	9.2	1.023
72R	SANTALDIH	480	150	0.60	3.6	0.797
73R	TITAGARH	240	240	0.64	5.76	0.851
74R	BUDGE BUDGE *	500	500	0.77	12	1.023
75P	FARAKKA	1600	1470	0.83	34.95	1.103
76P	TALCHER - NTPC	460	390	1.01	9.4	1.342
77P	TALCHER - STPS	1000	490	0.75	11.60	0.997
78R	IB VALLEY - NTPS	420	406	0.91	9.70	1.209
79R	BONGAIGAON	240	0	0.66	0.8	0.877
80R	CHANDRAPUR (ASSAM)	60	7.82	0.66	0.33	0.877
81R	NAMRUP	30	5.13	0.66	0.21	0.877
TOTAL	ALL INDIA	53216	14115	0.73		

* Coal usage (kg/KWH) are the averaged for Eastern region

Coal usage (kg/KWH) are the averaged for Western region

@ Lignite fuel is used

TM Based on monthly average

R Rail feed plant

P Pithead plant

I Inter modal

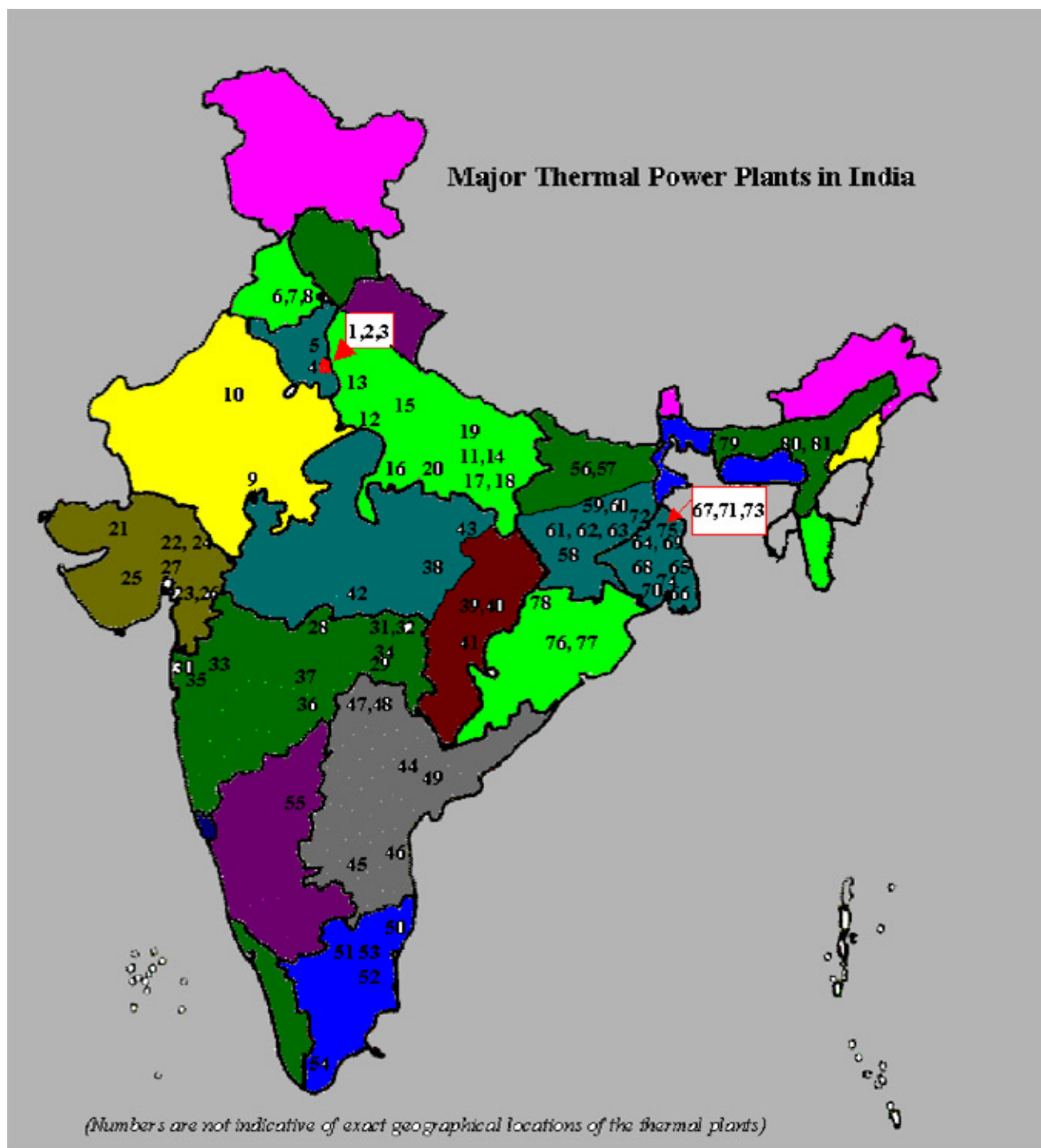
Note: Amarkantak and Amarkantak Extension are merged together. Similarly Korba II and III are merged together.

