



# THE HIDDEN COSTS OF POWER

## Health Effects of Coal Electricity Generation in India

*Maureen Cropper and Kabir Malik show how washing coal and controlling sulfur dioxide pollution from Indian power plants can save hundreds of lives each year.*

India relies on coal to supply 70 percent of its electricity and is likely to continue this dependence for many years to come. Almost 300 million Indians are without access to electricity, and the existing supply falls 10 percent short of the demand during peak hours. Determined to maintain the recent high rates of economic growth, India

has set ambitious goals to increase electricity generation capacity by either taking advantage of its domestic coal reserves or, failing that, importing large volumes of coal. But the increased use of cheap coal resources comes at a heavy cost.

Air pollution produced by coal-fired power plants has been linked to premature

deaths from lung cancer, respiratory illness, and heart disease. Studies have found air pollution to increase the incidence of diseases such as chronic bronchitis and asthma, as well as heart attacks and strokes. These health effects result primarily from emissions of particulate matter, sulfur dioxide (SO<sub>2</sub>), and nitrogen oxides (NO<sub>x</sub>), which can be reduced by installing pollution control equipment and washing coal prior to combustion. The important questions facing India are how stringently pollution from power plants should be regulated, and what form these regulations should take.

In a recent study we conducted in collaboration with Shama Gamkhar and Ian Partridge of the University of Texas, Austin, and Alex Limonov of RFF, we estimated the number of premature deaths associated

with emissions of the three pollutants from individual coal-fired power plants in India in 2008. We then estimated the number of lives saved by installing pollution control equipment or washing coal at two particular power plants. Our results suggest that when a power plant adopts one of these measures, it can save hundreds of lives at a lower cost per life saved than previously estimated.

### **Coal-Fired Power Generation in India**

Currently, India has 84 gigawatts of coal-fired electric generating capacity, 90 percent of which is government owned. Together, India's coal-fired plants emit more than 110,000 tons of particulate matter, 4.3 million tons of SO<sub>2</sub>, and 1.2 million tons of NO<sub>x</sub> per year.



Power plants in India use two strategies to limit particulate emissions from coal plants. First, they employ an electrostatic precipitator, which removes particulate

Such regulation could require power plants in India to install flue-gas desulfurization units (commonly known as scrubbers), or a tax could be placed on the sulfur

The Indian government has no controls on emissions of  $\text{SO}_2$  at coal-fired power plants because of the low sulfur content of Indian coal. But the question of whether  $\text{SO}_2$  should be regulated also depends on the number of tons of  $\text{SO}_2$  emitted and people exposed to these emissions.

matter from exiting gases. The Indian government effectively began requiring electrostatic precipitators in 1984 when it passed a law that limited particulate emissions from power plants. Second, power plants limit the ash content of the coal used. Beginning in 2002, the use of coal with ash content exceeding 34 percent was prohibited in any thermal power plant located more than 1,000 kilometers from the entrance of a coal pit or in urban, sensitive, or critically polluted areas. In practice, plants achieve the standard by blending washed and unwashed coal to reduce average ash content to the required amount.

The Indian government has no such controls on emissions of  $\text{SO}_2$  at coal-fired power plants because of the low sulfur content of Indian coal. On average, Indian coal is about 0.5 percent sulfur by weight; in contrast, coal mined in the eastern United States ranges from 3 to 4 percent sulfur by weight. But the question of whether  $\text{SO}_2$  should be regulated also depends on the number of tons of  $\text{SO}_2$  emitted and the number of people exposed to these emissions. Emissions of  $\text{SO}_2$  per megawatt hour are much higher in India than in the United States, and India is a much more densely populated country.

content of coal. The government also could extend its coal-washing requirements: only 5 percent of domestic coal used in power plants is washed, but this practice improves the combustion efficiency of coal and reduces the sulfur (as well as ash) content of the coal burned.

Whether scrubbers are required or coal washing is extended should depend on a comparison of their costs and benefits: how much would these requirements raise the cost of electricity, and what (in monetary terms) would be their health benefits?

### **Health Impacts of Power Plant Emissions**

We estimated premature deaths per ton of particulate matter,  $\text{SO}_2$ , and  $\text{NO}_x$  for 89 Indian coal-fired power plants that accounted for 88 percent of the electricity generated from coal in 2008. We also estimated total deaths associated with emissions of each pollutant for 62 plants. Specifically, we translated the data we collected into premature deaths from heart and lung disease among people 30 years of age and older, using an influential 2002 study by C. Arden Pope III and colleagues of the impact of fine particles on mortality in the United States. Our estimates are conservative

because they ignore the impact of air pollution on morbidity and deaths under age 30.

