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Assessing Policy Choices for Managing SO_2 Emissions from Indian Power Sector

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Chapter 1

INTRODUCTION

1.1 Overview

The production, transportation and consumption of energy resources, especially of fossil fuels such as coal, oil and natural gas, generate negative environmental externalities including air pollution. The use of energy resources are the largest anthropogenic source of air pollution and the impacts are felt both at the global and local level. At the global level, emissions include greenhouse gases (GHGs) like carbon-dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) and the local pollutants include sulphur-dioxide (SO_2), nitrogen-dioxide (NO_2), suspended particulate matter (SPM) and carbon monoxide (CO). The GHG emissions cause global warming, which impacts agriculture and food security, natural ecosystems, human health, energy and industrial infrastructures, and coastal areas. In the case of local pollutants, their concentration in the ambient air reflects the air quality in an area. These concentrations, if exceeded, result in direct and immediate damaging impacts on human health and ecosystems, besides having other local and regional impacts such as acid rains.

Policies and Instruments to Manage Air Quality

Energy and environment issues are, thus, significant areas for public policymaking. A major domestic concern for national policymakers is the continuously deteriorating local air quality in many urban centers. Thus, designing and implementing appropriate policies and measures for managing local air quality is emerging as a significant public policy concern in India (Planning Commission 2002a; Mashelkar et al., 2002).

Policymakers globally have initially relied on command and control (CAC) instruments to clean the local air (Stavins 2000a, 2000b). These instruments, which are based on regulations that specify rules and standards to control the emissions from polluting sources, have been successful in managing emissions from previously unregulated industries. However, they are considered to be economically inefficient when compared to market-based instruments (MBIs) like taxes and tradable permits, which influence the firms and individuals (usually through price signals) to change their behavior in relation to the environment and also offer flexibility in pollution control (Baumol and Oates 1988, Tietenberg 1995, OECD (1989, 1994b, 1997a), Stavins, R.N (2000a, 2000b). This has led to a rising interest in the use of MBIs to control emissions, often to complement existing regulations.

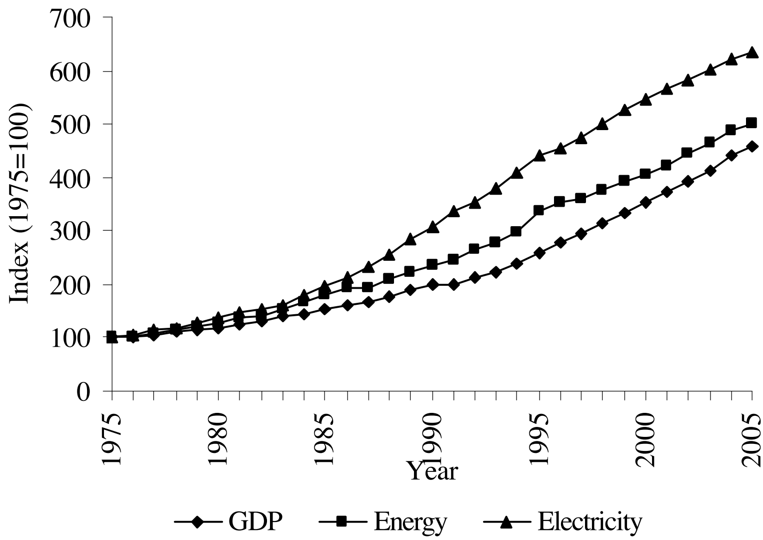
1.2 The Context: Indian scenario

Energy, electricity and emission trends

There has been high growth of the Indian economy since the 1990s, and an even higher growth of the energy sector (Figure 1.1). This was because this economic growth was driven by energy intensive sectors and the energy efficiency of these sectors has been low by international standards. Indian energy use has grown faster than GDP for the last twenty years (GOI 1991-2002, CMIE Energy 2003). Most notable is the case of electricity sector, where electricity consumption has grown at a rate higher than GDP and energy for the past two decades and this trend has become remarkably pronounced in 1990s (Figure 1.1 on next page).

The demand for energy resources is expected to grow further as the economy grows and there is increase in urbanization, population growth, and per capita incomes. The dynamics of transition from traditional to modern economy is expected to continue in foreseeable future, further adding to the growth in energy demands (Shukla, 1997).

Figure 1.1: Growth of Energy, Electricity and the Indian Economy



Sources: GOI (1991-2004); CMIE, Energy (2003, 2004); CMIE, National Income Statistics (2004)

Increasing demand for fossil fuel by major energy intensive sectors like power generation, steel, cement, chemical, fertilizer and transport contributes to high levels of GHG and local pollutant emissions in India - almost half of national CO_2 and SO_2 emissions in 2000. The present growth rate of CO_2 and SO_2 emissions in India is above 5% per annum (compounded) and the continued dependence on coal in the industrial sector implies continuation of this trend (Garg et al 2001b). Coal consumption contributes to 75% of total CO_2 emissions and 63% of SO_2 emissions in India. Since, coal is the mainstay of the Indian energy system due to its vast indigenous reserves, managing the externalities of coal consumption is a major concern for policymakers.

Managing externalities from coal consumption

The power sector accounts for nearly 72% of total coal-use in India (CMIE, Energy 2005). As the country moves on the path of economic development, energy and power demand would grow fast and the use of domestically abundant energy resource coal is expected to increase. Moreover, with the opening up of energy markets there are increasing number of power plants in coastal areas, which are using imported coal. Imported coal, while low in ash, usually has higher sulphur content as compared to domestic coal, which would generate negative externalities. These environment–related concerns may question the viability of coal in the long run. However, replacing coal with other energy sources like oil and gas raises questions on national energy security because according to the Ninth Plan document of the Government of India, the other hydrocarbon reserves, at projected production levels of 2001-02, would last only till around 2016 (unless new resources are discovered). Given the rising energy demands, the limited hydrocarbon supply, coal is projected to be the main stay of the Indian energy system; however its use would have to become cleaner in future, both at the global and local levels.

Clean-use of coal from a global perspective would require mitigating accompanying GHG emissions. Some studies have identified CO_2 capture and storage (CCS) as a promising technology for CO_2 mitigation from industrial sources (Garg et al 2004). The study targeted the large point sources[1] (LPS) for CO_2 mitigation, since they contributed to 64% of Indian CO_2 emissions in 2000 (Shukla et al 2004a). And, the 25 largest emitters among the LPS, comprising of power and steel plants, contributed almost one-thirds of India's CO_2 emissions. The study identified potential CO_2 storage sites for CO_2 captured including sedimentary rocks,

[1] The LPS are stationary emission sources like thermal power plants, steel plants, cement plants, sulphuric acid manufacturing plants, smelting of copper, zinc and lead ores, refineries etc. On the other hand, the vehicular emissions are from mobile, dispersed sources.

unmineable deep coal seams, depleted oil and natural gas reservoirs etc. The study indicated that if the largest 5 to 10 LPS adopted this technology, it would be possible to mitigate about 3 to 6 billion-ton CO_2 during 2010-2030. It also showed how future plant site selection could be influenced to enhance the economies of scale in CCS through clustering capture sites and CO_2 transport infrastructure. Thus, the CCS technology provides an option of managing CO_2 emissions from coal consumption, thereby increasing the viability of coal use in the industrial sector.

Managing local air pollution from continued and enhanced coal-use is a more important concern for Indian policymakers, since it has immediate impacts on human health and ecology. The paper aims to address this concern. The paper evaluates alternate policy options for SO_2 mitigation from the coal-based power plants. This would achieve several objectives. Firstly, targeting power plants substantially reduces all-India SO_2 emissions from coal consumption. Secondly, it demonstrates alternate economically efficient policy approaches for SO_2 mitigation. Thirdly, CO_2 and SO_2 emissions mitigation, along with cleaner technology penetration, have the potential to make coal use cleaner and sustainable for India – thus addressing the energy security issues.

Why SO_2 mitigation?

Mitigation of GHG emissions for climate change policy has important implications for the national energy systems and economy, but the mitigation of local pollutant emissions is a more urgent concern for national and local policymakers. This is because the impacts of climate change generally manifest over a longer duration, while local pollution is visible to the common man today and causes immediate impacts on health and ecology. Thus, mitigation of local pollution, since its benefits accrue to local constituents, enters the national agenda prior to CO_2 mitigation where the very low per capita emissions from India [0.98 t-CO_2 as compared to global average of 3.93 t-CO_2 in 2002 (EIA 2004)] provides the moral and practical reasons for delayed national actions in absence of a facilitating global regime.

This paper focuses on policies for SO_2 mitigation. High SO_2 concentration not only has local impacts such as on human health, but also regional impacts such as the acid rain problem. With respect to human health, high concentrations of SO_2 leads to respiratory diseases, increase in mortality, morbidity and impaired pulmonary functions. Moreover, once emitted, it is chemically transformed and returns to the earth as acidic deposition that damages trees, acidifies lakes and streams and accelerates decay in building materials.

Indian policymakers are addressing this problem through regulations (especially in the 1990s) that introduce desulphurization technologies for SO_2 mitigation, both for vehicular as well as industrial sources (Mashelkar et al 2002; CPCB 2003). These policies are at different stages of implementation. In this context, the paper analyzes alternate policy options for SO_2 mitigation.

Existing policies for air quality management

There is a comprehensive structure of legislations and policy initiatives for air quality management (AQM) in India. The problem has assumed greater significance in the 1990s due to the adverse impacts caused by the deterioration of air quality, both on human health and ecology. This is reflected in the numerous policy directives that have been formulated and gradually implemented during the 1990s for controlling emissions from different sources. Policy interventions for controlling industrial pollution include improving the quality of coal used in power plants, emissions standards for different industries, stack height criteria and use of pollution control technologies. The Auto Fuel Committee (known as the Mashelkar Committee) was set up by the Government of India in 2001 to address the problem of growing vehicular pollution. The Committee proposed progressive strengthening of emission norms for vehicles, improving the quality of fuel used in vehicles and proposed a roadmap for the same (Mashelkar et al 2002). Public awareness about the problems from air pollution has also risen during this period and is reflected in the numerous Public Interest Litigations (PILs) on air pollution filed in the Supreme Court of India.

There are organizations responsible for monitoring and enforcement of AQM policies, but there are instances of implementation failures, especially when strong monitoring and enforcement mechanisms are required. However, the systemic inefficiencies would be overcome with development. This argument is supported by the literature on environmental Kuznets curve (Grossman and Krueger, 1991; Hettige et al 1997; Garg et al 2003), which points out that pollution from industry, transport and households increases until development generates enough wealth to promote significant pollution control (Milanovic 1994). Thus, even though pollution levels rise initially with increasing incomes, after a certain point it is followed by an improvement in environmental quality (reflected by an inverted U curve). An empirical study by Torras and Boyce (1998) found that apart from income, social factors such as income equality, wider literacy and greater political liberties tend to have a significant positive effect on environmental quality, especially in low-income countries.

Thus, this research is based on the premise that there exists a general agreement among policymakers as well as public to tackle the problem of air pollution. Given that the resources are scarce and has multiple uses, the objective of policymakers is to adopt policies that utilize these resources efficiently. In this context, this paper analyzes alternate policies and instruments that would address the problem of the deteriorating air quality at lower costs. We also focus on understanding the institutions for air quality management, since they influence the process of policy formulation and implementation.

Here, it is also important to note that several of the policy initiatives taken by the Government focus on emissions in urban centers since the impact of the total pollution loads would be more severe in the populated urban centers. In this paper, we study the problem of air pollution from power plants, without specifically addressing the issue of pollution from power plants in urban centers vis-à-vis in other locations.

Why the power sector?

The power sector is a major contributor to Indian SO_2 emissions. In 2000, power generation contributed to around 54% of all-India emissions in 2000 and there is a rising sectoral trend. The contribution of the transport sector to the overall pollution loads of SO_2 is relatively low and is further declining due to implementation of SO_2 control measures; though it is relatively high for other pollutants like CO, NOx, HC and ozone in urban areas in India (Mashelkar et al. 2002).

The LPS including power, steel, cement and other industries, are the major contributors of SO_2 emissions in India. The LPS contributed to around 83% of all-India SO_2 emissions, with the remaining from other sources including transport. And, among the LPS, power plants are the major source, contributing around 54% of all-India SO_2 emissions followed by other industries, especially steel and cement manufacturing. Fossil fuel combustion in power generation and industry is responsible for their large share in all-India SO_2 emissions. Therefore, the power plants provide focused opportunities for SO_2 emission mitigation in India.

