Air Pollution, Environmental Regulation and the Indian Electricity Sector

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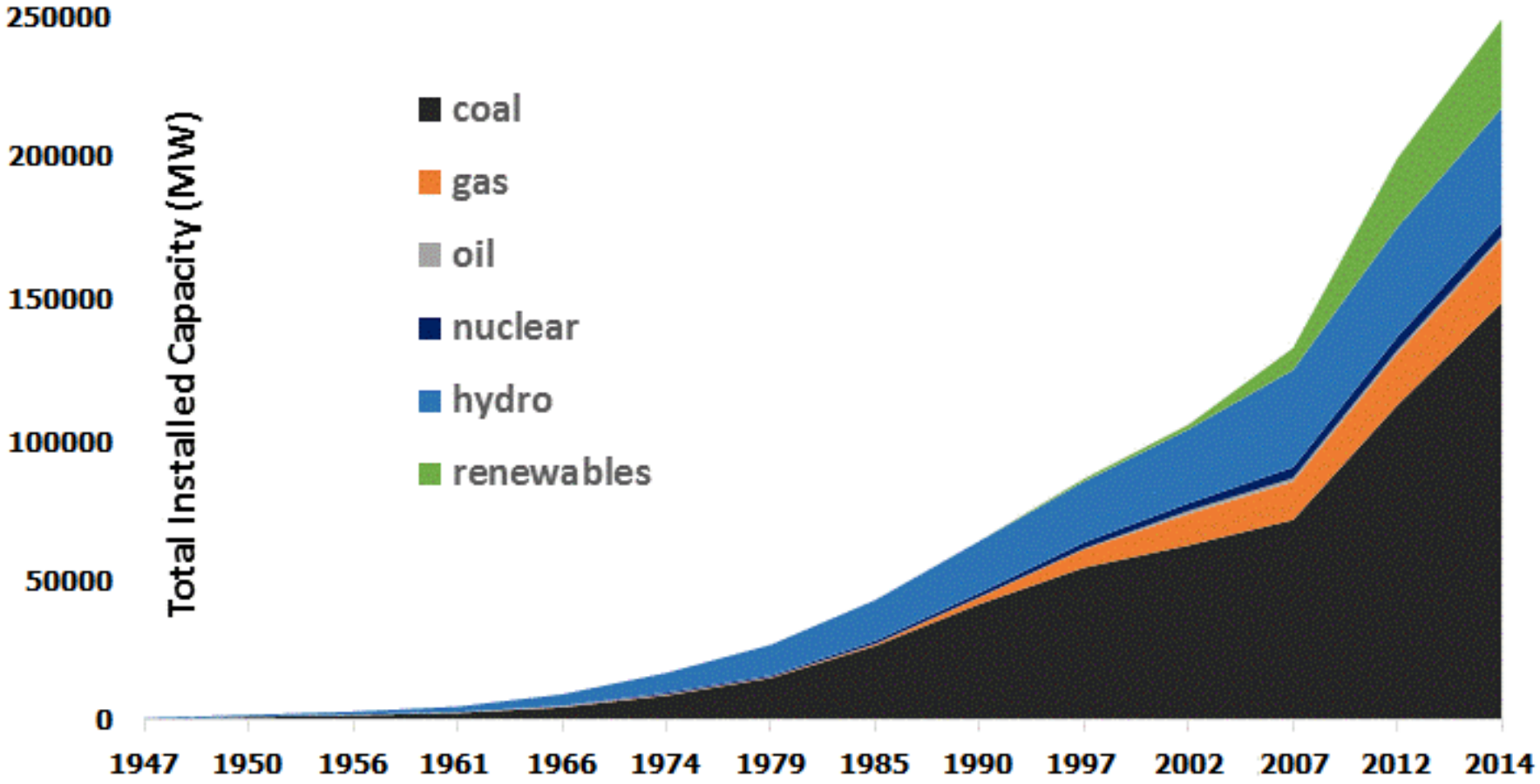
Main Points

- Coal-fired generating capacity has been expanding rapidly in India
  - Currently accounts for 76% of grid-connected generation
- In spite of India's INDCs, 78% of electricity generation likely to come from coal in 2030
- Local air pollution associated with coal-fired power plants is substantial
  - Power plants responsible for ~ 20% of air pollution related deaths in 2011
  - Are environmental regulations adequate to deal with this?
- What policy options would shift the mix away from coal?
  - Will the current coal tax be sufficient?

