Estimates of Emissions From Coal Fired Thermal Power Plants in India

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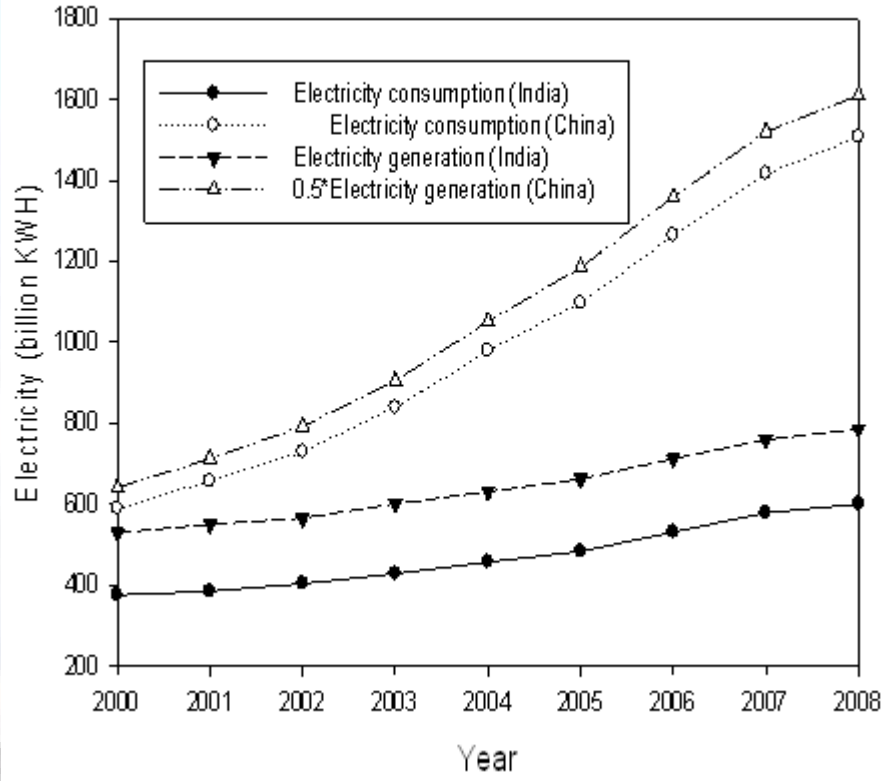
20th Emission inventory Conference, August 13-16, 2012, Tampa, Florida