Our results suggest that, on average, premature deaths per ton of pollution are greater for directly emitted particulate matter than for  $\text{SO}_2$  or  $\text{NO}_x$ . An average of 23 people die per 1,000 tons of particulate matter emitted. By comparison, an average of 10 people die per 1,000 tons of  $\text{SO}_2$  emitted, and 9 people die per 1,000 tons of  $\text{NO}_x$  emitted.

Although damages per ton of particulate matter are greater than damages per ton of  $\text{SO}_2$ , the latter accounts for a much greater fraction of total deaths because of the larger amount of  $\text{SO}_2$  emitted.  $\text{SO}_2$  is associated with an average of 500 deaths per plant. By comparison,  $\text{NO}_x$  is associated with roughly 120 deaths and directly emitted particulate matter with about 30 deaths.

sulfur coal to bridge supply shortages of domestic Indian coal.

Whether the use of scrubbers to reduce  $\text{SO}_2$  emissions passes the benefit–cost test depends on the cost of scrubbers, their efficiency in removing  $\text{SO}_2$ , and plant location. Only one Indian power plant—the Dahanu plant in Maharashtra—is currently fitted with a scrubber. Our study suggests that this scrubber passes the benefit–cost test. The Dahanu plant is a 500-megawatt plant located in an environmentally sensitive area. We estimated the plant’s scrubber raises the cost of electricity generation by 9 percent, is 80 percent effective in reducing  $\text{SO}_2$  emissions from the plant, and saves 123 lives annually at a cost of just over US\$71,000 per life saved. This cost is below estimates of the amount that people in India are willing to pay per life saved. Whether this result

Per ton of emissions, particulate matter is more harmful to human health than is  $\text{SO}_2$ . But approximately three-quarters of the premature deaths associated with coal-fired power plants in India are attributable to  $\text{SO}_2$  emissions.

### Policy Implications

Per ton of emissions, particulate matter is more harmful to human health than is sulfur dioxide. This along with the high ash (and low sulfur) content of Indian coal has prompted the regulatory focus on controlling emissions of particulate matter, while  $\text{SO}_2$  remains unregulated. But approximately three-quarters of the premature deaths associated with coal-fired power plants in India are attributable to  $\text{SO}_2$  emissions. In response, the country needs to consider controlling this harmful pollutant. Regulation becomes even more important if India increases its imports of lower-ash, higher-

generalizes to other power plants depends on the type of scrubber used, its efficiency at removing  $\text{SO}_2$ , and the damages per ton of  $\text{SO}_2$  at those plants.

To illustrate the significant health benefits of coal washing, we also estimated the decline in premature mortality for the Rihand plant in Uttar Pradesh—a plant that is not currently required to use washed coal—if it were to adopt this practice. Rihand is a 2,000-megawatt plant that in 2008 produced 17,000 gigawatts of electricity, using coal with a sulfur content of 0.39 percent and an ash content of 43 percent. We considered a coal-washing program





that would reduce the ash content of coal burned at the plant to 35 percent. This also would reduce the sulfur content of coal to 0.34 percent and, by raising the heating value of the coal, would reduce the amount of coal burned to produce the same amount of electricity by 14 percent.

By our calculations, this coal-washing program would save approximately 250 lives annually and raise electricity prices by 16 percent. Coal washing has other benefits than lives saved. For example, washing coal at the pit would reduce transportation costs. Ignoring these other benefits, the cost per life saved is US\$250,000. The decline in fatality is due to a 30 percent reduction in emissions of directly emitted particulate matter, which saves 13 lives, and a 25 percent reduction in SO<sub>2</sub> emissions, which saves 238 lives. Most of the reductions in emissions of particulate matter and SO<sub>2</sub> occur because less coal needs be burned to generate electricity when the coal has been washed.

Although coal washing is usually regarded as a measure aimed at reducing emissions of particulate matter, our analysis indicates that benefits due to the reduction in SO<sub>2</sub> emissions far outweigh those of lower particulate emissions.

The health benefits of the Dahanu scrubber and of coal washing at the Rihand plant are only case studies, but they illustrate the importance of quantifying the health impacts of electricity production from coal and the difference that such estimates could make in informing pollution control policy. ●

#### FURTHER READING

- Cropper, Maureen, Shama Gamkhar, Kabir Malik, Alex Limonov, and Ian Partridge. Forthcoming. *Air Pollution Control in India: Getting the Prices Right*. Discussion paper. Washington, DC: Resources for the Future.
- Pope, C. Arden, III, Richard T. Burnett, Michael J. Thun, Eugenia E. Calle, Daniel Krewski, Kazuhiko Ito, and George D. Thurston. 2002. Lung Cancer, Cardiopulmonary Mortality, and Long-Term Exposure to Fine Particulate Air Pollution. *JAMA: The Journal of the American Medical Association* 287(9): 1132–41.