Installed Capacity in India, 1947-2014



Capacity and Generation by Source, 2014-15

Power Source	Capacity (%)	Generation (%)
Coal/Lignite	61%	75.6%
Hydro	15%	11.7%
Renewables	13%	5.6%
Gas	8%	3.7%
Nuclear	2%	3.3%
Diesel	1%	0.10%

India's INDC Committments

- Electricity generation accounts for ~ 37% of India's GHG and ~54% of CO2 emissions
  - 2012 data, excluding land-use change and forestry
- INDC commitments call for fossil-free fuel (FFF) energy to be 40% of installed capacity by 2030
  - This implies FFF capacity of 280 GW assuming total installed capacity of 700 GW in 2030
  - Plan is: 63 MW nuclear (v. 6 MW today)

    67 MW hydro (v. 41 MW today)

    150 MW renewables (v. 36 MW today)

India's INDC Committments

- More realistic scenario is:
  - Nuclear = 17 MW
  - Hydro = 67 MW
  - Renewables = 196 MW
- Using today's capacity factors for 2030, this implies:

  22% of electricity from FFF sources

  78% from coal and gas
- So coal will continue to be important
  - Increasing plant efficiency could reduce CO2

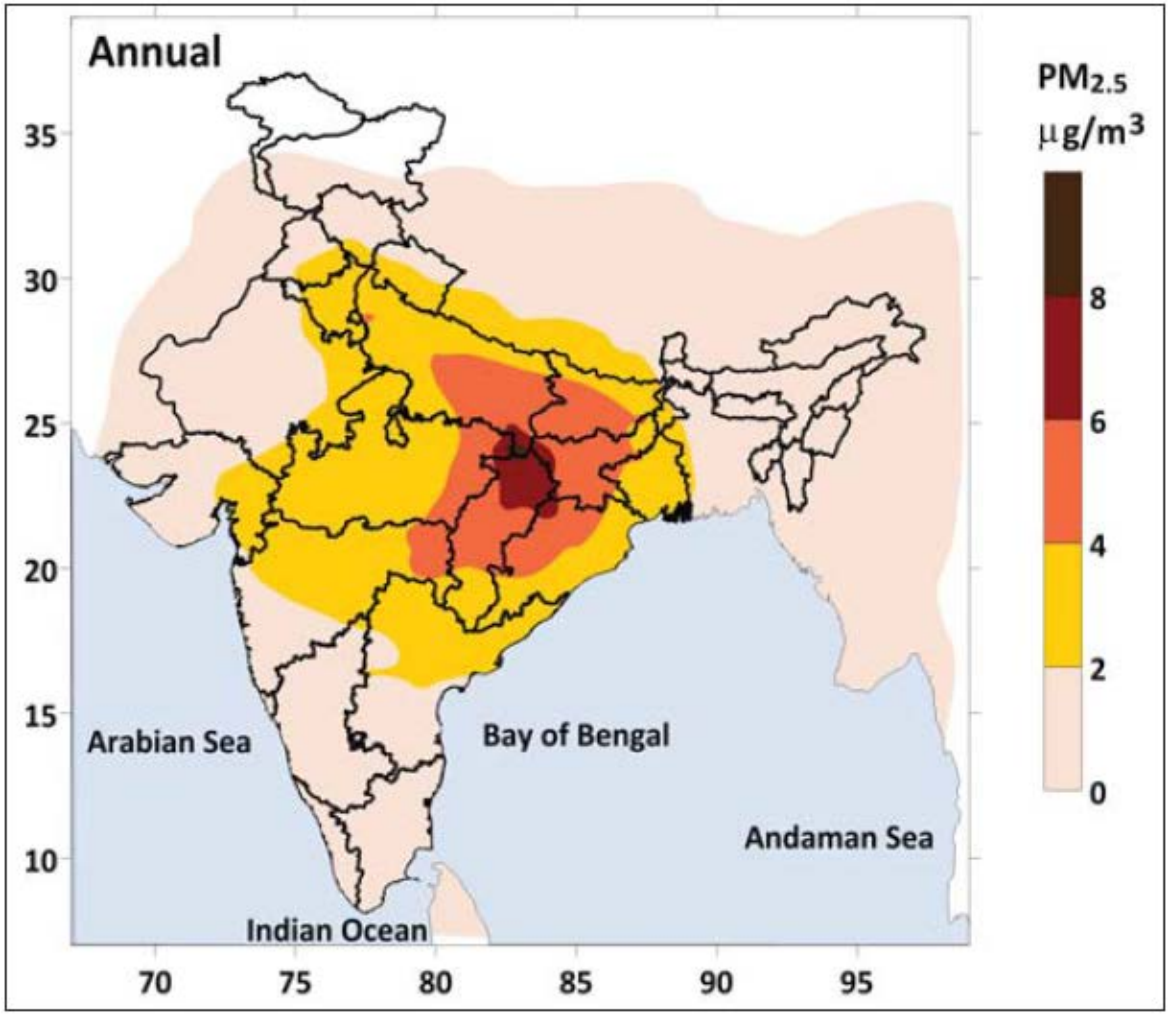
Coal-Fired Power Plants in India

- State plants much less efficient than central, private plants
- Coal burned per kWh 60% greater than in US
  - Heating value of coal about 35% lower than in the US
  - Operating heat rate about 5% higher
- Ash content of coal = 30-50%; Sulfur content = 0.5% by weight
- Plants have electrostatic precipitators (ESPs) to remove PM, although ash content affects their efficiency
- Only 3 EGUs have flue-gas desulfurization units (scrubbers)

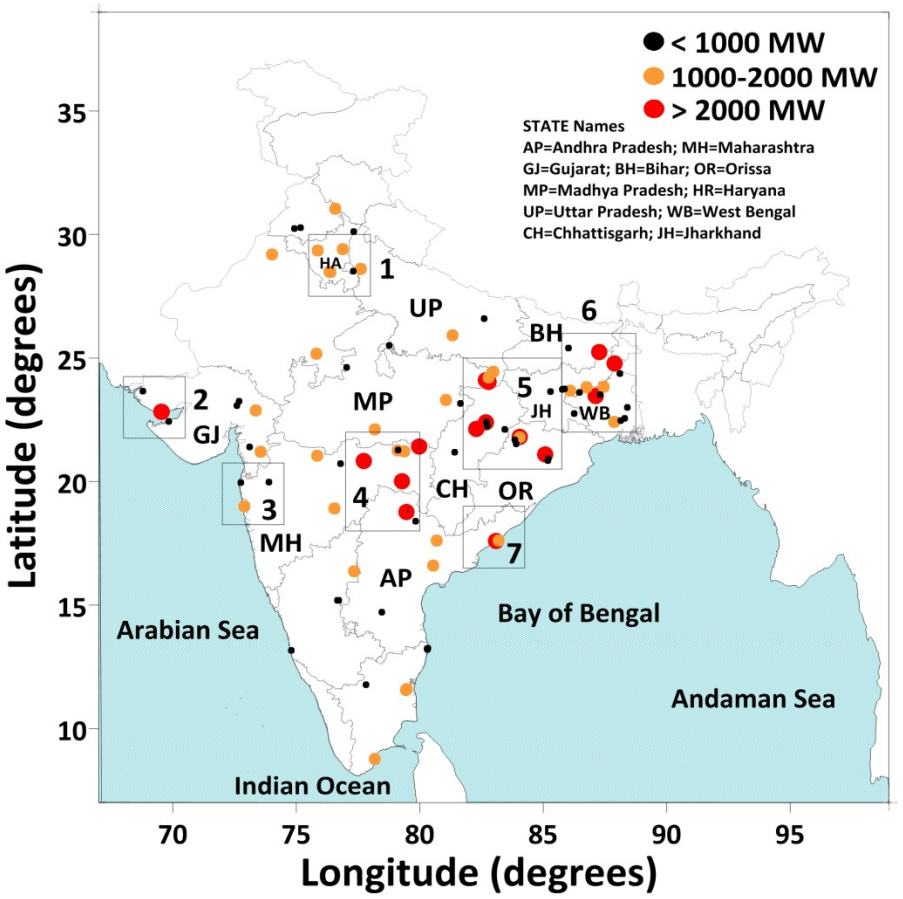
Coal Plant Emissions and Ambient Air Quality in India