Source: www.cea.nic.in/data/opt2-daily_coal.htm and www.cea.nic.in/data/opt2_seb.htm

The specific coal consumption in 1997-98 is 0.73 Kg/KWH (per unit of electrical power). The average heat input for all the power plants was 2801 Kcal/KWH in 1997-98. Some power plants are more efficient than others. The efficiency depends on the combustion technology, operating conditions, and the coal properties. Out of 81 coal-fired power plants listed above, overall thermal efficiency for 13 power plants was less than 25%, 25% to 30% for 42 plants, and more than 30% for 26 plants as shown in Figure 3.

Approximate location of major thermal power plants in India is indicated in the following map (Figure 5). Numbers in the figure correspond to the power plants as listed in the Appendix–A.

Figure 5: Geographical location of major thermal power plants in India¹³



¹³ Some new states were created after 1998. Hence maps in Figure 4 and Figure 5 differ.

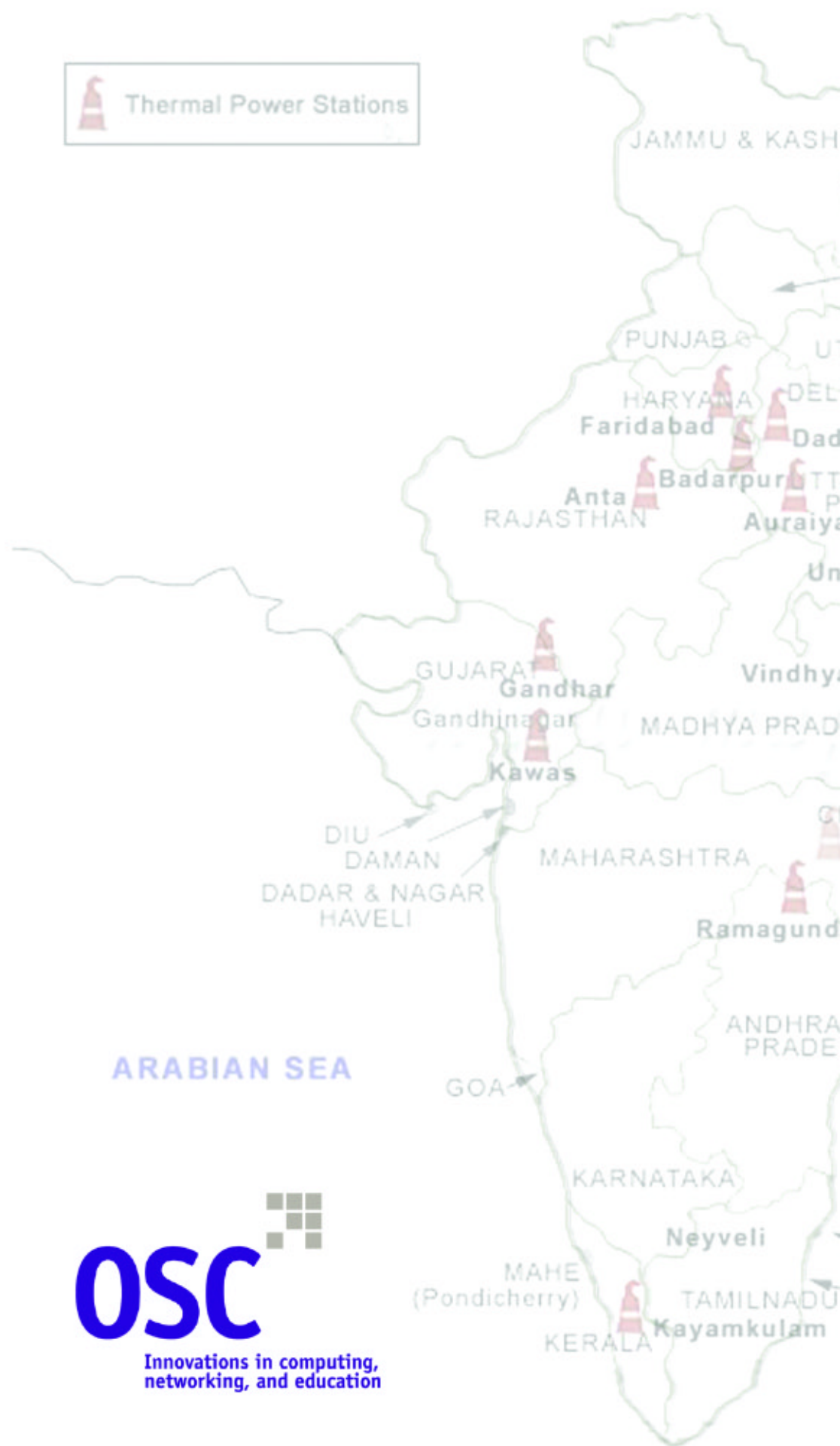
NOTES

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