Why SO_2 emissions trading?

The choice of instruments for emissions mitigation has remained a contentious issue, even in global climate change negotiations. However, there is an agreement, in principle, on economic efficiency of mitigation, which is cost-effectiveness, as given in Article 3.3 of the United Nations Framework Convention on

Climate Change (UNFCCC 1992). According to this, varied instruments can be used for achieving global cost-effectiveness of mitigation. Emissions trading is often used as a stylized caricature of an instrument that achieves economic efficiency and it is in this context that the paper analyses an SO_2 emissions trading instrument.

Emissions trading is defined as," Essentially, a properly designed emissions trading programme is a form of environmental regulation that allows a group of sources to reach a specified emissions target at lower cost" (UNEP, UCCEE and UNCTAD 2002). There are three forms of emissions trading: 'cap-and-trade', 'baseline and credit' and 'offset'. This paper focuses on the cap and trade system[2], which is also known as allowance trading. A cap-and-trade system is a policy approach to control large amounts of emissions from a group of sources at costs that are lower than if sources were regulated individually. In this system, individual control requirements are not specified for sources. Instead, regulators set an overall cap, or maximum amount of emissions per compliance period that will achieve the desired environmental effect. Authorizations to emit are then allocated to participating sources in the form of emission allowances through some mechanism (either freely in proportion to historical emissions or performance standards and/ or by selling them through auctions), with the total number of allowances not exceeding the cap. The sources must completely and accurately measure and report all emissions and turn in the same number of allowances as emissions at the end of the compliance period.

However, it is imperative to understand that it is also possible to achieve an economically efficient solution for SO_2 control by using multiple instruments that can offer greater flexibility and further

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[2] In the "baseline and credit" program the participants define their baseline and if actual emissions are below the baseline they earn credit that can be traded. The "offset" programs are used to compensate for the additional emissions from a new source or expansion of an existing one.

research is required to study this aspect. The focus of this paper is on comparing the costs of an emissions trading instrument with a technology push instrument for equivalent reductions. The objective is not simply to replace existing CAC instruments; rather it is to show the opportunities of MBIs. In any case, an emissions trading system has to be complemented with stringent local air quality standards (this is explained further in Chapter 5).

1.3 Chapter structure

This paper is divided into six chapters. Chapter 1 provides an overview of the energy-environment scenario in India, including the problem areas. It also explains the context in which the problem is being studied and the focus areas of the study.

Chapter 2 provides an overview of the Indian power sector. It studies the structure of the power sector in India and analyses the trends in the composition of the installed capacity and generation, where coal dominates. The reforms in the electricity sector, which were introduced in early 1990s, are also examined. Further, the chapter analyzes the externalities from power sector, focusing on SO_2 emissions and the role of different abatement measures in SO_2 mitigation. Finally, the chapter proposes that given the strong environmental linkages of the electricity sector it is necessary to integrate environmental concerns in the overall frame of electricity reforms.

Chapter 3 studies the air quality management processes in India in terms of existing policies, instruments and institutions that influence policy formulation and implementation. While policies are the goals, instruments are tools to achieve these goals. The institutions influence the process of formulation and implementation of these goals. Therefore, these components have to be clearly understood while studying the air quality management in India. The chapter focuses on the existing policies and instruments for SO_2 mitigation from power plants. It identifies the lacunae in the existing technology-push approach, and proposes the case for alternate instruments like emissions trading by examining the theoretical literature as well as other country experiences.

Chapter 4 compares two alternate policy instruments, namely technology-push and the emissions trading system. An energy-environment model is used to analyze future SO_2 emissions from power plants and study the cost implications of using alternate instruments. It is shown that significant cost savings arise in an emissions trading system as compared to the technology push instrument for equivalent reductions.

Chapter 5 highlights the design elements of an emissions trading system in terms of the emissions cap, allowance allocation, institutional issues and other challenges. It details out the process of allocating the emission allowances among participating power plants. It points out the issues related to the political-economic-legal structure and the organizations that influence the process of policy implementation. It further highlights the spillover benefits of an emissions trading regime, while also identifying the challenges that exist in developing this regime in India.

The conclusions from the study are presented in Chapter 6. This chapter emphasizes that an emissions trading system allows every plant to make their abatement choice depending on factors such as economic and logistical constraints, fuel quality, efficiency in operations and abatement costs vis-à-vis the allowance price. As opposed to this, the existing technology-push instruments specify the abatement measure to be adopted by each plant, resulting in higher compliance costs. Moreover, considering the energy security concerns, an SO_2 trading instrument would promote the use of the large indigenous coal resources efficiently and with minimal environmental externalities. This is because it tackles the problem of local air quality impacts of coal use by promoting the use technologies such as FGD, coal washing and clean coal technologies (rather than replacing coal with alternate energy sources) such that they reduce sulphur emissions in an efficient manner. However, it is necessary to precisely work out the details regarding the actual implementation of this regime. Given that India is a developing country, these mechanisms are gradually developing. Once this infrastructure is in place, it would generate future benefits in a global carbon regime.

Chapter 2

INDIAN POWER SECTOR

2.1 Overview

Power is a critical infrastructure for economic growth in a country, and it has been given due importance by policymakers. In India, since Independence (in 1947) the generating capacity has increased from 1362 MW to 100,000 MW in 2001. Yet there is shortage of power in all parts of the country (Ministry of Power, 2001). The electricity consumption in India has been increasing rapidly due to growing industrialization, modernization of agriculture and rising income. The per capita consumption of electricity, which was 236 KWh in 1990 increased to 355 KWh in 2000 (Planning Commission, 2002b). However, the per capita consumption is among the lowest in the world (Ministry of Power, 2001), lower when compared to other developing countries (China 719 kWh; Brazil 1783 kWh in 1997) and developed countries (USA 8747 kWh, UK 5843 kWh in 1997).

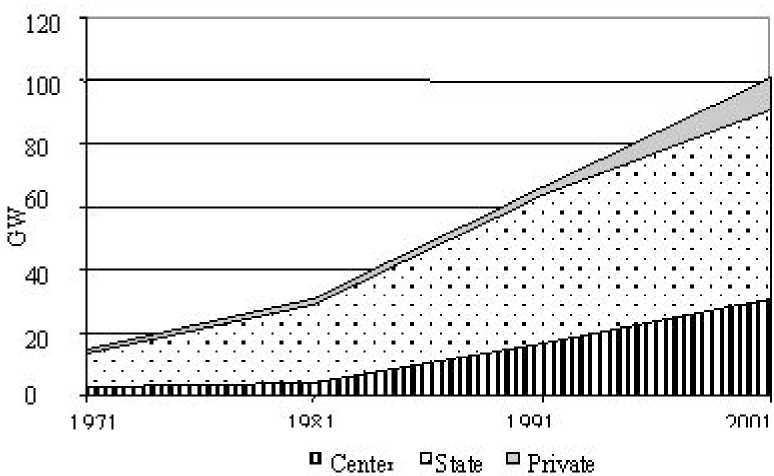
As the economy develops, there is expected to be increase in demand for electricity from all sectors. Since electricity energy shortages at all-India level were about 7.5% of energy demand in 2001-2002 and capacity shortages were 12.6% of peak demand (Ministry of Power, 2002), it is clear that a great deal of new generation capacity will have to be added to avoid even more serious shortages in the future.

Structure

From 1947 to 1991, the central government adopted a policy of development of electricity through the public sector, which was based on the Industrial Policy Resolution of 1956. State Electricity Boards (SEBs) were instituted after the formation of states, according to the provisions of the Electricity Supply Act, 1948. These SEBs were vertically integrated entities in charge of generation, transmission, and distribution of electricity in the respective states. Apart from SEBs, the central government owned agencies operated considerable generating capacity, which was also allocated to different states. The prominent centrally-owned power plants are units under the National Thermal Power Corporation (NTPC), the National Hydroelectric Power Corporation (NHPC) and the Nuclear Power Corporation of India.

Power sector has been kept in the Concurrent List of the Constitution of India; therefore, it is a combined responsibility of the state and central government. As a consequence, there has been a dominance of government-owned, especially State government owned power plants in the pre- 1990s and the private players were present only in some urban centers like Kolkata (Calcutta Electricity Supply Company), Ahmedabad (Ahmedabad Electricity Company), Mumbai (BSES and Tata) etc. In 1990s, after the opening up of the power sector, various private players also invested in power generation. In 2001, the share of the state government owned plants, central government owned plants and the privately-owned plants were 60%, 30% and 10% respectively.

Figure 2.1: Ownership Pattern – Installed Capacity



Source: CEA, 2002 and Planning Commission, 2002b

Composition of capacity and generation

Historically, coal has been the dominant primary fuel for power generation (Table 2.1). Its share in generation has been increasing, even though its share of installed capacity has been declining. The role of hydroelectric, the other dominant energy source, has been declining, both in terms of share in generation and share in generating capacity. The share of natural gas has been increasing rapidly but is still relatively small, while the share of nuclear remains small and relatively constant in both installed capacity and generation. Wind energy comprises less than 1% of installed capacity and probably even less than that in generation.

Table 2.1: Composition of India's generating capacity and generation

	1991		1996		2001		2012	
Installed Capacity	GW	%	GW	%	GW	%	GW	%
Total	66.1	100	83.3	100	101.6	100	215.8	100
Hydel	18.8	28.4	21.0	25.2	25.2	24.8	57.8	26.7
Coal	43.0	65.1	53.5	64.2	61.0	60.0	114.5	53.0
Oil	0.2	0.3	0.3	0.4	2.1	2.0	*	*
Gas	2.6	3.9	6.3	7.6	10.5	10.3	31.4*	14.6*
Nuclear	1.6	2.4	2.2	2.6	2.9	2.9	12.1	5.6
Generation	TWh	%	TWh	%	TWh	%		
Total	264.3	100	379.9	100	501.2	100		
Hydel	71.6	27.1	72.6	19.1	74.3	14.8		
Coal	178.3	67.5	273.7	72.1	355.3	70.9		
Oil	0.1	0.03	0.7	0.2	4.6	0.9		
Gas	8.1	3.1	24.9	6.6	50.1	10.0		
Nuclear	6.1	2.3	8.0	2.0	17.0	3.4		

Source: Center for Monitoring Indian Economy, April 2000; Government of India Tenth and Eleventh Plan Projections

** Oil and gas are not separated in the year 2012 projections. However, it is likely that it will be almost all gas.*

The 10th and 11th Five-Year Plans call for the central public sector under the Ministry of Power (National Thermal Power Corporation, National Hydroelectric Power Corporation and Nuclear Power Corporation of India) to add 46.6 GW and for the SEBs and private entities to add 41.8 GW (Ministry of Power, 2002). Of this, 6.4 GW is expected to be from new nuclear capacity and 10.7 from "unconventional" sources.

2.2 Reforms

The power sector reforms were initiated in early 1990s as a part of the process to increase investments in power generation. The SEBs were financially weak and were slowly becoming dependent on substantial funding in the form of government subsidies. This was because the tariffs, which were usually influenced by the state government, did not fully cover the cost of supply, though the SEBs were expected to earn three percent return on capital. Hence, they were making losses. Added to this, the SEBs had to provide electricity to some consumer categories like agriculture at highly subsidized rates. The high transmission and distribution (T&D) losses- 27.8% in 2002 (Planning Commission, 2002b), also contributed substantially to the financial weakness of SEBs (Haldea 2001).

By 1991, the government's capacity to publicly finance infrastructure projects was eroded to a great extent and the need to attract private and foreign capital was acutely felt. The servicing of international debt had led to a worsening balance of payments situation and the country was on the verge of economic bankruptcy at the beginning of the nineties (Putti, 1998). Following this, in 1991, the policy of economic liberalization was launched. This has brought about institutional reforms in many infrastructure sectors including the power sector. In the power sector, the reforms were initiated by implementing policies for enhancing revenues and mobilizing investment in the short run and by changing the ownership structure and establishing an independent regulatory regime in the long run. Electricity sector reforms undertaken in

India fall broadly into the following categories: Corporatization of State Electricity Board, privatization of power corporations, unbundling, and regulatory restructuring. The reforms also include fuel price reforms, promotion of renewable energy sources and energy efficiency measures.