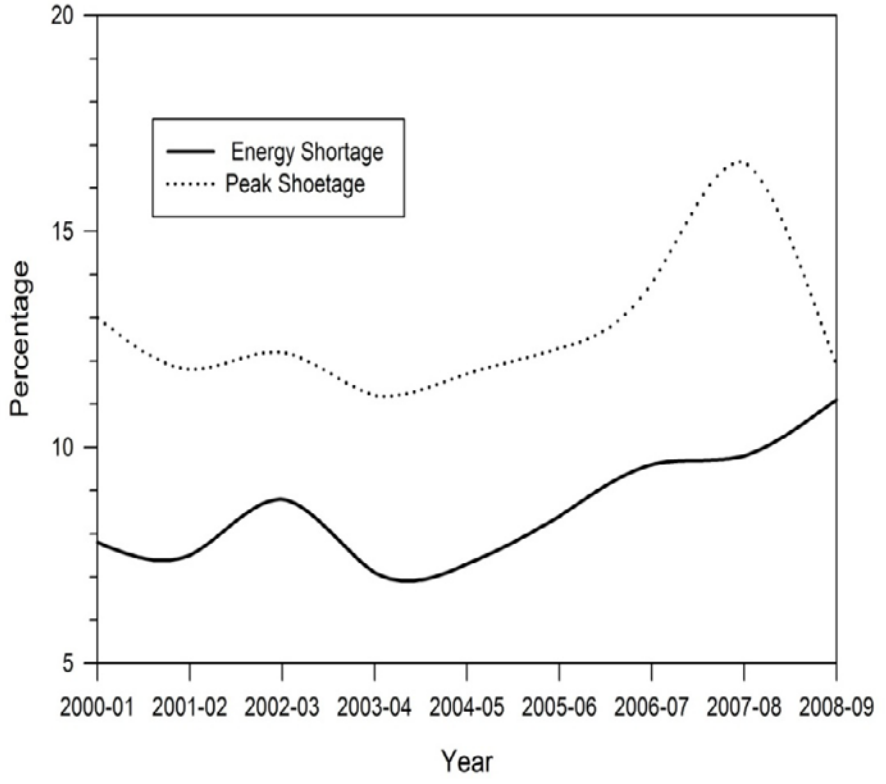
INTRODUCTION

- Emissions of greenhouse gases and other pollutants are increasing in India due to increased fossil fuel consumption for meeting the increasing demand for electricity.
- Electricity consumption grew from 375.39 billion kWh in 2000 to 600.65 billion kWh in 2008 (Annual growth rate = 6.67%)
- Electric power generation grew from 529.12 billion kWh in 2000 to 835.27 billion kWh (Annual growth rate = 5.78%)
- India 's current electric power availability is approximately 11.1 % short of demand with peak load shortages of 11.9 %, whereas in 2000-01, power capacity was 7.8 % short of demand with peak load shortage of 13%.
- Coal is the favorite fuel for the electricity generation in India due to its availability locally .
- Coal is approximately 90% of the total fuel mix for electricity generation
- Coal and lignite based power plants have approximately 54.42% of the total electric power generation capacity in India
- Thermal power plants, using about 70% of total coal in India are among the Large Point Sources (LPS) having significant contribution (47% each for CO_2 and SO_2) in the total LPS emissions in India.

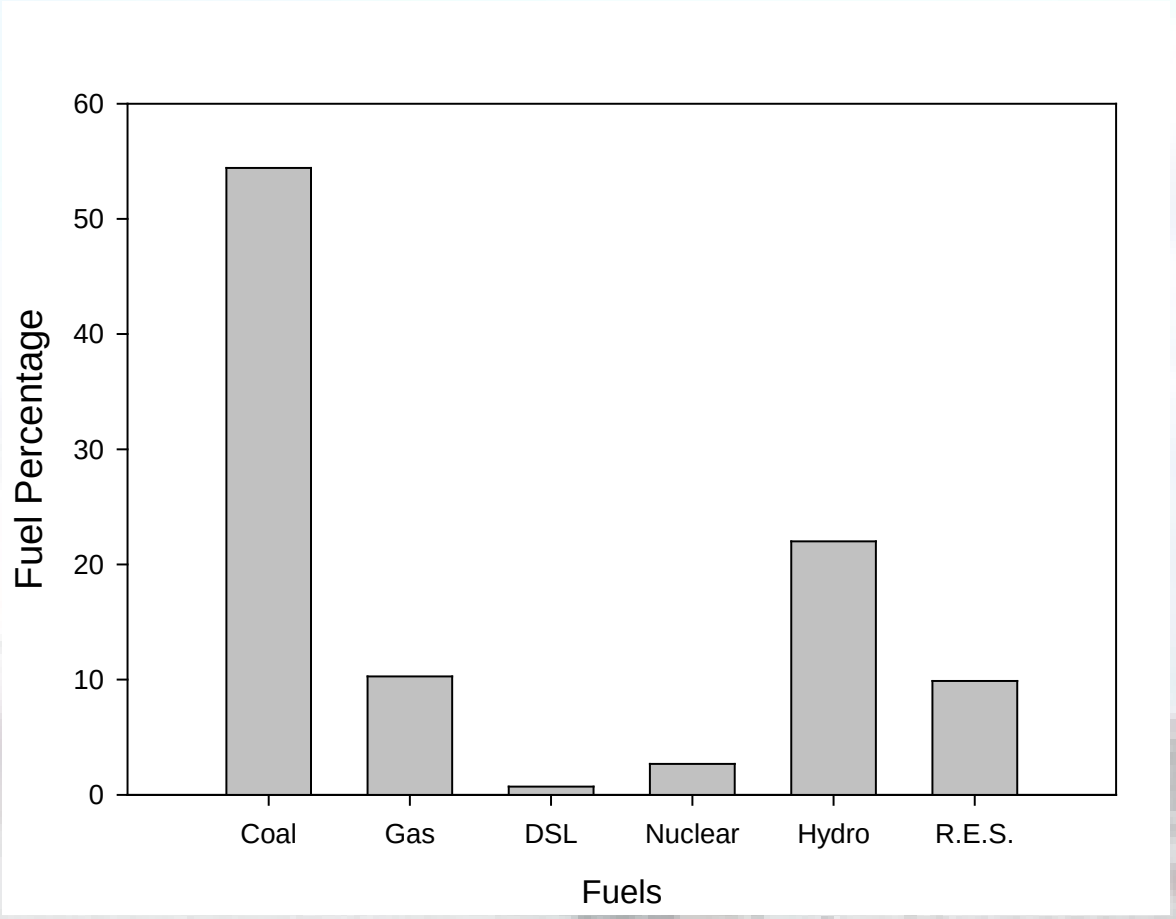
Growth of electricity generation and consumption in India and China



Trend of energy and peak shortage in India (%)



Fuel percentage used in the electricity generation as on December 2010



- Earlier electric power generation from thermal power plants was estimated to have contributed about 96% of total CO_2 emissions during 1990 while in 1994, it was estimated about 62% and in 2007, about 69% of the total CO_2-equivalent emissions have been estimated to occur from energy sector .

