US-China Strategic Economic Dialogue

US-China Joint Economic Study:

Economic Analyses of Energy Saving and Pollution Abatement Policies for the Electric Power Sectors of China and the United States

Summary for Policymakers

US-China Joint Economic Research Group

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Table of Contents

Executive Summary ii
1. Introduction 1
2. Energy Saving and Pollution Abatement Experience in China and the United States 2
  2.1 The Electric Power Sectors in China and the United States 2
  2.2 Energy Saving and Sulfur Dioxide Pollution Abatement Programs for China's Electric Power Sector 3
  2.3 Energy Efficiency Policies and Programs in China 6
  2.4 Sulfur Dioxide Pollution Abatement Programs for the United States' Electric Power Sector 7
  2.5 Energy Efficiency Policies and Programs in the United States 10
  2.6 Sulfur Programs for Mobile Sources in the United States 12
3. Costs and Benefits of Energy Saving and Pollution Abatement Policies in China's Electric Power Sector 13
  3.1 The Energy Saving and Pollution Abatement Scenario 13
  3.2 The Analytical Approach 14
  3.3 Energy Saving and Pollution Abatement Policy Impacts 16
4. Costs and Benefits of the United States Clean Air Interstate Rule 19
  4.1 Clean Air Interstate Rule Emission Reduction Requirements 19
  4.2 Electric Power Sector Impacts 19
  4.3 Air Quality, Health, and Environmental Benefits 20
  4.4 Clean Air Interstate Rule Costs and Benefits Summary 21
5. Policy Recommendations 21
  5.1 Recommendations for Chinese Policymakers 21
  5.2 Recommendations for United States Policymakers 23
  5.3 Next Steps 24
References 25

List of Figures

Figure 1: Electricity Generation by Fuel Type – China and the United States (2005) 3
Figure 2: Trends in Electricity Generation and Emissions – China and the United States 3
Figure 3: The Pollution Abatement Framework for China's Electric Power Sector 4
Figure 4: Annual United States Acid Rain Program Sulfur Dioxide Emissions (1980 to 2006) 8
Figure 5: Annual Average Wet Sulfate Deposition in the Eastern United States 9
Figure 6: Benefit-Cost Modeling Approach for Evaluating the Environmental Goals of China's 11th Five-Year Plan 15
Figure 7: Cost of Desulfurization Equipment in China by Generating Capacity and Coal Sulfur Content 15
Figure 8: Projected Annual Average Sulfur Dioxide Concentrations in China (2010) 17
Figure 9: The Impacts of Sulfur Dioxide Pollution Abatement Policies on GDP (2006 - 2010) 18
Figure 10: Projected Ozone and Fine Particulate Nonattainment Areas in the United States (2020) 20

List of Tables

Table 1: The 11th Five-Year Plan Energy Saving Targets for the Electric Power Sector 14
Table 2: The 11th Five-Year Plan Sulfur Dioxide Emission Targets for the Electric Power Sector 14
Table 3: United States Clean Air Interstate Rule Emission Caps 19

Executive Summary

In December 2006, China hosted the first meeting of the China-United States (US) Strategic Economic Dialogue (SED). During the meeting, China and the US agreed to cooperate on joint research to assess the economic impacts of efforts to conserve energy and protect the environment. In April 2007, the Chinese State Environmental Protection Administration (SEPA) and the US Environmental Protection Agency (EPA), the two government agencies responsible for the research, launched *The Joint Economic Study of the Strategic Economic Dialogue: Economic Analyses of Energy Saving and Pollution Abatement Policies for the Electric Power Sectors of China and the United States* (JES*).*

The overall goals of the JES are to evaluate the costs and benefits of achieving the energy saving and sulfur dioxide (SO_2) emission targets defined in China's 11th Five-Year Plan, assess the costs and benefits of achieving the US's long-term goals to reduce ozone and fine particle ($PM_{2.5}$) concentrations in the Eastern US, and provide policy recommendations.