The Electricity Act 2003 attempted to further introduce competition in every sector of the electricity industry. It replaces the three existing legislations, namely, Indian Electricity Act, 1910, the Electricity (Supply) Act, 1948 and the Electricity Regulatory Commissions Act, 1998. The objectives of the Act are "to consolidate the laws relating to generation, transmission, distribution, trading and use of electricity and generally for taking measures conducive to development of electricity industry, promoting competition therein, protecting interest of consumers and supply of electricity to all areas, rationalization of electricity tariff, ensuring transparent policies regarding subsidies, promotion of efficient and environmentally benign policies, constitution of Central Electricity Authority, Regulatory Commissions and establishment of Appellate Tribunal and for matters connected therewith or incidental thereto" (http://www.powermin.nic.in).

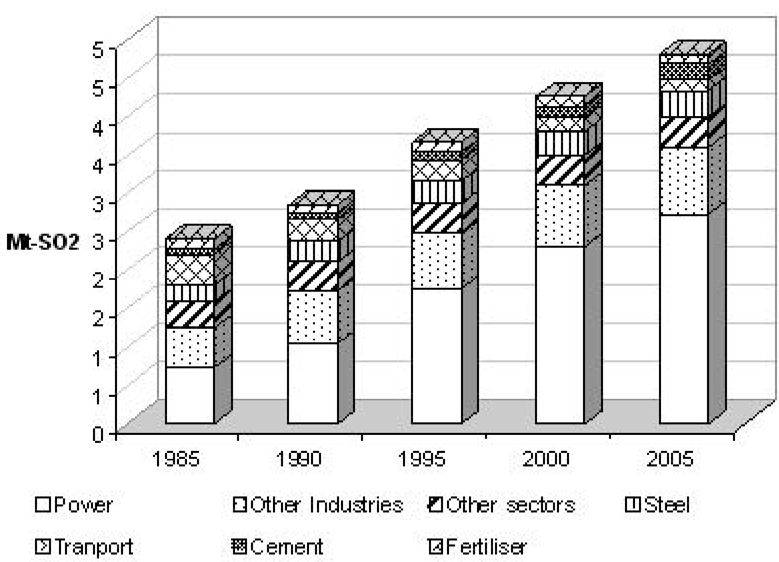
2.3 Externalities

The generation mix in power plants is biased in favor of thermal, which is coal dominated. The share of coal-based power in gross generation from utilities has increased steadily from 55% (in 1980) to 67% (in 1990) and to 72.1% (in 2003) (CMIE Energy, 2005). As a result, power generation is a significant contributor to air pollution, both local and global pollutants. The Government of India's Blue print of Power Sector Development indicates that 52% of power generated in India in 2012 will still be from coal, while gas will be 15%, hydro will be 27% and rest will be renewables and nuclear (Ministry of Power, 2001). The present trends, however, indicate a larger share for coal.

SO_2 emissions from Indian Power Sector

Indian SO_2 emissions are estimated at around 4.26 million tons for 2000. 368 LPS falling under the category of energy sector (including power plants, steel, cement, fertilizer, sugar, paper industries), contributed to around 83% of all-India SO_2 emissions in 2000 . Among the LPS, 82 power plants contributed a major chunk of around 54% of all-India SO_2 emissions. Figure 2.2 indicates the sectoral shares for SO_2 emissions over the years. The SO_2 emissions from power plants have increased from 0.72 Mt-SO_2 in 1985 to 2.72 Mt-SO_2 in 2005 (projected) at around 7% per year. The emissions from the transport sector declined since early 2000 due to drastic reduction in sulphur content of diesel and gasoline. Coal-use in railways also declined sharply. Emissions from biomass combustion stagnated. All these resulted in an increase in power sector share in Indian SO_2 emissions from 30% in 1985 to over 57% in 2005.

Figure 2.2: Sectoral shares of SO_2 emissions



2.4 SO_2 Abatement choices in Power Plants

The abatement options in power plants include both direct and indirect measures. Direct measures to control SO_2 emissions can be implemented by changing quality of fuel inputs, during combustion through use of advanced generation technologies and by controlling output emissions. Indirect measures such as efficiency improvements would have an impact on fuel consumed, thereby influencing the output emissions.

To elaborate further, the direct measures for SO_2 mitigation include fuel quality improvements through coal-washing with fine/coarse grinding, coal input mixing and management and using low-sulphur coal, using advanced generation technologies such as Atmospheric Fluidized Bed Combustion (AFBC) and Integrated Gasification Combined Cycle (IGCC) and end-of-the-pipe solutions like Flue gas desulphurization (FGD), limestone injection dry scrubbing, duct sorbent injection, and SOx-NOx Rox Box (Nolan 2000). These technologies are explained below:

Fuel inputs

Coal quality: Improving the quality of coal is an important step in reducing the emissions. One technique is coal washing. Coal washing, technically called coal beneficiation, is a process by which the quality of raw coal is improved by either reducing the extraneous matter that gets extracted along with the mined coal or the associated ash or both. This process also has implications on the sulphur content of coal. A study on China estimates the impact that coal washing could have on future sulfur dioxide emissions in China and assumes that coal washing could reduce about one-third of the sulphur content in coal (Liu and Spofford 1994). As a general rule, the amount of sulfur removed increases with decreasing coal particle size. A study shows that coal washing reduces about 20-25% of SO_2 emissions when the coal is finely ground (http://www.cartage.org.lb/en/themes/Sciences/Earthscience/Geology/

Coal/Physicalcoal/Physicalcoal.htm). However, finely ground coal has drawbacks in terms of their transportation and storage.

Low-sulphur coal: The sulphur content in Indian coal ranges from 0.2 to 0.7 % and is relatively low as compared to imported coal where sulphur content is often greater than 1%. Using low sulphur coal is also a direct measure to control the SO_2 emissions.

Advanced Power generation technologies

Atmospheric Fluidized Bed Combustion (AFBC): This is a relatively new generation technology, which has high flexibility to burn low grade coals effectively and meets emission limits at reasonable efficiency. Compared to pulverized coal plants, these plants can reduce sulphur emissions by 70 to 95%. There are technical barriers in the development of this technology in sizes greater than 100 MW, which is the major barrier in its widespread adoption (IEA, 1997).

Integrated Gasification Combined Cycle (IGCC): This is the most advanced clean coal technology, but with little experience of operating plants under commercial conditions. The prime advantages of IGCC are its high thermal efficiency and environmental performance, which are expected to be the best of any clean coal technology. It is suitable for burning high ash Indian coal. Around 98% removal of sulphur can be achieved (OECD/ IEA, 1997; World Bank 1997). Sulphur removal is technologically simple and a part of the sulphur is removed insitu. There are lesser problems in the handling of solid wastes compared to the other coal conversion technologies. The major barriers in technology adoption are the complexity of the process, high investment costs, large construction period and so on and so forth.

End-of-pipe solutions

Flue Gas Desulphurization: SO_2 can be removed with more than 90% efficiency with a Flue Gas Desulphurizer (FGD) fitted with conventional pulverized coal technologies (IEA, 1997). FGD can be classified into the following six main categories, namely wet scrubbers, spray dry scrubbers, sorbent injection processes, dry scrubbers, regenerable processes and combine SO_2/NOx removal processes. Wet scrubbers take the lead followed by spray dry scrubbers and sorbent injection systems in the FGD market throughout the world. Regenerable and combined SO_2/NOx processes have a small share and the trend is not expected to change in the short-term according to current plans for new FGD installations (http://www.iea-coal.co.uk/site/database/cct%20databases/fgd.htm).

Efficiency improvements

Apart from the direct measures, other processes also have an indirect impact on SO_2 emissions. Efficiency improvements in boiler efficiency, reducing auxiliary consumption and reducing heat loss are measures that do not directly target SO_2 emissions; however, they have an impact on the emissions due to reduction in coal consumption per unit power generated. Other efficiency improvements measures include variable speed drive motors, residual heat recovery, excess air control and exhaust temperature control.

We take the case of the NTPC coal-based plants (which have 27.1% share in total power generation in India in 2004-2005) plants to understand the implications of various abatement measures (Table 2.2). Here, it is important to note that these are average figures for all NTPC plants, and there exists variability even among the different plants under NTPC.

Table 2.2: NTPC's experience with Different Abatement Measures for SO_2 emissions

Measures	SO_2 emissions abated (%)	Remarks
Efficiency Improvements		
Boiler efficiency	-2.07	This is due to 1 percent increase in boiler efficiency
Reducing auxiliary consumption	-1.08	This is due to 1 percent point reduction in plant auxiliary consumption
Reducing heat losses	-0.06	This is from 1 degree Celsius reduction in boiler exit gas temperature
Fuel Quality		
Washed coal	-15 to -20	Washed coal sulphur content is taken as 0.45% with heating value of 4200 Kcal/Kg
Imported coal	+1.06	Imported coal sulphur content is taken as 2.5% with heating value of 6000 Kcal/Kg
Using less fuel oil	-0.91	This is due to 1 ml/KWh consumption in fuel consumption
Generation Technology		
Super-Critical PC[a]	-2.56	Compared to Sub-critical PC technology
IGCC	-95	Compared to Sub-Critical PC technology
Output Emission Control Measures		
Sprinklers	-85	
FGD	-95	FGD considered here is wet scrubbing technology

Note: Negative sign indicates reduction in SO_2 emissions
[a] *Pulverized Coal*
Source: Based on discussions with experts and officials at NTPC

The experience in plant operations at NTPC reveal that indirect abatement measures, such as coal washing (which is primarily for reducing ash content in coal) could reduce as much as 20% of SO_2 emissions. However, this assessment would vary considerably depending on the sulphur content of coal and the form of its occurrence. In NTPC, the sulphur content of coal used by its plants varies from 0.2% to 0.69%. Based on our discussion with experts, we estimate that the average sulphur reduction from coal washing in utilities in India would be around 15-20%.

Thus, the choice of coal washing as an abatement option would differ across the plants, depending on the extent of emission reduction required and the economic and logistical constraints related to fuel choice. This is true for the other operating characteristics of the plants. Direct measures, such as advanced generation technologies and FGD technologies have higher abatement potential, but they may penetrate at later stages when policies either call for greater sulphur mitigation or there are other incentives for plants to bring about further reduction.

2.5 Integrating energy-electricity-environment markets

The energy, electricity and environment sectors have strong linkages. The consumption of energy resources generates negative externalities in the form of environmental degradation, including air pollution. Power plants are major contributors to local and global pollutant emissions in India, mainly because of the dominance of coal as a fuel in these plants (nearly 72% share in total power generated). The continuous increase in generation to bridge the demand-supply gap in the electricity sector, and the dominance of coal in the generation mix would have serious implications on the air quality. This would be reflected in terms of their damaging impacts on human health. The same is true for the energy sector, since energy costs is nearly 80-90% of electricity costs. For power plants, the use of emission control technologies has implications on their fixed and operating costs, which in turn affect their competitiveness. Therefore, they should be given the flexibility in making the technology choice. Thus, aligning the energy-electricity and environment markets is crucial for the success of the reforms in the electricity sector.

However, the reforms in the electricity sector have not always specifically addressed the environmental concerns. Policies and measures to manage the air quality have not been integrated in the overall framework of electricity reforms; but, there have been indirect environmental implications of the reforms. The indirect implication have been shown in the case studies of Gujarat and Andhra Pradesh, which were conducted to understand the varied firm-level implications of policy reforms in the electricity sector (Shukla et al 2004b). These case studies showed that the changes in technology choices and efficiency improvements in power generation after the reforms have also resulted in the reduction in emission intensity of carbon and sulphur.

To conclude, the complex interplay between the different sectors implies that policies in a specific sector would not achieve the desired impacts without complementary policies in related sectors. Thus, an integrated approach that takes into consideration the multi-sectoral linkages should be adopted in electricity reforms.

Chapter 3

AIR QUALITY MANAGEMENT IN INDIA

Over the last decade, air quality improvement has been an important issue in the national and local policy agenda. An integrated approach is required, whereby all the components of an air quality management strategy are taken into consideration while formulating policies. There are three basic components of a comprehensive approach to public policymaking, including environmental policymaking. These components are,

- Policy objectives, which are the goals, set for attaining a particular level of air quality and should be based on scientific studies and public values.
- Policy instruments, which are defined as "the myriad techniques at the disposal of governments to implement their policy objectives" (Howlett 1991). They include CAC instruments that are purely regulation based, economic instruments that harness market forces to achieve an efficient outcome, voluntary approaches and informational designs.
- Institutions are "the rules of the game of a society, or, more formally, [...] the humanly devised constraints that structure human interaction. They are composed of formal rules (statute law, common law, regulations), informal constraints (conventions, norms of behavior and self-imposed codes of conduct) and enforcement characteristics of both (North 1994).