- Eighty six power plants with total installed capacity of 77682 MW are considered in this analysis which represent about 76% of the total installed capacity of thermal power plants in India.

- It is estimated that 1% to 2% increase in heat rate improvements through incorporation of better combustion technologies will result in 1% to 2% decrease in emissions per unit of electricity.

Specific coal usage in Indian Thermal Power plants (Source: CEA 2010)

Specific Coal Usage (kg/kWh)	Number of Plants
< 0.6	3
0.6-0.7	19
0.7-0.8	39
0.8-0.9	15
0.9-1.0	7
>1.0	3

METHODOLOGY

- The combustion process of the pulverized coal in the boiler is a complicated non-linear phenomenon.
- The pollutants emitted from thermal power plants depend largely upon the characteristics of the fuel burned, temperature of the furnace, actual air used, and any additional devices to control the emissions.
- The control devices used in thermal power plants in India is electrostatic precipitator (ESP) to control the emission of fly ash (SPM). Some new plants use low NO_x burners for high temperature (> 1500 K) combustion technologies and dry/wet SO_2 scrubber, if chimney height is less than 275 meters.
- Mass emission factors for CO_2, SO_2, and nitric oxide (NO) are computed based on the input data, such as chemical composition of the coal used at the power plants and the actual air used during combustion. These calculations are based on theoretical ideals and do not take account for the control devices. Indian coal generally has low sulfur contents. The operative combustion temperature is assumed to be 1200 K.

Carbon Dioxide and Sulfur Dioxide

Oxygen (O_r) required to burn one kilogram (kg) of coal =

$$O_r = C*(32/12) + H*(16/2) + S*(32/32) - O_2 \quad (1)$$

Air mass required for O_r kg of oxygen = (O_r / mass fraction of O_2 in the air)

$$= O_r / 0.233 \quad (2)$$

If E is the percentage of excess air used in the furnace to burn the coal, the air mass used =

$$\text{Air (used)} = (1 + E)* O_r / 0.233 \quad (3)$$

Knowing the air mass used to burn one kg of coal, mass of O_2 and N_2 are calculated as

$$O_2 \text{ in the air used} = (1+ E)* O_r \quad (4)$$

$$N_2 \text{ in the air used} = 0.767* (1+ E)* O_r / 0.233 \quad (5)$$

Mass of CO_2, SO_2, NO, and H_2O are calculated by mass balance as

$$CO_2 = C*44/12 \quad (6)$$

$$SO_2 = S*64/32 \quad (7)$$

$$H_2O = H*18/2 \quad (8)$$

Oxidation of Nitrogen

- Generally accepted principal reactions for 'thermal NO' formation are

  $O + N_2 = NO + N$ (09)

  $N + O_2 = NO + O$ (10)

  $N + OH = NO + H$ (11)

- A kinetic model is beyond the scope of present analysis. Present estimates give the equilibrium concentrations of NO assuming long residence time as found in large boilers. The oxidation of nitrogen is represented by the overall balance.

  $N_2 + O_2 \rightarrow 2NO$ (12)