SEPA and EPA established a strong foundation of coordination and cooperation for the JES. Experts from both countries conducted extensive research over six months to complete the analysis of the costs and benefits of energy saving and pollution abatement. The results of this research are respectfully submitted to both governments for the third China-US Strategic Economic Dialogue in Beijing in December 2007.

Benefit-Cost Analysis of Energy Saving and Pollution Abatement Measures in China's Electric Power Sector

The following is a summary of the findings of the benefit-cost analysis of China's energy saving and SO_2 pollution abatement policies for the "11th Five-Year Plan":

- The installation of flue gas desulfurization (FGD) equipment and the shutdown of small coal-fired boilers are two key policy approaches to ensure that China's electric power sector achieves its energy saving and SO_2 emissions targets.
- Achievement of the SO_2 emissions target of the 11th Five-Year Plan will lead to significant air quality improvements in Chinese cities. Controlling power plant SO_2 emissions at 24 percent below 2005 levels will reduce ambient SO_2 annual concentrations in the majority of regions by more than 10 percent, and by up to 30 percent in some areas. In addition, $PM_{2.5}$ concentrations will decline. This will lead to significant health, environmental, and economic improvements.
- The quantifiable health and non-health benefits of controlling SO_2 emissions from existing power plants will outweigh the costs by a ratio of more than 5 to 1 with significant additional benefits that were not assessed. A limited analysis demonstrated that if the government were to implement a cap and trade program to encourage power plants to find the most cost-effective approach for reducing emissions, the cost of achieving the same benefits would be at least 16 percent lower. The actual cost savings from a cap and trade program would be much larger because the JES only assessed one emission control option – install FGD equipment; in reality electric power plants would have the flexibility under a cap and trade

program to deploy one of several cost-effective approaches to reduce SO_2 emissions (e.g., coal washing, fuel switching, alternative technologies).

- The macroeconomic impact of SO_2 pollution abatement from the electric power sector is an estimated reduction in gross domestic product (GDP) of less than 0.1 percent in 2010. However, accounting for the small-boiler shutdown and other energy saving policies would reduce the overall impact on GDP. The combination of policies may even have a positive effect on GDP.
- Together, the energy saving and pollution abatement policies provide a win-win solution: strong, sustainable economic growth with environmental protection leading to a more productive, healthy, and stable society.

Benefit-Cost Analysis of Pollution Abatement Measures in the United States' Electric Power Sector

The following conclusions of the benefit-cost analysis of the US's SO_2 pollution abatement policy (which also provides significant reductions of nitrogen oxides (NO_X)) – the Clean Air Interstate Rule (CAIR) – are similar to the results of the Chinese analysis:

- CAIR includes a cap and trade program to reduce air pollution in 28 Eastern states and the District of Columbia to help areas attain the 1997 ambient air quality standards for $PM_{2.5}$ and ozone. CAIR will require electric power plants in the Eastern US to reduce SO_2 and NO_X emissions by 73 percent and 61 percent, respectively, below 2003 levels. This will lead to significant air quality improvements across the Eastern US.
- The emission reduction requirements of CAIR are anticipated to result in a total of over 220 GW of installed FGD equipment and over 170 GW of installed NO_X selective catalytic reduction (SCR) units by 2015. By 2020, about 80 percent of all the electricity generated by coal combustion will come from sources with advanced pollution control equipment – FGDs, SCRs, or both. Because CAIR uses a cap and trade approach, these controls will be installed where it is most cost-effective.
- The annualized cost of CAIR is estimated to be about $4.4 billion (33 billion RMB) per year. The annual health and non-health benefits in 2015 from pollution abatement are estimated to be $104 billion to $122 billion (780 billion RMB to 915 billion RMB)[1]. The monetized benefits, including the prevention of 17,000 premature deaths, 22,000 non-fatal heart attacks, 12,300 hospital admissions, and 1.7 million lost workdays, outweigh the costs of pollution abatement by a ratio of greater than 20 to 1. There are additional benefits to the public that the study was unable to quantify in monetary terms. These include reductions of mercury emissions, acid rain, and coastal and estuarine water eutrophication, and improved visibility at national parks.
- While the costs and impacts are significant, the analysis estimates that the macroeconomic impact on the US's GDP is less than 0.04 percent in 2015. In addition, the policy will preserve both low electricity prices and fuel diversity.