These components are inter-linked in their roles and influence the overall process of policy formulation and implementation; therefore, they have to be addressed simultaneously. Policies for air quality management are the goals for air quality improvement and instruments are the tools to achieve these goals. The emphasis on environmental policymaking varies with the level of socio-economic development, financial and human resources and institutional capabilities of the country. Therefore, the choice of policies and instruments depends on the existing and developing institutions related to environment management. Institutions influence the entire decision-making process, starting from policy formulation to effective implementation.

We consider the existing strategy for air quality management in India, in terms of existing policies, instruments and institutions for managing the entire process. Further, we look at an alternate instrument to achieve the objective of improving the air quality in an optimal manner, focusing on SO_2 mitigation from power plants.

3.1 Policies, Instruments and Institutions

Policies

There is a comprehensive structure of legislations and policy initiatives to manage the air quality in India. The most comprehensive legislation is the *Environment (Protection) Act,* 1986, which was passed in response to the decisions taken at the Stockholm Conference in 1972. This is an umbrella Act that empowers the Central Government to take necessary measures for, a) protecting and improving the environment; and b) for prevention, control and abatement of pollution. Among the other Acts related to air pollution, the *Air (Prevention and Control of Pollution) Act*, 1981, provides for the control and abatement of air pollution. The National Ambient Air Quality Standards (NAAQS) for industrial, residential and sensitive areas was notified in 1984 under the *Air Act,* which was made stringent in 1994 and notified under the *Environment Protection Act*. Mass vehicular emission norms for new vehicles were notified for the first time in India in 1991, under the *Environment Protection Act, Central Motor Vehicles Rules and Air Act*.

Instruments

Policies for controlling emissions from different sources are primarily regulation-based and instruments adopted are command and control instruments. The most prevalent instruments are the emission standards for industrial and vehicular emissions and regulating the fuel quality.

In the case of vehicular emissions, the instruments used include progressive tightening of auto-emission norms (in 1991, 1996, Euro norms since 2000) and the improvement in fuel quality by using unleaded gasoline and reducing the sulphur content in diesel. Policy instruments for controlling industrial emissions include monitoring of air pollution from highly polluting industrial units, closure or shifting of polluting industries, and time bound action plan to control pollution in identified "hot spots" (http://envfor.nic.in/soer/chap6.html). For instance, in some cities like Delhi, the polluting industries have been moved to the periphery of the city through Court directives. In the Taj Trapezium Zone in Agra, the small-scale polluting industries have been relocated, while the large industries have been directed to use natural gas as fuel. There are emissions standards for specific industries and pollutants and also minimum stack height criteria for the dispersion of pollutants.

Different instruments are also being adopted for managing specific pollutants and improving fuel quality. For instance, instruments for controlling sulphur include reduction of the sulphur content in petroleum oil products. The sulphur content in the diesel oil supplied to metropolitan cities (Delhi, Mumbai, Chennai and Kolkata) has been reduced by the Indian refineries during the year 2000 from 1% sulphur by weight to 0.25% as per the Government's directive. It was further reduced to 0.05% by weight in Delhi by late 2001 (Mashelkar et al 2002). In the case of power plants, provisions have to be made for future installation of FGD (CPCB 2003). Lead in vehicular fuel is controlled through unleaded gasoline for vehicles (introduced in 1996) and leaded gasoline has been completely phased-out by 2000. Instruments for reduction of particulate emissions include installing electro-static precipitator in industrial units, use of cleaner fuels and efficient vehicles. Apart from improvements in vehicular fuel mentioned above, there have also been measures to improve the quality of coal. A policy directive has made it mandatory to use of beneficiated coal for all power plants set up after 2000, as well as for plants located 1000km away from the pithead and in urban areas (CPCB 2003).

Institutions

Informal institutions

In India, there is an adversarial attitude between the government and institutions such as environmental activists and NGOs. These institutions put pressure on the government to take stringent and immediate steps to control the air pollution in urban areas. Such pressure is required in a developing country like India where development objectives are often prioritized over environmental protection. This pressure is reflected in the several Public Interest Litigations (PILs) filed in the Supreme Court of India against the impacts of growing air pollution.

Legal structure

Judicial activism has become prominent in air quality management since late 1980s and the Supreme Court has played a major role in the introduction of policies and measures. A major push factor for these measures is public pressure, which has taken the form of PILs being filed in the Supreme Court. The subsequent Court rulings have led to the introduction of several pollution control policies, the prominent ones being in the case of vehicular pollution in Delhi and protecting the air quality in the Taj Trapezium Zone in Agra. The Court has also intervened to ensure effective implementation of its directives.

Policy formulating and implementing organizations

The Ministry of Environment and Forests (MoE&F) is the nodal agency at the center for planning, promoting and coordinating environment management policies. The Central Pollution Control Board (CPCB) is the executive body, assisted by State Pollution Control Boards (SPCBs), which implement the policies in different States. Other government organizations that influence the process of air quality management include the Ministry of Power, Ministry of Petroleum, Ministry of Urban Development and Poverty Alleviation, Department of Science and Technology, State Department of Environment, Urban Development Authority, Ministry of Road Transport and Highways, Ministry of Coal and Mines and Ministry of Health and so on and so forth. Central government agencies such as the Bureau of Indian Standards and CPCB contribute, either directly or indirectly, to the process of determining emissions norms and fuel quality standards. Stakeholders, including regulated parties and NGOs, also have a say in this process.

3.2 Existing strategy for SO_2 control from power plants

There are regulations specifying SO_2 emission concentrations in industrial areas (annual average concentration of $80\mu/m^3$ and maximum permissible daily level of $120\mu/m^3$). In the case of power plants, the emission standards are not specified; rather there are mandates for other technology requirements. There are minimum stack height criteria for dispersion of SO_2 emissions (for plant capacity up to 500 MW it is 220 meters and for capacity above 500 MW it is 275 meters). After the year 2000, policies have also been formulated for use of emission control technologies in the future. For instance, new coal power plants above 500 MW and not using IGCC generation technology are required to keep space for installing flue gas desulphurization equipment (CPCB 2003). This directive implies that the use of FGD technology may be made mandatory in future. The policy directive to use washed coal, while aimed at reducing the fly ash in coal, would also reduce its sulphur content.

Thus, at present, policies and measures for controlling SO_2 emissions from all industrial sources, including power plants, are specified by regulations and the plants have little flexibility in making their abatement choice.

3.3 Alternate strategy: Case for emissions trading

Strengths and weaknesses of technology push (CAC) vis-à-vis emissions trading (MBI)

Historically, the policymakers have relied on CAC instruments to achieve their objectives of air quality management. However, as countries have moved towards higher levels of socio-economic development and economic reforms take place, the role of MBIs in policy implementation has also become significant. With development, constraints are overcome and the country has the wherewithal in terms of resources and institutional capability to implement MBIs to achieve a more efficient solution. The strengths and weaknesses of the two instruments have been summarized in Table 3.1.

Table 3.1: Attributes of the Instruments: Their Strengths and Weaknesses

Category	Strengths	Weaknesses
Command-and-control instruments	• Force of law in implementation • Dependability • Consistency and Predictability. • Accountability.	• Inflexible in accommodating changes in economic conditions and abatement technologies. • High informational requirements, with regulators required to keep track of technological changes. • Inefficient, as they give limited incentive for innovation or going beyond compliance. • Administrative complexity.
Economic instruments	• Static efficiency: a) Creates financial incentives for abatement. b) Firms free to choose abatement technologies that minimize costs. • Dynamic efficiency and greater flexibility in long-run: a) Encourages innovations. b) Provides incentive for continuous improvement. • Reduces compliance costs. • More flexible to changes in economic conditions or abatement technologies. • Minimal informational requirements help to decentralize decision-making. • Raises revenues.	• High enforcement costs. • Higher administrative and monitoring costs. • Politically contentious, especially if different political parties exist in Centre and State.

Source: Compiled from Montogmery 1972, Baumol and Oates 1988, Tietenberg 1995, OECD (1989, 1994, 1997), Stavins, R.N (2000a, 2000b); Sorell 2001

Suitability of instruments

The choice of alternate policy instruments is not solely based on their strengths and weaknesses, rather they are influenced by the suitability of the instrument vis-à-vis the emission source, the context and existing institutions. For instance, the effectiveness of instruments to control emissions depends on the individual characteristics of a source. Emissions from transport sector are from mobile, dispersed sources, and targeting individual vehicles would require strong implementing mechanisms to monitor and enforce it. For instance, while Pollution under Control (PUC) certificates are used to check emissions from in-use vehicles, there are often issues related to lack of transparency and ineffective enforcement. Rather, policymakers rely on instruments like emission norms to control vehicular emissions since it acts at the point of refining and manufacture of the vehicle, or on standards for fuel quality (e.g. sulphur content in diesel) or taxes could be imposed on relatively less clean fuels (on leaded gasoline to promote unleaded gasoline). On the other hand, the LPS such as power plants, are stationary and concentrated, therefore instruments can target each source. Thus, instruments like emissions trading are easier to monitor and enforce for the LPS, while they would not be practical for the transport sector.

The emphasis on CAC instruments for implementing air pollution control policies often exists because of the relative ease in implementation and effectiveness of monitoring and enforcement. However, specifying uniform technology-based standards for all plants increases the overall compliance costs because technology push policies do not consider the differences in marginal abatement costs of plants, thereby limiting the flexibility of plants in abatement choices. Reducing the flexibility of the emitter would ultimately result in higher compliance costs.

As opposed to pure command-and-control instruments, an emissions trading system would control emissions in an optimal manner in the long run. A well-designed cap-and-trade program is a form of environmental regulation that not only controls emissions, but also creates significant cost savings. This is achieved in two ways. Firstly, the regulator while specifying the target does not impose specific reduction technologies on each source. Therefore, sources have the flexibility to determine the least cost emission strategy for their specific facility. Secondly, as sources are able to reduce emissions at relatively low cost, they would implement larger reductions, since they gain by trading with those firms that incur higher marginal abatement costs. And, firms facing high marginal abatement costs can lower their own compliance costs by purchasing the right to emit SO_2 from firms with lower costs. Thus, there would be cost savings compared to a purely regulation-based approach to controlling the emissions.

3.4 Country Experiences

Policymakers, both in developed and developing countries have relied on technology-based emission standards during the initial phases of controlling emissions from polluting sources. The command and control pattern of regulation set uniform targets of how much polluting sources could emit, either by specifying the standards, and sometimes even specifying the processes or technologies to be used to meet the standards. In the case of vehicular emissions too, developed countries have relied on setting emission norms for vehicles and fuel quality. There is continuous upgradation of emission norms and technologies in the US, EU and Japan, and the developing countries have usually adopted the standards followed in any of these countries. The CAC instruments were successful in controlling and reducing emissions from the previously unregulated polluters. However, there is a gradual transition where countries are also using MBIs, like emissions trading, to tackle the problem of industrial pollution. This is true for both developed and developing countries and we highlight some instances.

In the US, the Emissions Trading Program (ETP) is the earliest air permit program, which was grafted onto the existing regulations-based regime for industrial air pollution control. The Environment Protection Agency (EPA) established a program of "offsets" whereby new sources were allowed to locate in non-attainment zones if they were able to secure sufficient "emissions reductions credits" from existing firms. While environmental impacts of this program were negligible, there were significant cost savings. State-level emissions credit programs, authorized by the U.S. EPA, are also operating in California, Colorado, Georgia, Illinois, Louisiana, and New York. Mobile sources can generate credits by scrapping high emission vehicles and replacing them with cleaner ones, by fuel switching, or by trip reduction (Stavins 2000b).

The Acid Rain Program in the US is considered as one of the most successful applications of a market-based instrument for environmental protection. It was established under Title IV of the 1990 Clean Air Act Amendments to achieve a major reduction in the electric generating facilities' SO_2 and NOx emissions through emissions trading. In the case of SO_2 emissions, the objective was to reduce the emissions from electric utilities from the 1980 level of 17.5 million tons of SO_2 to a permanent level of 8.95 million tons by 2010 (http://www.epa.gov/airmarkt/progress/arpreport/acidrainprogress.pdf). These reductions would be achieved through a two-phase tightening of the restrictions placed on fossil fuel-fired power plants. As of 2001, the program encompassed nearly 2,300 units at 1,000 plants. In 2002, SO_2 emissions from power plants were 10.2 million tons in 2002, 9% lower than in 2000 and 41% lower than 1980 (http://www.epa.gov/newsroom/headline_091503.htm). Studies have confirmed the benefits of this approach. The General Accounting Office has projected that the allowance trading system could save as much as $3 billion per year -over 50%- compared with a command and control approach of previous environmental protection programs (http://www.epa/gov).