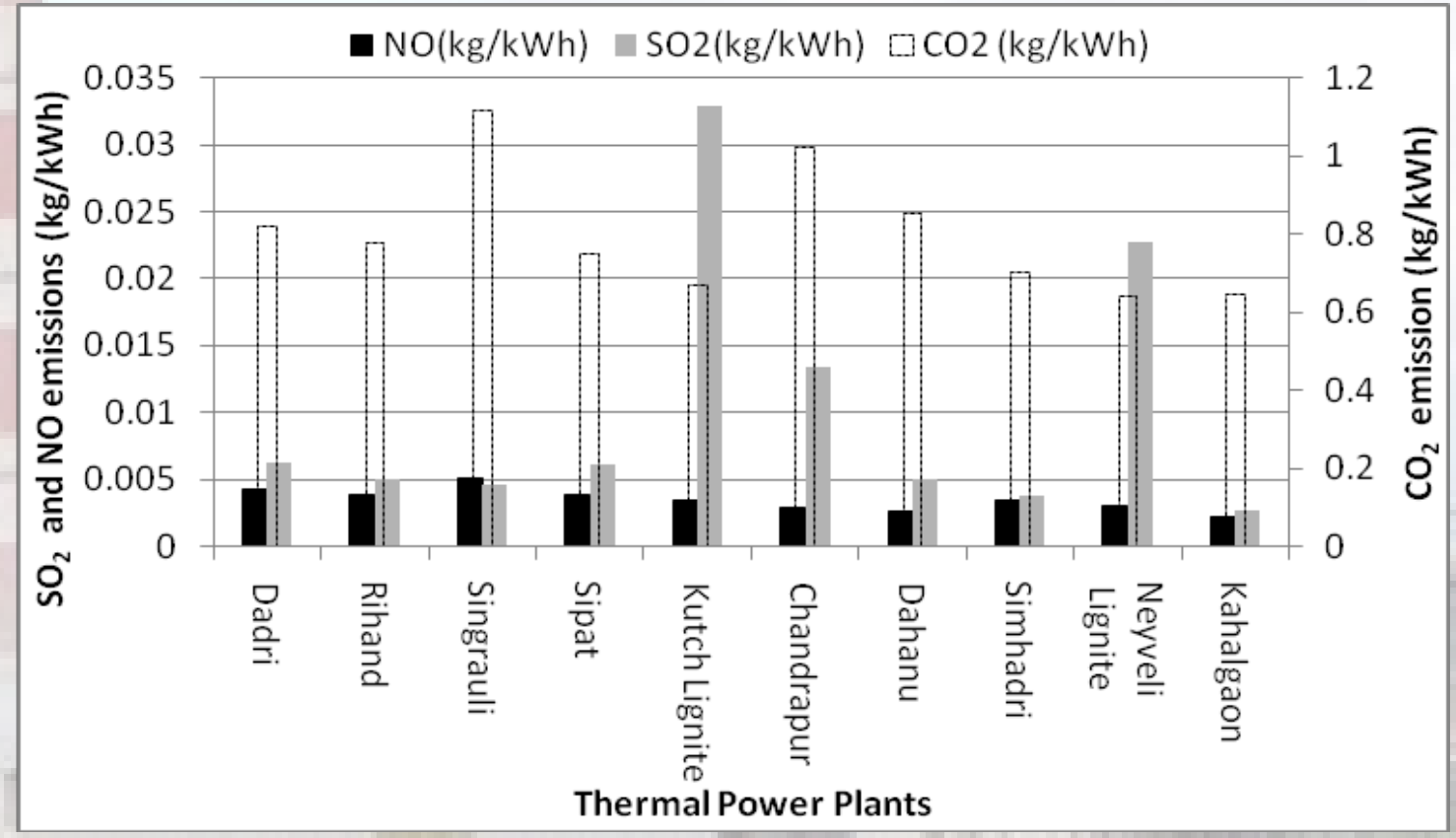
  A simple stoichiometric calculation gives the equilibrium NO concentration as

$$\chi_{NO} = K_{10.1}(\chi_{N_2})^{0.5}(\chi_{O_2})^{0.5} \quad (13)$$

where χ is the species concentration and K10.1 is is an equilibrium constant that depends upon the temperature of the gas. At 1200 K, $K_{10.1} = 0.00526$.

RESULTS

Emission factors of CO_2, SO_2 and NO in ten Indian thermal power stations



Region wise CO_2 emissions from thermal power plants in India (Gg) during 2001-02 to 2009-10

Year	Region				
	Northern	Western	Southern	Eastern	All India
2001-02	89704.89	109796.74	71134.90	52838.33	323474.85
2002-03	93165.88	116728.55	78587.62	56000.77	344482.83
2003-04	102371.06	116817.91	77032.98	66264.89	362486.84
2004-05	99915.90	122452.03	78511.49	73157.09	374036.51
2005-06	104038.33	119666.63	76152.41	78400.36	378257.73
2006-07	118752.49	127870.66	82755.09	87848.35	417226.59
2007-08	120947.31	153831.83	89031.37	91272.11	455082.62
2008-09	124185.42	169576.14	93626.06	94165.38	481553.00
2009-10	127763.21	173415.44	99547.80	97929.32	498655.78

Region wise CO_2 emissions per unit of electricity generation (kg/kWh) during 2001-02 to 2009-10

Year	Region				
	Northern	Western	Southern	Eastern	All India
2001-02	0.93	0.93	0.89	0.95	0.92
2002-03	0.94	0.91	0.88	0.96	0.92
2003-04	1.00	0.94	0.82	1.00	0.94
2004-05	0.95	0.96	0.82	1.00	0.93
2005-06	0.94	0.95	0.82	0.92	0.91
2006-07	0.98	0.97	0.84	0.95	0.94
2007-08	0.96	1.00	0.88	0.96	0.95
2008-09	0.94	1.00	0.87	0.94	0.95
2009-10	0.93	0.98	0.87	0.94	0.94

Region wise SO_2 emissions (Gg) during 2001-02 to 2009-10

Year	Region				
	Northern	Western	Southern	Eastern	India
2001-02	558.85	873.55	745.74	341.79	2519.93
2002-03	579.01	915.25	774.32	361.94	2630.52
2003-04	643.27	918.21	782.97	428.09	2772.54
2004-05	623.81	952.22	803.65	473.56	2853.24
2005-06	650.25	916.95	800.00	507.66	2874.86
2006-07	748.97	1022.69	834.56	570.21	3176.43
2007-08	758.25	1243.12	906.36	593.67	3501.41
2008-09	780.51	1336.77	937.95	608.76	3663.99
2009-10	822.54	1374.66	1012.53	630.71	3840.44