[1] All figures are in 2006 dollars and assume a currency exchange rate of 7.5 Chinese RMB per US dollar.

Recommendations for Chinese Policymakers

1. Policymakers should enhance the decision support systems and regulatory measures to achieve the energy and environmental goals of the 11th Five-Year Plan. Whether technology mandates or market-based programs are used, the institutions and infrastructure to administer the programs must be in place. This includes a comprehensive program to continuously measure emissions from sources in the electric power and industrial sectors, verify accuracy of emissions data through electronic and facility audits, and assure compliance with programs through consistent oversight with meaningful incentives.
2. International experience has shown that cap and trade programs for controlling both SO_2 and NO_X are more cost-effective than traditional pollution abatement approaches. Policymakers should implement a cap and trade program to reduce SO_2 emissions from the electric power sector. In addition, they should explore its usefulness for addressing other sectors and other emissions, such as NO_X, from large stationary sources.
3. Policymakers should develop the capacity to apply benefit-cost and macroeconomic analysis to evaluate environmental policies and programs, such as emission targets and approaches for achieving those targets.
4. Policymakers should continue their efforts to promote the construction of more efficient power generation facilities utilizing the best technology options available (e.g., clean coal, cogeneration, supercritical boilers) and encourage improvements in the efficiency of the electric transmission and distribution system. Furthermore, policymakers should support improvements in end-use energy efficiency through a portfolio of policy and programmatic strategies, including cost-effective appliance and equipment efficiency standards, enhanced building energy codes, cost-effective end-user incentive and technical assistance programs, and electric power sector policies.
5. The JES illustrates the significant social and environmental benefits from controlling SO_2 emissions from the electric power sector. However, mobile sources are a rapidly growing source of sulfur pollution. Policymakers should address mobile source emissions through a low-sulfur fuels (i.e., gasoline and diesel) policy and relevant vehicle standards to significantly reduce sulfur-related PM emissions. Low-sulfur fuels and advanced pollution control technologies (e.g., advanced catalysts, diesel particulate filters) can reduce emissions of $PM_{2.5}$ by more than 90 percent.

Recommendations for United States Policymakers

1. Policymakers should pursue multi-pollutant legislation to control emissions from the electric power sector.
2. Policymakers should assess the opportunities to include key industrial sources in new and existing cap and trade programs to reduce SO_2 and NO_X.
3. Policymakers should ensure that EPA and state-level pollution abatement policies continue to be complementary in their efforts to protect public health while minimizing overlap and duplication that will hinder cost-effectiveness.

4. Policymakers should consider extending benefit-cost analysis by finding ways to quantify the full benefits of protecting the environment (e.g., wildlife and ecological systems) and welfare (e.g., the reduction of haze in urban and rural settings) and by using those analyses to inform future air programs at the federal and state level.

Next Steps

The JES has been a successful, mutually-beneficial program to share analytical tools, information, experience, and lessons. The JES work should continue under the SED framework with future work focused on: (1) designing and implementing an SO_2 cap and trade program for the Chinese electric power sector, and (2) strengthening the capacity of China's government research institutes to conduct economic analyses of environmental goals and policies.