Apart from the US, some other countries have experimented with the use of an emissions trading program. For instance, Chile has implemented a tradable permit system for total suspended particulates (TSP) from stationary sources in the Santiago area. While there is a reduction in TSP, the extent to which trading contributed is uncertain since natural gas was introduced as an alternative fuel during the same period, and also because the volume of trading was low (Montero and Sánchez, 1999).

In China, the power sector sector accounts for around 45% of national SO_2 emissions, and sources primarily use high chimneys (Wang et al 2004). As a result, they are key contributors to the regional acid rain problem. Therefore, emissions cap-and trade is considered to be a good instrument to manage these emissions cost-effectively. China has conducted emission-permit pilot projects in six cities of Baotou, Kaiyuan, Liuzhou, Taiyuan, Pingding-shan, and Guiyang as early as 1994. Going further, in 2001, the city of Taiyuan, in northern China's Shanxi province, established an SO_2 cap-and-trade program to reduce their emissions cost-effectively. Studies carried out showed that there was a good opportunity to implement an emissions trading system, as compared to other alternative mechanisms (Bell 2003).

Thus, while the existing technology-push policies have been successful in securing the first tranche of emissions reductions from previously unregulated industries; however there is a need to analyze alternate instruments like emissions trading that reduce emissions at lower costs. However, it is not intended that an emissions trading system should completely replace the CAC system; rather they would complement the existing strategy. These are explained in greater detail in the following chapters, where a comparative analysis is done between an emissions trading system vis-à-vis a technology-push policy instrument.

Chapter 4

ASSESSING TECHNOLOGY-PUSH VIS-À-VIS EMISSIONS TRADING

4.1 Methodology

A long-term energy-environment optimization model, Asia-Pacific Integrated/Local Model (AIM/Local) is used in this paper for analyzing the implications of alternate instruments. The model is used to project the SO_2 emissions from power plants till the year 2030 in the business-as-usual scenario (BAU), which is also referred to as the dynamics-as-usual scenario. This scenario reflects current official policies of the Government and forecasts of macro-economic, demographic and energy sector indicators. The BAU is projected based on assumptions about policy interventions that are bound to come in the future (specifying possible phases). These, in turn, are based on an understanding of the entire system, especially the energy sector and power sector dynamics- the history and current trends in India as also the trends in other countries. This understanding helps in developing the future trends of policies and these are incorporated in the BAU scenario.

Policy interventions that drive the trajectory in BAU could be brought about by different instruments. Existing approach is that regulations specify the technology to be used by the plants; this is termed as a technology-push instrument. An alternate approach could be using an emissions trading instrument that leaves the abatement technology choice with the plants and allows for trading. There is a further possibility of using multiple instruments to achieve flexibility in abatement, but that analysis is beyond the scope of this paper. Here we compare two instruments, *technology-push* and *emissions cap-and-trade,* which provide the two alternate pathways for BAU. Since the two pathways achieve the same trajectory of SO_2 emissions, the implications are compared in terms of the cost differences between them. In a perfect market, the costs and path of adopting pollution control technologies should be optimal in both technology-push and an emissions cap-and-trade system. However, due to imperfections in the system, this does not happen and there are cost differences to achieve the same outcome.

The period considered for this research is 2005-2030. There is need for long-term studies because there is considerable inertia for change in energy infrastructure-related systems such as the power plants. Once these plants are commissioned, they last for more than 30 years. Thus, there is a lock-in of technology, and retrofitting the technology would also require substantial investments. Hence, we use a long-term energy-environment model to study the problem.

4.2 Structure of AIM/Local

The AIM/Local is a bottom-up model[3], which takes into account the various technologies available for the system under consideration and allows a sectoral study. It allows for a detailed analysis of the technical and economic dimensions of specific policy options, which is required for studying the implications of an emissions trading instrument vis-à-vis technology-push instrument for managing SO_2 emissions from power plants. This is not possible with top-down models, since they are weak in capturing technological details, have a higher sectoral aggregation and assess the overall macro-economic impacts of a policy. Moreover, the Geographical Information System (GIS) interface of this model allows for a spatial representation of the distribution of emissions.

The AIM/Local model is a demand-driven model. It uses a linear programming approach to find an optimal solution by selecting a combination of technologies with the least cost while

[3] Economic models have two paradigms namely, top-down and bottom-up, depending on how the model captures the interactions between energy, environment and economy.

satisfying the given constraints of fulfilling the demand and meeting the environmental targets and/or energy supply constraints in the specific region (Shukla et al 2004a). The different generation technologies are provided as an input to the model with exogenous upper bounds of technology penetration. These upper bounds are estimated through an understanding of past trends, the most likely future estimates based on dynamics-as-usual situation, existing studies on future projections and expert opinion. The inputs to the model take into account the technological improvements and innovations that improve the efficiencies in generation and of the removal technologies of power plants. Three kinds of technology options are considered-existing technology, retrofit options and new future technologies. The retrofitting of technologies and retirement of old and inefficient technologies improve the efficiencies of existing units of plants, while the capacity expansion of existing plants involves setting up of new units that would have further advanced technologies. The new plants that are expected to come in the future would also have a higher share of advanced and cleaner technologies and fuel. These changes have a cumulative effect on the technical efficiencies of the plants and are reflected in the autonomous energy efficiency improvements, the fuel efficiency improvements and reduction of emission coefficients of the plants.

The following equation is used to estimate the total emissions of a particular gas.

$$Total\ Emissions = \sum_{Source\ Category} (Activity\ Level \times Emission\ Coefficient)$$

Calculating Emissions from Large Point Sources

Calculation of emissions from energy combustion may be done at three different levels referred to as tiers 1, 2 and 3 in the Inter-Governmental Panel on Climate Change Guidelines

(IPCC, 1996). Tier-1 methodology, concentrates on estimating the emissions from the carbon content of energy kind supplied to the country as a whole or to the main energy combustion activities. This is a simple method and emissions from all sources of combustion are estimated on the basis of the quantities of energy kind consumed and average emission factors. Tier-2 estimation methodology is based on detailed energy/technology information covering stationary and mobile sources. It is more detailed than tier-1 methodology but uses the same concept of energy kind consumption-based emission coefficients like CO_2 emissions per unit of coal combustion. Tier-3 is similar to tier-2 except that the emission coefficients are based on end-use demands like CO_2 emissions per unit of power generated. AIM/Local model uses a combination of tier-2 and 3 methodologies for emission estimation.

The LPS emissions in the model are estimated by two different approaches. The model follows an approach similar to tier-2 for estimating emissions from the LPS for energy consumption. The data required includes information about the production quantity, production process, energy combustion by various technologies, emission coefficients for the energy kind and pollution removal technologies used. The emissions are estimated by multiplying the energy consumption by each technology with respective emission coefficients for that energy kind.

In this model, tier-3 approach is used for estimation of emissions from the industrial processes. The data requirement for this approach includes production quantity, production process and emissions factors per unit of production. Emissions are estimated by multiplying the production quantity by the corresponding emission coefficients. The net emissions from an LPS in both the above approaches are calculated by accounting for the pollution removal factor due to the pollution removal technology.

Thus, emissions from LPS for energy consumption and production processes are given by

$$Q_l^{LPS} = R_l^{LPS} \times \{\sum_k (E_{l,k}^{LPS} \times f_k) + \sum_v (V_{l,v}^{LPS} \times f_v)\}$$

Where,

Q_l^{LPS} : Net emission from large point source l

R_l^{LPS} : Release rate of pollutants after removal technology of large point source l

$E_{l,k}^{LPS}$: Energy consumption of energy kind k for large point source

f_k) : Emission coefficient of energy kind k

$V_{l,v}^{LPS}$: Production quantity of production process v for large point source l

f_v : Emission coefficient of production process v

k : Energy kind

v : Production process

The AIM/Local model is used to analyze counter-measures and project emissions from the LPS as a result of these measures. The possible counter-measures include constraints on emissions from the LPS, setting a tax on the emissions or any measure at "used stage" such as maintenance, which improves the efficiency levels.

Data sources and coverage

Data for power plants in India are obtained from diverse data sources, including published documents of Government of India, state governments, government organizations, industry federations and autonomous organizations. The future LPS data is taken mainly from published reports and databases like CMIE (CMIE 2002a, 2002b). These provide status information of the planned investment projects in India for the power sector till almost 2010. The projections for power plants for the next 30 years have been made based on retrofitting and capacity augmentation options for existing plants, present policy directives of the government and expert opinion. The power plants for next 30 years are shown in Table 4.1.

Table 4.1: Number of Existing and Future Power Plants in India

	2000	2010	2020	2035
Power Plants (coal and oil)	82	111	131	150
Power Plants (natural gas)	12	17	20	23

4.3 Business-as-usual scenario

Assumptions

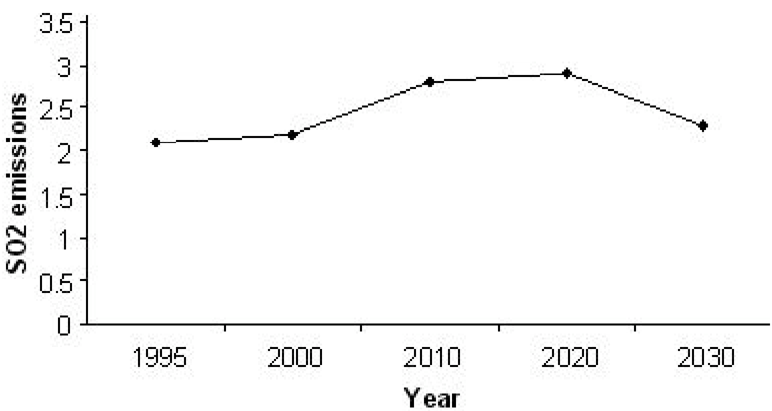
The key drivers that influence the storyline are interventions that impact SO_2 emissions from plants. These include government policies, forecasts of various macro-economic, demographic and energy sector indicators. Besides, it also includes specific measures adopted by the power plants such as efficiency improvements, fuel quality improvements, use of abatement technologies, improvement in generation technologies, and penetration of other generation technologies such as natural gas, nuclear, hydro and renewable technologies.

The assumptions for the BAU scenario includes continuation of macro-economic trends (including structural changes in the economy), demographic and energy sector trends (like autonomous energy efficiency improvements and penetration of clean technologies and renewable fuels), as well as government policy trends, including those related to power plants. In the case of power plants, it is found that coal continues to dominate as the generation technology in the BAU scenario. At present, there are no emissions standards mandated for sulfur emissions (except criteria for stack height) from power generation, but looking at the current trends, strict legislations are expected to come in future (CPCB, 2003). These are built in the BAU scenario.

BAU trajectory

Based on assumptions of these drivers, the model estimates a trajectory for the BAU scenario. The SO_2 emissions trajectory rises initially in the BAU scenario reaches a peak by 2020 and starts declining thereafter (Figure 4.1). This decline is the impact of policy interventions in earlier periods, coupled with stricter enforcement of local air quality regulations. This trajectory is supported in literature on the environmental Kuznets' curve (described in Ch.1), which shows that even though pollution levels rise initially with increasing incomes, after a certain point it is followed by an improvement in environmental quality. This is because with economic growth and rising income levels, there are more resources to invest in cleaner technologies and processes and there is also greater demand for a cleaner environment.