Region wise SO_2 emissions per unit of electricity generation (g/kWh) during 2001-02 to 2009-10

Year	Region				
	Northern	Western	Southern	Eastern	India
2001-02	5.77	7.39	9.38	6.12	7.19
2002-03	5.84	7.16	8.71	6.17	7.02
2003-04	6.27	7.39	8.35	6.48	7.17
2004-05	5.93	7.44	8.43	6.45	7.10
2005-06	5.88	7.29	8.66	5.96	6.94
2006-07	6.20	7.75	8.44	6.15	7.15
2007-08	5.99	8.09	8.94	6.23	7.34
2008-09	5.89	7.88	8.74	6.11	7.20
2009-10	6.01	7.75	8.87	6.02	7.20

Region wise NO emissions (Gg) during 2001-02 to 2009-10

Year	Northern	Western	Southern	Eastern	India
2001-02	447.05	510.06	332.86	212,10	1502.07
2002-03	464.52	543.33	369.05	224.35	1601.25
2003-04	511.53	541.42	361.46	262.01	1676.42
2004-05	499.13	567.06	366.9	284.46	1717.56
2005-06	523.38	564.68	349.23	306.49	1743.78
2006-07	594.73	628.77	383.24	341.29	1948.03
2007-08	603.75	720.07	413.11	352.09	2089.02
2008-09	620.69	772.89	423.17	374.16	2190.91
2009-10	639.75	820.95	464.85	389.14	2314.95

Region wise NO emissions per unit of electricity generation (g/kWh) during 2001-02 to 2009-10

Year	Region				
	Northern	Western	Southern	Eastern	India
2001-02	4.62	4.32	4.19	3.8	4.29
2002-03	4.68	4.25	4.15	3.83	4.28
2003-04	5.0	4.36	3.85	3.97	4.34
2004-05	4.74	4.43	3.85	3.88	4.27
2005-06	4.73	4.43	3.8	3.6	4.22
2006-07	4.92	4.78	3.88	3.68	4.39
2007-08	4.78	4.69	4.07	3.69	4.38
2008-09	4.69	4.56	3.94	3.75	4.34
2009-10	4.67	4.64	4.07	3.72	4.34