The Joint Economic Study of the Strategic Economic Dialogue

Economic Analyses of Energy Saving and Pollution Abatement Policies in the Electric Power Sectors of China and the United States

China-US Joint Economic Research Group[2]

1. Introduction

The first meeting of the China-United States (US) Strategic Economic Dialogue (SED) was held in Beijing, China in December 2006. During the meeting, China and the US agreed to conduct joint research on the economic impacts of measures to conserve energy and protect the environment. The research project – the Joint Economic Study (JES) of the SED – was launched in April 2007 by the China State Environmental Protection Administration (SEPA) and the US Environmental Protection Agency (EPA) with the general goal of assessing the costs and benefits of energy saving and sulfur dioxide (SO_2) pollution abatement strategies in China and the US. The objectives of the JES are to:

- Share information about Chinese and US experiences with programs to control and/or avoid emissions from key sectors – the electric power sector and transportation.
- Evaluate the costs, benefits, and macroeconomic impacts of achieving China's energy saving and SO_2 emissions targets of the 11th Five-Year Plan.
- Evaluate the costs, benefits, and macroeconomic impacts of achieving the US's long-term pollution abatement goals to reduce ozone and fine particle ($PM_{2.5}$) concentrations in the Eastern US.
- Recommend strategies, policies, regulations, institutions, and infrastructure for China to achieve the SO_2 pollution abatement target of the 11th Five-Year Plan.
- Recommend policies and programs for the US to achieve long-term goals to reduce ozone and $PM_{2.5}$ concentrations in the Eastern US.
- Enhance the capacity to identify and design policies and programs that cost-effectively improve air quality and energy efficiency in China and the US.

The JES is a collaborative effort of experts from China and the US. The members of the research group participated in extensive discussions and training programs to share relevant experiences, analytical approaches, tools, and lessons for conducting benefit-cost and macroeconomic analyses of pollution control programs. As part of the JES program, the project team developed a new software model for the Chinese power sector and customized several existing models to predict air quality changes, health and non-health impacts, and macroeconomic impacts. These models and the associated training, data collection and sharing efforts, and communication across Chinese and US organizations have helped build

[2] This summary report was prepared by Mr. REN Yong (China), Mr. Sam Napolitano (US), Ms. ZHOU Guomei (China), and Mr. Jeremy Schreifels (US), with technical support from Ms. LI Liping and Mr. ZHOU Jun. This report is based on the six technical reports of the Joint Economic Study.

long-term capacity to conduct future benefit-cost and macroeconomic analyses of energy saving and pollution abatement programs in China.

This report provides a summary of the Chinese and US experiences with SO_2 pollution abatement and energy efficiency programs, the results of the benefit-cost analyses for controlling SO_2 emissions from the electric power sector in each country, and policy recommendations for China and the US.

2. Energy Saving and Pollution Abatement Experience in China and the United States

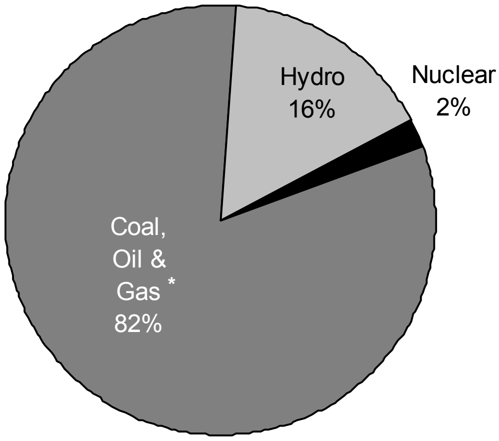
2.1 The Electric Power Sectors in China and the United States

In China and the US, the electric power sector plays a critical role in economic growth and quality of life by providing safe, reliable electricity to industry, government, commercial, and residential customers. However, the electric power sector is a major source of air pollution. Electric power plants emit SO_2, nitrogen oxides (NO_X), particulate matter (PM), mercury, carbon dioxide (CO_2), and other pollutants from the combustion of fossil fuels, such as coal, oil, and natural gas, to produce electricity. The resulting environmental problems include acid deposition, $PM_{2.5}$ pollution, regional haze, ground-level ozone (O_3) pollution, nitrogen deposition (i.e., nutrient enrichment), mercury deposition, and climate change. Research shows that these emissions and resulting environmental problems have a significant impact on human health, forests and farmland, wildlife, buildings and infrastructure, and cultural resources (e.g., statues and relics.) To respond to these impacts, the Chinese and US governments have developed approaches to air quality management, including policies and programs to reduce or avoid emissions from the electric power sector and mitigate environmental and human health impacts in their respective countries.