Figure 4.1: SO_2 Emissions from Power Plants under BAU



As mentioned earlier, this trajectory for BAU can be achieved through alternate instruments and here we compare the technology push instrument vis-à-vis an emissions trading instrument. The different measures for SO_2 mitigation that are available to the power plants while using either instrument are described in detail in Chapter 2. These are summarized as follows:

1. Input side (coal washing with fine/coarse grinding, coal input mixing and management, low-sulphur coal)

2. Energy efficiency of the power plant (variable speed drive motors, residual heat recovery, boiler efficiency, reducing auto-energy consumption, excess air control, exhaust temperature control etc)
3. End-of-the-pipe solutions (FGD {including wet scrubbing, dry scrubbing, limestone forced oxidation and magnesium enhanced line}, limestone injection dry scrubbing, duct sorbent injection, SOx-NOx Rox Box etc)
4. New power generation technologies like IGCC

4.4 Alternate instruments for BAU

Technology-push for BAU

Adopting this instrument implies that policymakers specify, through regulations, the technological solutions to be adopted by power plants to reduce SO_2 emissions. An example is the government directive that requires all new coal based power plants with more than 500 MW capacities to provide space for fitting of FGD for control of SO_2 emissions (CPCB, 2003). This pathway assumes that there would be similar directives that would introduce new emission control technologies in the plants at specific time periods.

Thus, the regulations bring about penetration of new technologies and improvement in efficiencies that ultimately reduce SO_2 emissions. Here, power plants do not have the option of choosing between alternate technologies or no abatement to minimize their abatement costs. This path does not consider the use of any economic instrument for SO_2 mitigation.

Emissions cap and trade for BAU

This path assumes that a cap-and-trade instrument is adopted to reduce the SO_2 emissions and emission caps are specified to attain the BAU levels of SO_2 emissions. This policy is similar to technology push in that it also enhances the penetration of new and efficient SO_2 control technologies. The difference lies in the flexibility provided and cost savings that happen due to the trade. The emissions trading system does not recommend any technology or fuel and each plant is free to decide and choose the SO_2 mitigation option. It is based on the assumption that different emitters incur different costs when they reduce emissions. If they can trade in the emission allowances, then emitters with low marginal abatement costs can cut emissions below their target and sell the difference to emitters having high marginal abatement costs, thereby making a profit. At the same time, high-cost emitters can reduce their emissions more cheaply by purchasing some of the required allowances from low-cost emitters. The result is that overall emission reductions can be achieved at lower costs than what would be achieved by a technology push instrument.

4.5 Implications of alternate instruments for BAU

Cost savings

As a result of the different mitigation options chosen by plants and the resultant trade (in an emissions trading system), there is a difference in compliance costs between technology-push and an emissions cap-and-trade instrument. An emissions cap and trade system results in lower compliance costs as compared to the costs of technology-push for equivalent emission reductions.

We elaborate the differences in compliance costs for three mitigation options, namely the use of FGD, coal washing and efficiency improvements. The capital costs for FGD over the modeling period are taken to be between US$ 40-70 per kW of generation capacity- both for new plants as well as retrofit plants (http://www.worldbank.org/html/fpd/em/power/EA/mitigatn/aqsowet.stm). Considering that the total coal-based power generation capacity in India in 2030 would be over 150 GW as per our modeling projections, it is estimated that the costs for adopting FGD technology in a technology-push policy would be around

US$ 3.6 billion during 2005-2030. As opposed to this, the costs under an emissions trading scenario is around US$ 1.4 billion.

In coal washing, the washery capital costs and process costs is estimated to be around US$ 9-15 per ton of coal washed (http://www.teri.res.in/teriin/news/terivsn/issue5/analysis.htm). Indian power sector is projected to consume above 570 million-tons coal in 2030 (Kapshe et al 2002; Shukla et al 2004a). Under a technology-push scenario, around 18% of total coal used will be washed in 2030 depending upon distance of use from the mine-mouths; therefore coal-washing costs in this scenario would be around US$ 1.3 billion. In an emissions trading scenario, on the other hand, these costs are around US$ 0.7 billion. In the case of efficiency improvements, the costs would be around US$ 0.6 billion in a technology-push scenario, while it would be around US$ 1 billion in an emissions trading scenario.

The cost differences arise due to various reasons. Firstly, in a technology-push policy instrument, interventions come through regulations that specify the plants supposed to control emissions, method of compliance and time of introduction. For instance, there are different grades of FGD technologies that vary in costs and extent of reducing sulphur emissions. A technology-push policy instrument is assumed to specify the installation of the best technology among the different grades. This limits the flexibility of plants to choose the grade of technology they would want to use for marginal abatement. However, the emissions trading system gives them this flexibility to choose the technology based on price signals. This makes it less expensive for the plants since it aligns economic and environmental interests. Again, current trends in technology-push instruments suggests that new regulations place few costs or burden on plants that choose to operate older and dirtier units, but require those building new units to install expensive controls. The new units would anyway be less polluting; however, they are required to become even cleaner to mitigate additional SO_2 emissions that should have been otherwise imposed on the existing dirtier units. Marginal mitigation costs of additional SO_2 mitigated from a plant that already has low emissions are much higher than those from older plants with high emissions and fewer emission control technologies. This is seen in the policy directive that requires installation of FGD for new plants with capacities above 500 MW. In such a case, overall compliance costs would be higher. Finally, a technology policy results in the firm installing and maintaining the same technology; however, a cap-and-trade system is more dynamic since firms have continuing incentives to reduce pollution to meet their quota or create additional allowances.

Our modeling assessment gives an overall estimate of the differences in compliance costs between the two instruments following the BAU trajectory over the period 2005-2030. The compliance cost in a technology push instrument is around US$ 5.5 billion over the 25-year period. On the other hand, over the same period and for equivalent reductions, an emissions cap-and-trade regime would result in compliance costs of around US$ 3.1 billion. Thus, the cost of a cap-and-trade regime is 44% lower to achieve the same emissions trajectory; this would accrue a saving of US$ 2.4 billion in 25 years, i.e. an average annual saving of US$ 96 million. Further research on specific plant level mitigation costs is required to assess the impacts of different levels of emissions reductions.

Allowance prices in an emissions cap-and-trade system

The allowance price in a year reflects the marginal abatement costs of SO_2 reduction in that year; if a perfect trading system is assumed. The marginal abatement costs under the cap-and-trade system would be high in the initial years, when the cap is applied, due to the investments in technologies to meet the allotted emissions as well as other transition costs (Table 4.2). However, the increase in demand for alternate technologies and increasing competition would lower the cost of these technologies, thereby reducing the marginal abatement costs for the plants in the later periods. The replacement and retrofitting of existing sulfur intensive technologies by cleaner technologies in initial periods generates a momentum that reduces the costs in the later period.

Table 4.2: Marginal Cost of SO_2 Mitigation (US$[4]/t$SO_2$)

Parameter	Scenario	2010	2020	2030
Marginal Cost (US$/t$SO_2$)	Emissions cap and trade for BAU	148	120	98

Allowances traded among plants

In this paper, we have analyzed the implications of a cap-and-trade system by assuming an overall emissions cap. The surplus or deficit of allowances (or emissions) in each plant which would induce trading depends on the allowances allocated to each plant. In Chapter 5, we propose a broad framework of allowance allocation methodology that could be adopted, but further research is required to formulate the detailed allocation strategy. However, the allocation strategy per se would not impact the analysis because the total number of allowances allocated to plants would be equal to the emissions cap assumed here.

To conclude, the differences in compliance costs between the two scenarios arise because regulations are developed more on a policy basis, where the focus is on broad political and social considerations, whereas business decisions are made mainly on an economic basis, in which small differences in cost and regulatory design make an enormous difference. A balance between the two objectives is necessary and an emissions trading system strives to achieve this balance.

[4] The exchange rate assumed is Rs 43.72/US$

Chapter 5

DESIGN ELEMENTS OF A CAP-AND-TRADE PROGRAM FOR INDIAN POWER PLANTS

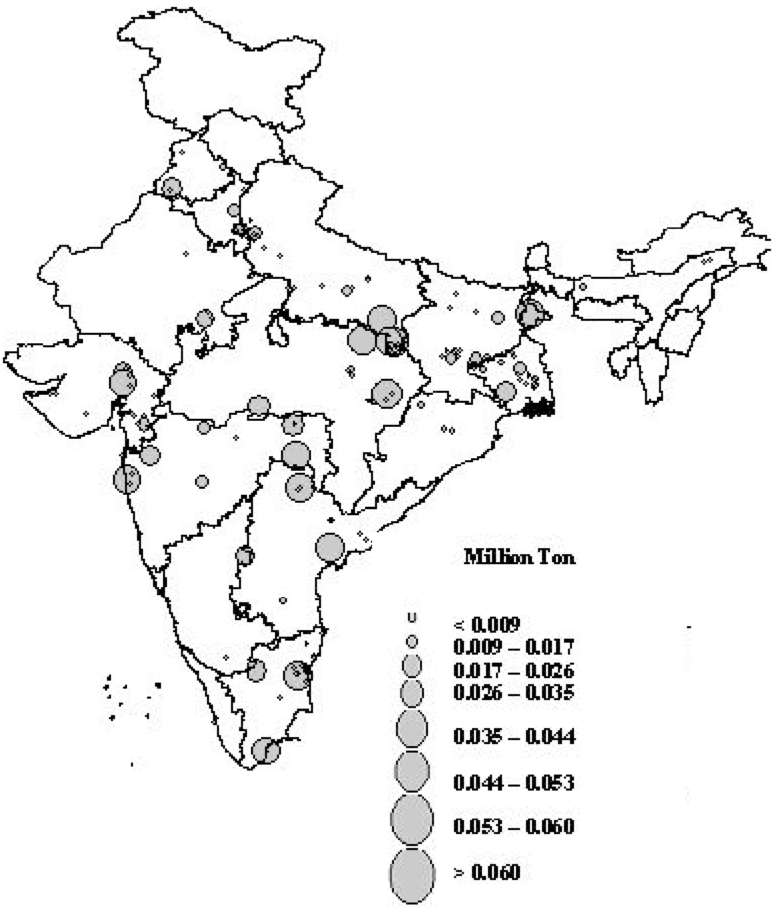
5.1 Existing opportunities

The development of an emissions trading system is influenced by the presence of different attributes, which include a) there are a significant number of sources responsible for the problem, b), the problem occurs over a relatively large area, c) there are varying control costs, and d) adequate institutions are present for monitoring and enforcement (USEPA 2003). The presence of these attributes contributes towards the effectiveness of an emissions cap-and-trade system.

As mentioned earlier, around 82 power plants contribute to nearly half of the all-India SO_2 emissions in 2000. These plants are widely distributed throughout India because this sector has evolved around the different state utilities. The regional spread of SO_2 emissions from the power plants in 2000 is shown in Figure 5.1.

Power plants in India are characterized by differences in terms of performance, fuel quality, generation technologies, efficiency of operations and maintenance, emission control requirements, plant load factors, plant ownership, region of operation and vintage etc. These differences create differences in the marginal abatement costs for plants. For instance, the average age of power plants in India is 22 years and the older generation units emit more SO_2 per unit power generated (Garg and Shukla 2002; Kapshe 2003). The marginal abatement costs for the older units would be higher as compared to those of the newer plants that are more efficient in generation and operations.

Figure 5.1: Regional Spread of SO_2 emissions from power plants in India in 2000



5.2 Program Structure

The first phase of the program should start in 2010, with existing coal-based power plants participating in the program. The reason for opting for coal based power plants initially is that they offer substantial potential for SO_2 emissions reduction. They contribute to nearly half of all-India SO_2 emissions and reducing their emissions would substantially reduce all-India numbers. Moreover, their numbers are limited, locations are concentrated and they under public domain, which makes implementation relatively easy.

The SO_2 emissions due to transportation of goods (electricity, steel, and other materials) are not accounted for with the goods. They are accounted for in the transport sector. The cost of reducing SO_2 emissions due to transportation of goods has to be therefore borne by the transportation sector and will be reflected in enhanced unit price of transportation. Therefore, conceptually, for the power sector as well, the transmission and distribution (T&D) losses in the wires amount to SO_2 emissions since that much extra electricity has to be produced to meet the final end-use demand – resulting in additional SO_2 emissions. This again is not accounted for with the power plants but is borne by the T&D company. National SO_2 emission emissions trading regime would cover these T&D companies as well and high-transmission losses (or inefficient companies) have to either reduce their losses or buy allowances from the market.

The other LPS can come in at the next phase of the program. The insights from this program would also be beneficial for designing similar programs for the upper ends of the transport sector, such as at the refinery and manufacturer's level.

The design elements of a cap-and-trade program include four broad areas (Ellerman 2001; Svendsen and Vesterdal, 2003; Morgenstern et al 2004), namely the setting of the emissions cap, the allocation of allowances, mixing the national level emissions trading system with other instruments such as local air quality standards, and its enforcement. These elements are addressed in the following sections.