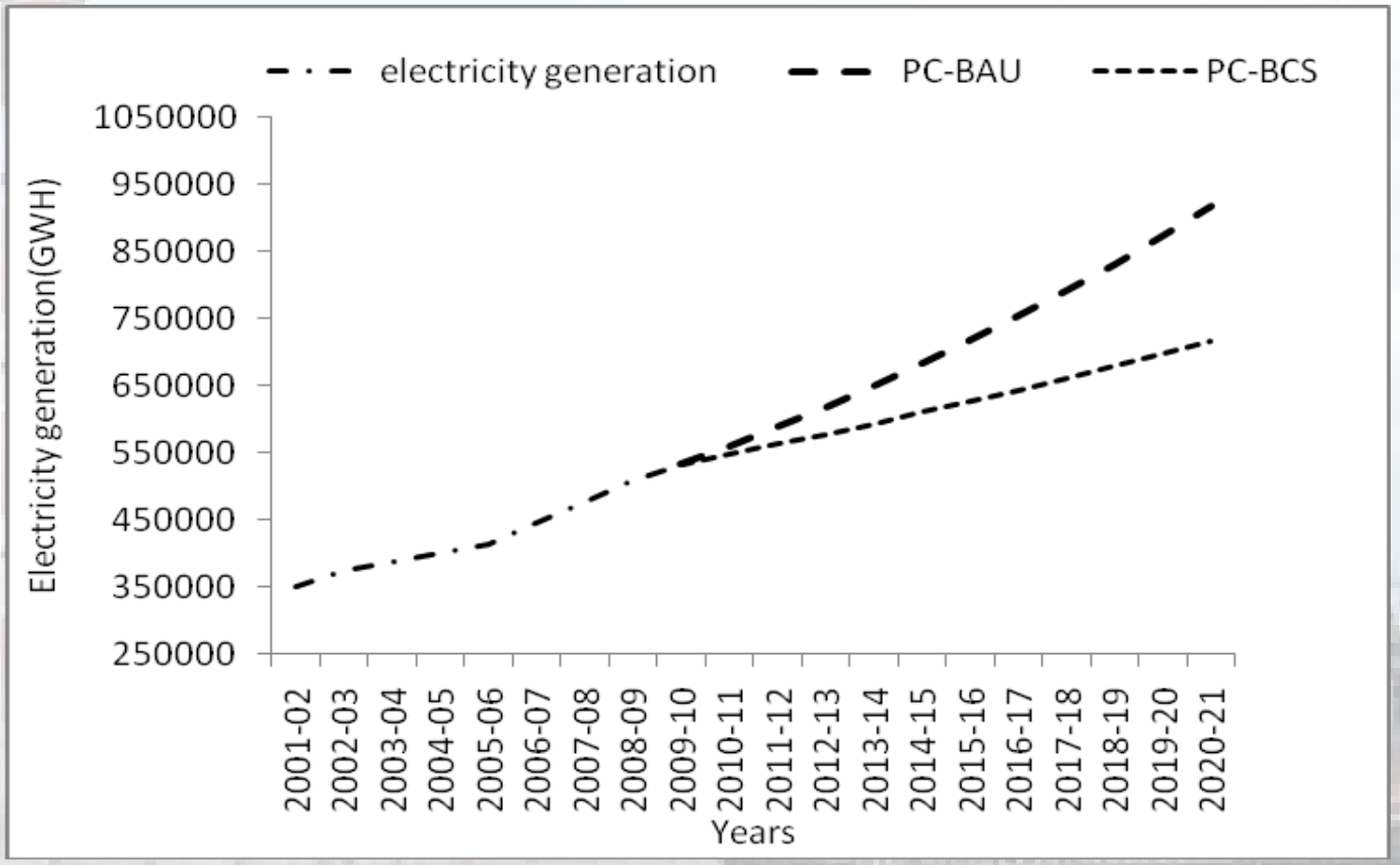
Emission Trends

- Two scenarios are generated for future emission trends:

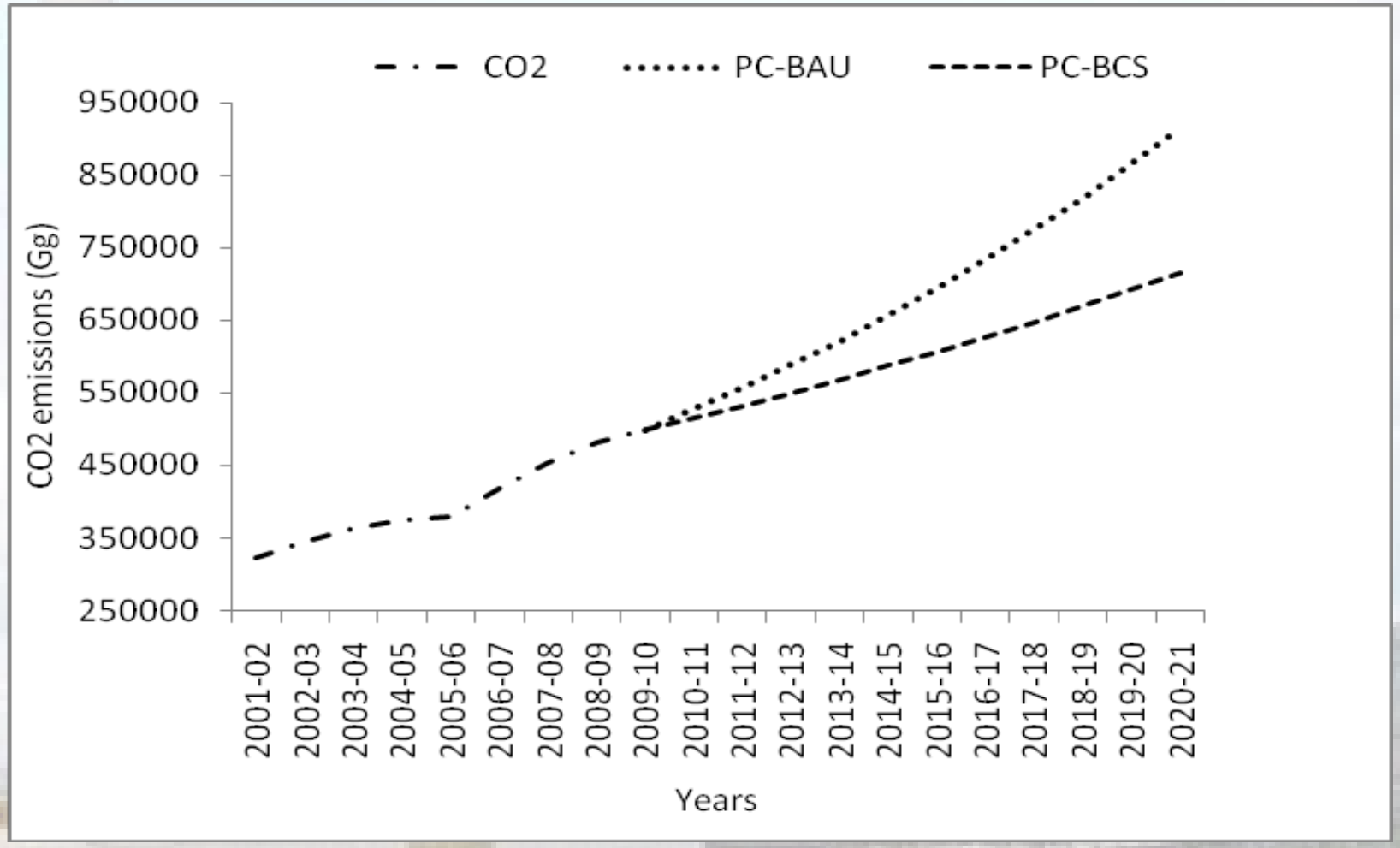
  (1) PC-BAU scenario is based on coal consumption projected by Planning Commission of India in 2020 for thermal power generation under business-as-usual (BAU) scenario (scheme 1); and