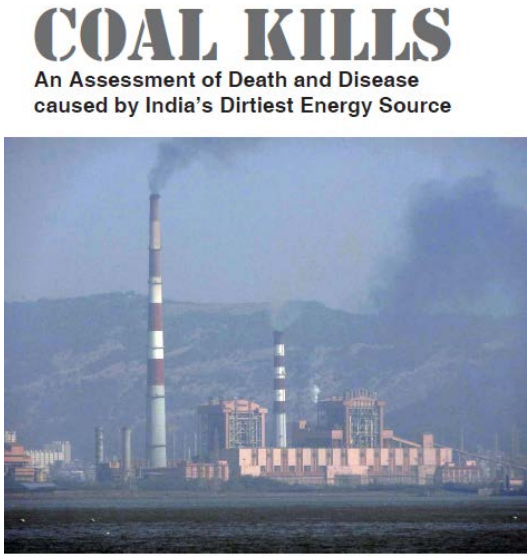
- Coal-fired power plants in India emitted about 4.6 million tons of SO_2 in 2011-12
- Net generation about 0.620 Trillion kWh (cf. 1.733 Trillion kWh in the US in 2011, with ~ equal tons SO2
  - Emission rate in India per kWh 2.8 times as high as the US
  - Reflects lack of pollution controls; more coal burned per kWh
- PM2.5 emissions/kWh also higher in India: 1 lb/MWh v. 0.5 lbs/MWh in the US (2005)
- 2011 emissions from coal plants in India imply an increase in annual average PM2.5 of 3.6 µg/m3

Modeled annual average $PM_{2.5}$ ambient concentrations due to the emissions from coal-fired thermal power plants in India



Health Impacts of Coal-fired Power Plants





2011-12

111 plants operating

Conservation ACTION TRUST

80,000 to 115,000 premature deaths

GBD study estimate: 587,000 deaths from air pollution in 2013

Atmospheric Environment (2014)