Setting the emissions cap

The emissions cap should be set at a level that is expected to address the environmental problem and health concerns at an acceptable cost (USEPA 2003). This cap is set by policymakers based on epidemiological studies that estimate the health impact of various levels of pollutant concentration in the ambient air. This requires a detailed cost-benefit analysis, which is beyond the scope of this paper. Here, we have analyzed the implications of setting caps based on BAU projections for SO_2 emissions, with periodic revisions to follow the same trajectory as the existing technology-push policy.

Allowance distribution

The allocation of emission rights falls under two broad categories-auctioning and free allocation. Auctions apply the polluter-pays principle, where polluters bid for the number of allowances they would like to purchase. As opposed to this, allowances are also distributed at no-cost to participating sources through allocations. Till date, globally, the policy choice in cap-and-trade systems for distributing allowances to sources has been through free allocations (Svendsen 1998, USEPA 2003). There are several approaches for free allocation such as through grandfathering (allocation in proportion to historical parameters) or based on per capita allocation. However, each approach has its pros and cons and there is a need to adopt a flexible approach that takes into consideration the equity issues. As such, the equitable allocation of emission allowances among the participating sources is a complex issue. Even in the multilateral climate change negotiations, there are debates on how to allocate emission quotas to the Parties of the UN Framework Convention on Climate Change. A consensus is yet to be reached among developed and developing countries on the approach for distribution of emission quotas (Muller 2001).

There are debates in adopting a grandfathering approach since it implies rewarding historically high emitters and penalizing low emitters; however, this approach has been used globally as a starting point for allowance allocation. In the Kyoto Protocol, the initial allocation of emission reduction targets is also based on grandfathering, where the emission reduction targets given to the Annex 1 countries are relative to their 1990 emission levels. However, there are still debates on the transitions which have to be made while distributing emission rights to other countries (IEA 2003, Ashton and Wang 2003).

In this context, a grandfathering approach could be considered for the initial allowance allocation. Under this approach, allocation is based on historical parameters such as fuel inputs (e.g. emissions per unit of fuel used), outputs (e.g. fuel consumed per unit of electricity generated, emissions per unit of electricity generated), or weighted emissions (based on the emission sources' relative share in total emissions). Since each parameter has its pros and cons, a combination of parameters can be also be considered, such as power generated per unit of coal consumed (kWh/MJ) or SO_2 emissions per unit of energy consumed (gSO_2/MJ) or per unit of generation (g-SO_2/ kWh). While kWh/MJ of coal is a surrogate for efficient utilization of coal in generation, the gSO_2/MJ of coal or gSO_2/kWh captures the emission characteristics of the plant and fuel used. A combination of these parameters would develop flexibility and efficiency in the allocation system, which would not be the case if a single parameter were adopted. For instance, allocating allowances based solely on share in coal consumption would give higher share to plants that are historically inefficient and gives no incentive to efficient generators. Using efficient utilization of coal in generation as a parameter aims to address this aspect. Again, plants that perform efficiently in terms of coal consumed might still have high sulphur emissions due to poor quality of coal used. The quality of fuel used depends on economic and logistical factors that have developed historically and many state owned plants have little choice in choosing their input fuel sources. We propose that plants should not be penalized for this, especially during the initial allowance distribution and the parameter on emission performance gives due consideration to this aspect of fuel quality. A combination of performance parameters gives due consideration for the dynamics of the power sector in a developing economy. Further in-depth analysis is required to understand the weightage for each parameter based on which the SO_2 allowance allocations can be made. The SO_2 cap-and-trade program in the US used the historic level of activity (heat input) and emission standard[5] as the primary basis for allocation, apart from annual auctions (non- revenue-raising) (USEPA 2003).

However, grandfathering is only for initial allocation; there is need for transitions in the allocation process to incorporate the changing dynamics. For instance, there would be entry of new plants, which would either have to buy allowances from the market, or they would be issued new allowances. The latter implies that there would also be periodic revisions in the emissions cap. As the emissions trading market emerges, plants would also adopt different strategies such as setting up of new units using other energy sources like natural gas, hydro etc. In such a case, decisions would have to be taken on the right of these units to get emission quotas. Decisions would also have to be made on updating the allocation criteria at periodic intervals so that entities would have the incentive to continuously improve their performance. Thus, a flexible approach is required in allowance allocation as the market matures.

In India, the ownership of power generation capacity is largely under the public sector; with 30% of the capacity owned by the central-government, 60% by the state-government and 10% is privately-owned (Ministry of Power 2001). Therefore, it should be possible to allocate the emission allowances based on ownership levels and internal targets could be set by each owner to meet their quota of allowances. However, given the existing federal structure in India, this could be a contentious issue if there are different

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[5] Emission standard was 2.5 pounds of SO_2 / mmBtu and 1.2 pounds of SO_2/ mmBtu of energy generated in Phase I and in Phase II respectively.

political parties at the Centre and State. Besides, there are differences among States in the level of economic development, population, endowment of natural resources etc; therefore any allocation schema would have to give due consideration to these factors. Thus, allocation of emission allowances involves several complexities and could result in transaction costs. The level of transaction costs of developing and implementing an emissions trading system would have to be compared with the cost-savings generated to arrive at a decision on using this policy instrument.

Complementing emissions trading with local air quality standards

An emissions trading program has to be implemented in coordination with local air quality regulations. This is because an emissions trading instrument imposes a national cap, but no control on the local intensity of pollution. This would allow polluters to acquire an inordinate number of permits from the market to cover their excess emissions. In the absence of stringent local air quality regulations such plants can create hotspots, or lead to deterioration of existing hotspots since the SO_2 concentrations in the ambient air would be higher than permitted. Thus, while national emissions cap would be met, the air quality would deteriorate in local areas.

The deterioration in the local air quality is prevented by adopting local air quality standards that are more stringent than the national ambient air quality standards (NAAQS). Stringent standards would make it impossible to purchase allowances to cover emissions that result in higher than permitted concentrations in the local area. It also restricts the setting up of new plants in such areas. These measures have to be supplemented by proper inspection, monitoring and enforcement, with penalties imposed on the defaulters.

These policies would not only prevent the emergence of hotspots, it would also spread the new plants to other locations, thereby improving the local air quality. To elaborate, the location of future power plants (projected based on data from published reports and databases like CMIE, present policy directives of the government and expert opinion) indicate that new plants are coming up in areas close to existing ones, including in the hotspots. The presence of existing infrastructure and raw material creates path dependencies, resulting in setting up of new plants in the vicinity of older plants or expanding existing plants, which would aggravate the problem of the existing hotspots. The path dependency has to be reduced to prevent further deterioration of the air quality in the hotspots. This is achieved by the stringent local air quality standards that would spread the plants to other locations and prevent setting up of new plants in the hotspots.

5.3 Institutional Aspects

Political-Economic-Legal Issues

According to the Constitution of India, power sector is under the concurrent list[6] and thus the development of the sector is a collective responsibility of both the central government and state government. This implies that good coordination is required in issues related to policy formulation, such as the criteria for distributing emission allowances among the different SEBs, as well as policy implementation, especially since the State Pollution Control Boards (SPCBs) are responsible for implementing the emission control policies in their respective states. These issues are significant, more so if different political systems operate at the center and a particular state.

The Environment (Protection) Act 1986 empowers the Central Government "to take all such measures as it deems necessary or expedient for the purpose of protecting and improving the quality of the environment and preventing controlling and abating

[6] The various responsibilities of the Federal Government and the state government are enumerated in three lists in the Constitution of India- Concurrent List, State List, and the Central List. The Concurrent List enumerates the responsibilities jointly shared by the federal government and the state government.

environmental pollution." An emissions trading system can be established under this Act, whereby the Central government can "lay down standards for the quality of environment in its various aspects". Also, under the provisions of this Act, the Central Government can "…. constitute an authority or authorities by such name or names as may be specified in the order for the purpose of exercising and performing such powers and functions of the Central Government under this Act…"

Implementing organizations

The critical issue in developing an emissions trading system in India is the question regarding the authority that would be responsible for managing this system. The Ministries directly involved include the MoEF and Ministry of Power; though there are other Ministries such as the Ministry of Coal, Ministry of Petroleum and Natural Gas, which would also be affected by this system.

Since power plants are involved, it could be possible for the MoP to manage the emissions trading system. However, as of now, it is the MoEF, which issues guidelines related to environmental implications from all sectors. The organizations for implementing the environmental policies also come under the MoEF and include CPCB and the different SPCBs. With respect to power plants the MoEF has issued indirect measures, such as coal washing, to control emissions. There is also a move to introduce direct measures, such as the asking new power plants above 500 MW to keep provisions for installing FGD (CPCB 2003). In this context, it would be appropriate for the MoEF to manage the emissions trading system, which is a direct polluter-pays approach for controlling control power sector emissions. Moreover, as mentioned earlier, this system should be expanded to include other LPS, such as steel and cement plant, in later phases. In such a case where different sectors are involved, it would be more appropriate for the MoEF to coordinate the entire process. Finally, related concerns from coal consumption, including CO_2 emissions and the climate change issues, are being addressed by the MoEF. Therefore, it is a more suitable organization, as compared to other concerned organizations, to manage the emissions trading system.

Resource Requirements

Human resources

There is need for trained human personnel for effective functioning of the program. Presently, there is lack of human resources in the SPCBs, both in terms of numbers as well as their technical efficiency, for accurate and continuous monitoring of emissions from individual sources. An assessment of the SPCBs carried out by the Planning Commission of India (http://www.planningcommission.nic.in/reports/peoreport/peof.htm) showed that there was a pre-dominance of non-technical members in most Boards. Similarly, there is a lack of manpower in both the Central and State Pollution Control Boards. But, it should also be understood that the monitoring and enforcement of an emissions trading system also requires certain level of automation, which reduces the need for a huge manpower. For instance, in the SO_2 trading program in the United States, it is estimated that around 150 workers per year is required to operate this program since it is heavily automated. Three quarters of that workforce would focus on auditing the performance of emissions monitors and quality assuring data reports. The remainder would handle all other functions, including permitting, allowance transfers, allowance auctions, data system operations and enhancements, end-of-year allowance reconciliation, program evaluation, and general administration (http://www.epa.gov/airmarkets/articles/mclean/).

The justification for technology push policy has itself been the relative ease in implementation. However, as seen in the analysis it also results in significant compliance costs. Therefore, there is a need to strengthen the existing implementing organizations, especially in terms of technical personnel, who are qualified to manage the functioning of this system.

Technical and Financial resources

Monitoring of emissions

Accurate and continuous monitoring of emissions from individual sources is very important in a cap-and-trade program. Existing measurement methods have to be improved and measuring equipments in power plants have to be standardized. Continuous Emission Monitors (CEMs) would have to be installed in plants; but, if it is too expensive and proves to be a barrier to implementation, the mass-balance method for measurement could also be adopted. Certification agencies would certify these equipments and the emissions reported from the units. A repository for the emissions data from the different units has to be maintained.

Accounting of transactions

An accounting system is required to track the holdings of allowances, to record the transactions that take place, and at the end of the year give the details to authorities who would then compare the annual emissions with the allowances held by the plant. The unit would have to register with this system to participate in the trading process. The allowances can be held by the regulated parties who are participating in the program or by any other person and anyone can be involved in trading. Strict penalties that would act as a deterrent against false reporting have to be imposed on defaulters. In the US, penalties were around US$2900, which was several times higher than compliance costs for the plants and therefore acted as a deterrent against defaults.

Utilizing savings generated

The savings generated in the emissions trading system should be used for supporting this system by investing in the infrastructure required for monitoring and enforcement and strengthening implementing institutions. It should also be invested in clean coal technologies and for improving the air quality in hotspots. Thus, there is a good opportunity for using economic forces to control SO_2 emissions from power plants optimally and using the savings generated for additional air quality gains, making it a socially optimal solution.

5.4 Spillover Benefits

An emissions trading regime would have spillover benefits in terms of technological innovations and spurring the development of an environmental industry.

Increase in R&D investments
A cap-and-trade system creates incentives for far greater reductions in emissions, spurring technological innovation and energy efficiency. It leads to investments in R&D to invent and commercialize new technologies, leading to technological breakthroughs. In the US, the freedom of technology choice led to unexpected innovation in fuel blending that allowed far greater use of low-sulfur coal for compliance, dramatically reducing the cost of compliance. It created competition for scrubbing that drove innovation and cost reductions in scrubbing (Swift 2001). In the 1990s, scrubber costs dropped by 40%, and the sulfur removal efficiencies of scrubbers improved from 90 to 95 % (http://www.epa.gov/airmarkt/articles/clearingtheair.pdf).