  (2) PC-BCS scenario is based on future coal consumption projection for thermal power generation in India in 2020 by Planning Commission of India under best case scenario (BCS) (scheme 2).

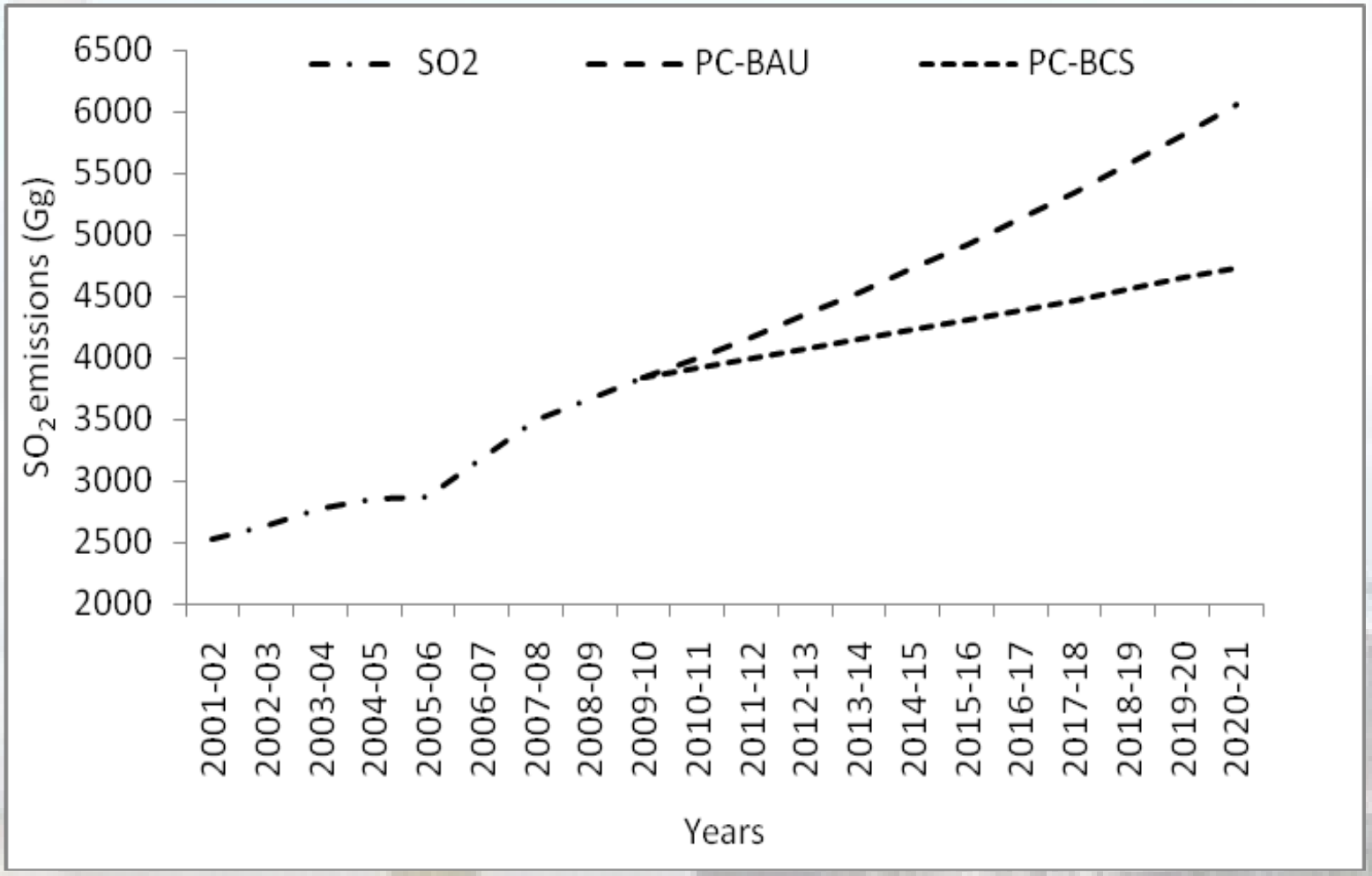
Scenarios of electricity generation from coal based thermal power plants in India