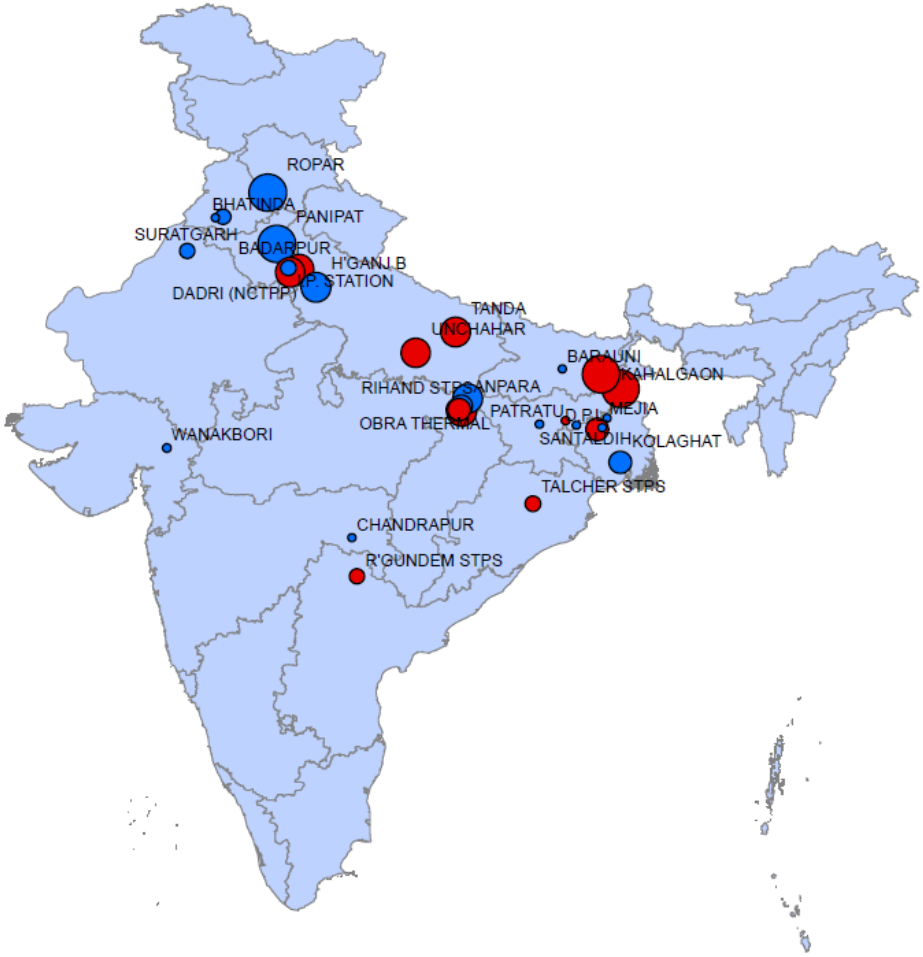
Pollution Regulations on Coal Plants

- Emissions standards prior to Dec. 2015
  - Concentration standards set in 1984 for TSP
  - No limits on SO2, NOx emissions
- Ash content of coal must be ≤ 34% in sensitive and critically polluted areas (since 2002)
- Standards set for SO2 in Dec. 2015 will effectively require scrubbing (installing FGDs):
  - For plants built before 2017:
    - 600 mg/Nm3 (units < 500 MW)
    - 200 mg/Nm3 (units ≥ 500 MW)
  - For plants built after 2017:
    - 100 mg/Nm3

Do FGDs Pass the Benefit-Cost Test?

- Cropper et al. (2016) investigate costs and benefits of retrofitting 72 plants with scrubbers
  - Plants constituted 90% of installed coal capacity in 2008-09 (68 MW)
- Conduct a plant-by-plant analysis to determine:
  - Number of lives saved at each plant by retrofitting an FGD
  - Cost per life saved (CPLS)
- 18,000 lives lost due to SO2 emitted by these plants
- Cost per life saved of installing FGDs at all plants averages $131,000 (2013$)
- So passes, on average, but great variation in CPLS
  - CPLS varies from $25,000 to $1.2 million

Coal-fired Power Plants – Top 30 Sulfate Deaths



Cost-Effectiveness of FGD Installation, US$

	Total Lives Saved	Total Cost (Mil.)	Average Cost per Life Saved
All Plants	**12,890**	**$1,691**	**$131,000**
30 plants with lowest CPLS	**9,196**	**$ 615**	**$ 67,000**
30 plants with most deaths	**10,061**	**$ 965**	**$ 96,000**
30 largest plants (MW)	**7,910**	**$1,164**	**$147,000**

Conclusions

- Coal is likely to be main source of electricity generation in India in the years to come
  - Coal capacity rose from 71 GW (2007) to 165 GW (2015)
  - It is likely to double by 2030 even if India fulfills is INDC
- New pollution control laws will have a huge impact on power plant emissions, assuming full implementation
  - But they will require installing FGDs
  - But PM reduction could be implemented more efficiently
- Will the coal tax move India towards FFF?
  - Coal tax doubled in February 2016 from Rs. 200 to Rs. 400
  - Effectively raises price of coal by 30%