Development of the environmental industry
The success of an emissions trading regime depends on the presence of a strong environment industry that provides alternate compliance technologies and know-how. As pollution control policies are becoming stringent in India, the environmental industry is emerging to cater to the need for pollution control equipments. The demand created by an emissions trading regime would provide further impetus to this process of the growth of an environmental industry in India. For instance, this regime

would increase demand for beneficiated coal and create competitive markets, which would provide momentum for developing coal washeries. Currently, India has 21 large coal washeries but only two are devoted to power requirements, due to the huge investments required. An emissions trading regime could make it economical for setting up more washeries.

5.5 Challenges

Inter-linkages between energy-electricity-emissions market

The existing distortions in the energy and electricity market create challenges in developing an emissions trading market is India. Adopting measures that improve the economic efficiency of the emissions market need not necessarily be effective due to the inter-linkages with the energy and electricity markets. For instance, there is administered pricing in the electricity markets. This implies that it could be possible for plants to pass on their compliance costs to consumers, which would negate the purpose of an emissions trading system. Similarly, there is a substantial demand-supply gap in the electricity sector. For instance, in 2001-02, capacity shortages were 12.6% of peak demand (Ministry of Power, 2002). In such a scenario, it is crucial that policies for air quality management do not have adverse impacts such plants shutting down their operations if their emissions exceed their allowances. Stringent penalties could be a deterrent to this. Besides, there could be regular updating of the allowance distributed to plants. In that case, when a new base year is taken during the update, then plants that shut down their operations for a certain period during that year would stand to lose.

Inter-linkages between environment-technology markets

The success of an emissions trading regime depends on the presence of alternate compliance technologies and know-how. This implies the need for a well-developed technology market in the country that would enable the emitters to choose between alternate technologies. In the absence of such choices, an emissions trading system would not be different from a technology-push policy. As mentioned earlier, an emissions trading system would provide impetus for further development of technology markets; but specific policies that promote the growth of this market are also necessary.

To conclude, there exist several attributes that are favorable to the development of an emissions cap-and-trade system for the power plants in India. However, a gradual transition is required while moving towards a full-fledged emissions trading system. This process has to consider the socio-economic implications while designing the program structure of the cap-and-trade system. Besides, there are several issues related to the implementation process in terms of the technical, human and financial requirements, the need for regulators to manage the process, and the need to further develop the implementing organizations to ensure effective monitoring and enforcement.

Chapter 6

CONCLUSIONS AND POLICY RECOMMENDATIONS

To conclude, as the country moves on the path of economic development, the use of energy resources is bound to increase, thereby increasing air pollution. Especially, the consumption of coal in industries makes them significant contributors to local and GHG pollutants. This has led to a growing concern about the use of coal as a major fuel in industries. However, coal is a primary resource that has to be utilized without causing environmental externalities. Energy-environmental policies should, therefore, also focus on making coal more competitive vis-à-vis other energy sources. The study addresses some of these concerns of policymakers in the context of local pollutant mitigation. We take the case of coal-based power plants, which provide focused opportunities for SO_2 mitigation from coal consumption.

The choice of instruments for SO_2 mitigation also plays an important role in determining the costs of mitigation. This paper shows that an emissions cap-and-trade system incurs lower costs to achieve equivalent reductions as the existing technology-based policy instrument. Since resources are scarce, air quality management should aim at an economically efficient solution. It is also possible to adopt multiple instruments for greater flexibility and achieve an efficient outcome, but this is beyond the scope of this paper.

We discuss further the specific policy issues related to the managing emissions from LPS in India.

Importance of coal for energy security

The energy sector in India has grown rapidly in the 1990s along with rapid growth of the economy. The consumption of energy resources, especially fossil fuels such as coal has generated negative externalities, including air pollution. These are visible in the form of increasing GHG and local pollutant emissions. Coal contributes to 75% of total CO_2 emissions and 63% of SO_2 emissions in India (Garg et al 2001b).The problem is expected to aggravate as the economy grows. But, it is also worthwhile to note that coal is an indigenous resource, in abundance in India; while the supply of other hydrocarbons including gas is limited. This implies that replacing coal with gas to limit the GHG and local pollutant emissions could lead to energy security concerns in the long run; therefore, the need is to analyze ways and means to utilize coal in an optimal manner, and with minimal environmental externalities, both at the global and local level.

Managing CO_2 emissions from coal use

The LPS are major consumers of coal and thus contribute significantly to all-India CO_2 emissions (around 64%). The 25 largest LPS contributed almost one-thirds of India's CO_2 emissions and these are mainly power and steel plants. The share of coal-based power in gross generation from utilities has been steadily increasing from 55% (1980) to 67% (1990) to 71% (2000), contributing substantially to the growth of Indian CO_2 emissions [CMIE 2003]. Other industries, including steel and cement sector LPS, have set up coal-based captive power plants for assured and quality power supply. Thus, coal will continue to be a dominant fuel in the future.

Technological options for CO_2 mitigation from LPS include energy efficiency improvements, clean coal technologies, switch to less carbon intensive fuels, technology upgradation and carbon capture and storage (CCS). Of these, CCS technology offers an opportunity to target mitigation efforts to a select few LPS to achieve deep cuts in India's future CO_2 emissions. A study (Garg et al 2004) showed that CCS for the largest 5 to 10 LPS would be able to mitigate about 7-15% of cumulative Indian emissions over the period 2010-2030. Thus, this technology is capable of increasing the viability of coal in the LPS by managing CO_2 emissions from coal consumption.

Managing SO_2 emissions from coal use

The other major and more immediate concern from coal use is the SO_2 emissions. As mentioned earlier, coal based power generation contribute significantly to all-India SO_2 emissions. Moreover, the CCS technology, proposed earlier, implies that clusters of LPS would address a large portion of CO_2 emissions economically since the captured CO_2 from all these units can be transported through a common transmission pipeline network for storage at a common site. However, formation of such clusters would enhance the local air quality problem and also create (or worsen) hotspots. Therefore policies would be required to manage this problem. Public pressure is also building up on the government to control SO_2 emissions and some recent policy pronouncements in the transport sector like reducing sulfur content in diesel, Euro-II norms for new vehicles from 2002 etc are indicative of the present mind set of policy makers.

The mindset to tackle SO_2 emissions from power plants is also visible in policies that mandate the use of specific technologies to control SO_2 emissions. There are no specified emission standards in the power plants; rather there are other technology requirements. There are minimum stack height criteria for dispersion of SO_2 emissions. After the year 2000, policies have also been formulated for future use of emission control technologies. For instance, new coal power plants above 500 MW and not using IGCC generation technology are required to keep space for installing flue gas desulphurization equipment (CPCB 2003). This directive implies that the use of FGD technology may be made mandatory in future. There is another policy directive to use washed coal, which is aimed at reducing fly ash in coal, but it would also reduce the sulphur content. Thus, the emphasis is on using technology-based command and control instruments.

Cost savings in an emissions trading system vis-à-vis a technology-push instrument

However, specifying uniform emission control technologies for all plants increases the overall compliance costs because such technology push policies do not consider the differences in marginal abatement costs among plants and thereby limit the flexibility of plants in making abatement choices. On the other hand, an emissions trading system, offers this flexibility in making the abatement choice. Since the emitters can trade in emission allowances, those with low marginal abatement costs can cut emissions below their target and sell the difference to emitters having high marginal abatement costs, thereby making a profit. At the same time, high-cost emitters can reduce their emissions more cheaply by purchasing some of the required allowances from the low-cost emitters. The result is that emission reductions can be achieved at lower costs than what would be achieved by using a technology-based CAC instrument.

Our modeling assessment gives an overall estimate of the differences in compliance costs between the two scenarios over the period 2005-2030. It shows that an emissions trading system would result in 44% cost savings over a technology-push instrument for equivalent reductions. Further research on specific plant level mitigation costs is required to assess the impacts of different levels of emissions reductions. The cost-savings generated in an emissions cap-and-trade system should be used for further air quality management processes, including investing in clean coal technologies.

Institutional development

The implementation of any policy instrument is influenced by the political-legal systems, the organizations for monitoring and enforcement, resource requirements in terms of human, technical and financial resources and so on and so forth. In India, institutions related to environmental management are gradually developing, as a result of which there are implementation problems. As such, there are several legislations and policy initiatives for air quality management in India. But, the implementing organizations suffer from lack of manpower, especially technical personnel, inadequate funding and lack of legal backing for enforcement of policies. The justification for technology push policy has itself been the relative ease in implementation. However, as seen in the analysis it also results in significant compliance costs. Therefore, there is a need to strengthen the existing implementing organizations, in terms of technical personnel, who are qualified to manage the functioning of this system. The cost-savings generated from a cap-and-trade system could further promote the development of these systems.

Which agency to mange the system?

This entire process could be managed by the MoEF, which seems more appropriate when compared to the other concerned organizations since it can adopt a more comprehensive approach. For instance, the MoEF is already managing environmental pollution from different sectors. In the power sector, it is managing through direct and indirect policies. An emissions trading system allows it to manage the emissions directly and at lower costs. Moreover, in later phases, the emissions trading system should include other LPS, such as steel and cement plants and in that case too, the MoEF is more appropriate for managing the entire process.

Learnings through a pilot project

There is need for a gradual transition so as to reduce transaction costs in implementation. Therefore, an initial pilot project would provide a learning experience in the functioning of the cap-and-trade system in India. In this context, we propose that this regime be developed for NTPC, which is the largest power generating corporation in India and the 12 coal-based power plants, spread over different states, contributed to nearly 24% of all-India SO_2 emissions in 2000. The NTPC plants are also efficient operators as compared to many plants under the SEBs. For instance, the

PLF of its coal-based power plants stood at 84% as compared to national average of 73%. Moreover, NTPC has high incentive to improve efficiencies and promote an environment-conscious image since they have been recently listed in the Indian stock exchange.

Integrating environmental concerns in electricity reforms

The electricity sector in India is going through the process of reforms since early 1990s. The reforms were initiated for enhancing revenues and mobilizing investment in the short run and by changing the ownership structure and establishing an independent regulatory regime in the long run. The specific areas of reforms included State Electricity Board corporatization, privatization of power corporations, unbundling, and regulatory restructuring. The reforms also include fuel price reforms, promotion of renewable energy sources and energy efficiency measures. These reforms have had indirect implications on the CO_2 and SO_2 emissions; however, this process has largely bypassed environmental concerns from power generation. Given, the strong environmental linkages of the electricity sector, it is crucial to align environmental policies in the electricity reform process.

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Assessing Policy Choices for Managing SO_2 Emissions from Indian Power Sector

SUMMARY

Air quality management has become a focal issue in public policymaking in India since the 1990s. Among the different sources, coal consumption in large point sources (LPS), especially power plants, is a major source of air pollution. In the case of power generation, 82 power plants, accounting for more than 70% coal-use, contributed to around 54% of all-India SO_2 emissions in 2000. But, replacing coal with other energy sources could lead to national energy security concerns, since coal is an indigenous resource in abundance, while other hydrocarbon resources are limited in supply. Thus, a growing concern for policymakers is to utilize coal cleanly and the paper addresses some of these concerns.

The paper analyses policy choices for managing SO_2 emissions from the LPS, especially from power plants. We compare the existing technology-push policy instruments with alternate instruments like emissions trading that would control SO_2 emissions from these plants in an economically efficient manner. An energy-environment model, Asia-Pacific Integrated/Local Model (AIM/Local), is used for mapping future SO_2 emissions from power plants and comparing the implications of alternate instruments.

Compared to a technology-push instrument, an emissions trading system generates an annual average cost-savings of US$ 96 million during 2005-2030 for equivalent emission reductions. This is because an emissions trading system allows every plant to consider factors that influence their abatement costs, such as economic and logistical constraints, fuel quality and efficiency in operations and then make their abatement choice by comparing these costs vis-à-vis the allowance price. But, the technology-push instruments specify the abatement measure to be adopted by each plant, thereby resulting in higher compliance costs. The paper lays emphasis on the need for stringent local air quality standards to complement an emissions trading system. It further highlights the design elements of an emissions trading system in India. This is an initial assessment and other sources could participate in later phases of the program.

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