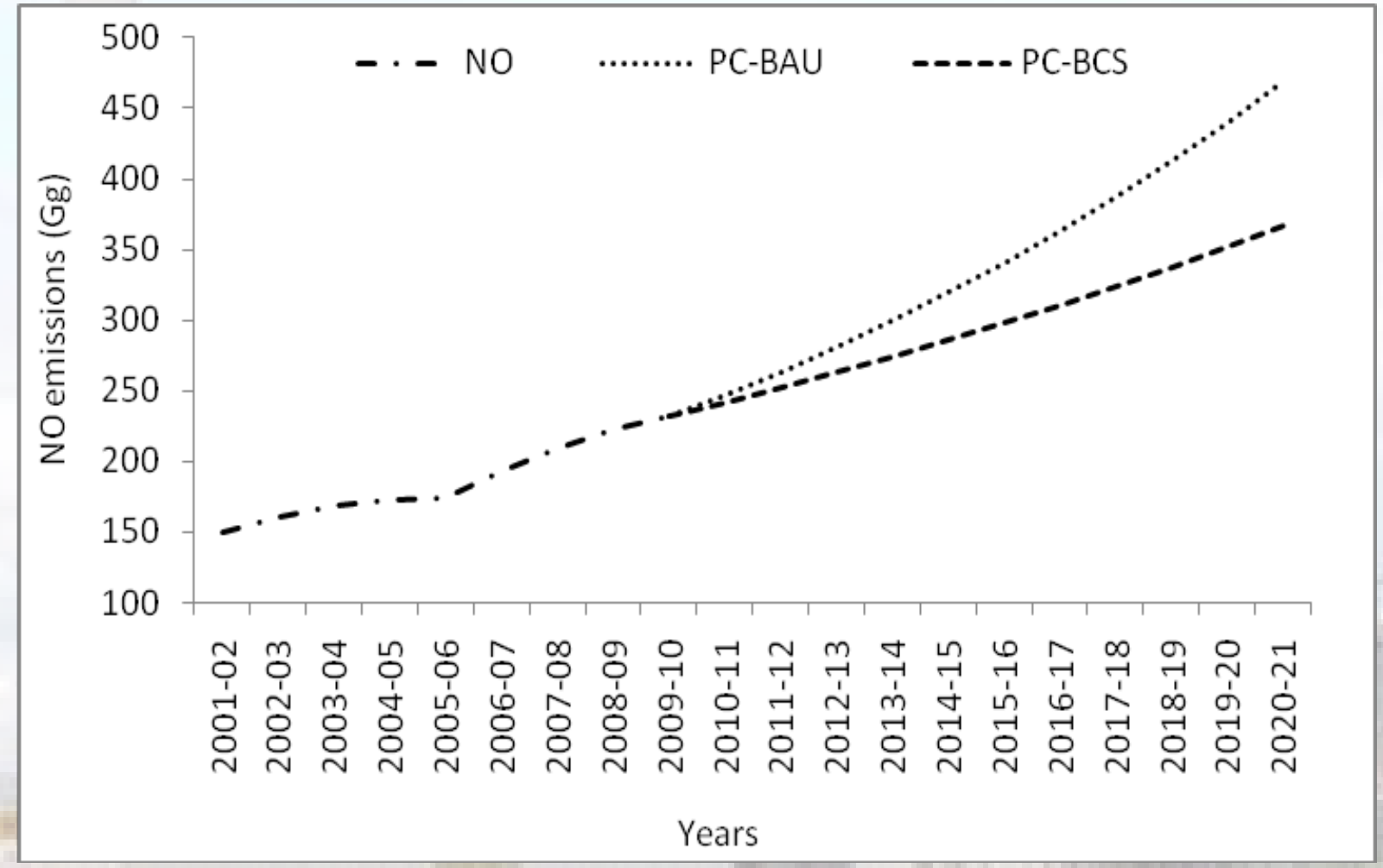
Scenarios of CO_2 emissions from coal based thermal power plants in India



Scenarios of SO_2 emissions from coal based thermal power plants in India



Scenarios of NO emissions from coal based thermal power plants in India



CONCLUSIONS

- This study provides a viable “bottom-up” (i.e. plant wise) methodology for the development of emission inventory of CO_2, SO_2 and NO from coal combustion in thermal power plants in India for which measured emission factors are still sparse.
- Thermal power plants vary widely in design and operating conditions and hence it is relatively cumbersome to develop plant specific emission factors by measurements.
- There is a wide diversity between plants for coal usage (kg/kWh), coal quality, and the operating conditions. Hence there are large differences in emission factors (g/kWh) of CO_2, SO_2, and NO as shown earlier.
- This study gives the emissions from 86 operational thermal power plants with future trends nationally.


THANK YOU