China and the US are the largest electricity generators in the world. In 2004, China and the US generated an estimated 2,203 billion kilowatt hours (kWh) and 3,979 billion kWh of electricity, respectively. Combined, the two countries generated approximately 36 percent of estimated worldwide electricity generation (EIA, 2007b). To generate that electricity, both countries rely heavily on coal (see Figure 1). In 2005, China consumed approximately 1,136.5 million tons (1,031 million metric tons) of coal for electricity generation while the US consumed approximately 1,037.5 million tons (941 million metric tons) of coal for electricity generation (EIA, 2007b).

Figure 1: Electricity Generation by Fuel Type – China and the United States (2005)

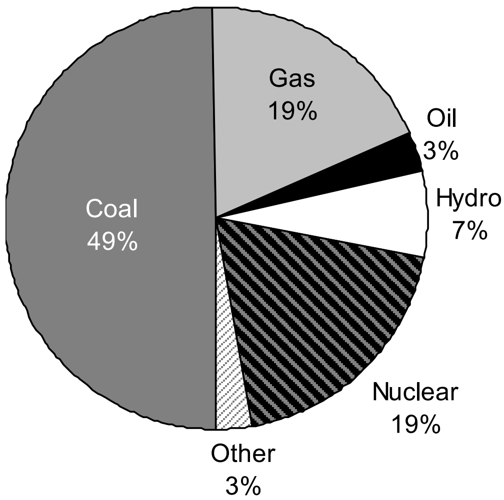
China



* Separate oil and gas electricity generation statistics are not available. However, these two fuel sources represent less than one percent of China's electricity generation.

Source: NBS, 2006

United States

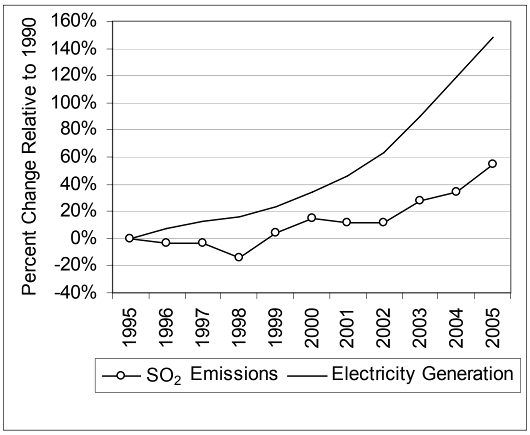


Source: EIA, 2007a

Although both countries currently consume similar levels of coal for electricity generation, China's coal use and gross domestic product (GDP) are growing much more rapidly than the US's. Nevertheless, the US emission control model may provide some valuable insights into how to maintain economic growth and increase electricity generation while reducing emissions from the electric power sector. During the period from 1990 to 2006, US power plants increased electricity generation by 37 percent while reducing SO_2 and NO_X emissions by 39 percent and 48 percent, respectively (see Figure 2). Between 1995 and 2005, China's electricity generation increased by approximately 148 percent while SO_2 emissions increased by 54 percent (see Figure 2).

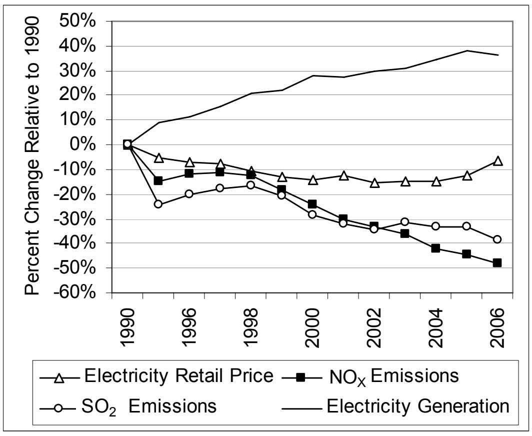
Figure 2: Trends in Electricity Generation and Emissions – China and the United States

China (1995 – 2005)



Source: NBS, 1996 – 2006

United States (1990 – 2006)

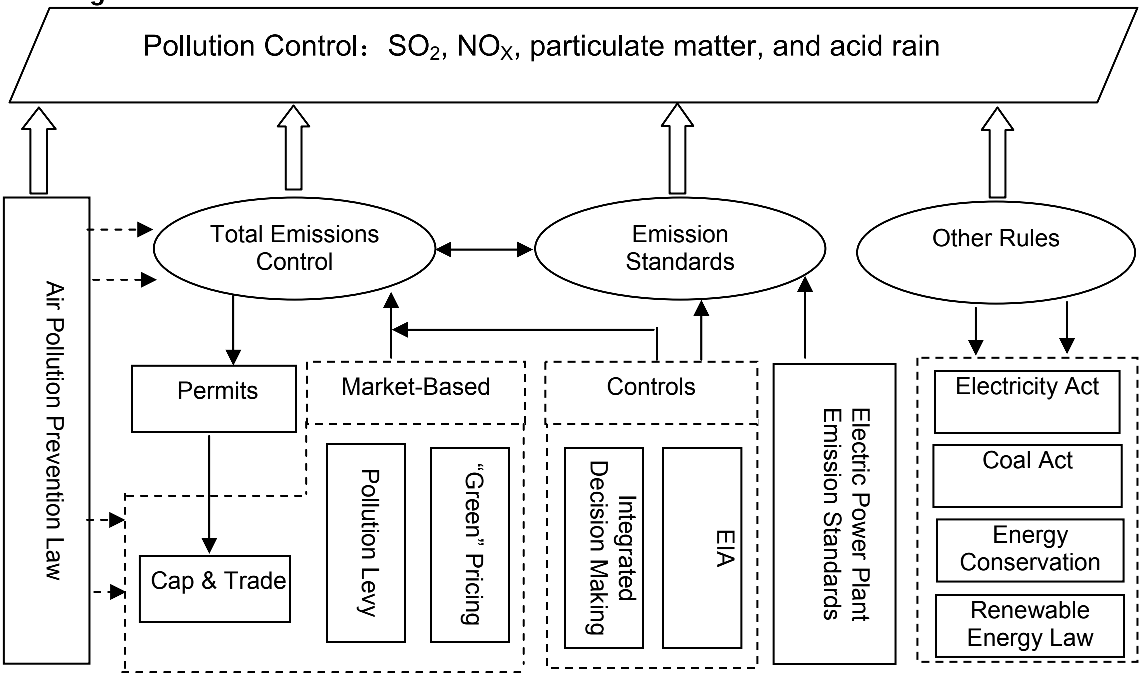


Source: Napolitano et al., 2007; EIA, 2007

2.2 Energy Saving and Sulfur Dioxide Pollution Abatement Programs for China's Electric Power Sector

In an effort to control SO_2 emissions and lessen the effects of acid rain, China has adopted a number of emission control programs for large stationary emission sources. The approaches can be grouped into four broad categories: (1) technology mandates, (2) emission performance standards, (3) total emissions control limits, and (4) market-based incentives and economic policies (see Figure 3).

Figure 3: The Pollution Abatement Framework for China's Electric Power Sector



Technology Mandates and Other Requirements

The electric power sector in China must comply with: (1) general environmental laws and regulations, such as the requirement to conduct environmental impact assessments prior to construction, and the "three simultaneous" system, which calls for the attainment of standards throughout the life of a project, including design, construction, and operation; (2) environmental laws and regulations specific to the electric power sector (e.g., the *Electric Power Industry Air Pollution Prevention Law*); and (3) other laws on electricity generation (e.g., *Electricity Act* and *Coal Act*) that include an environmental component. These rules, standards, and norms are key tools for controlling emissions from the electric power sector.

Sulfur Dioxide Emission Performance Standards

China has developed and implemented several different emission performance standards for the electric power sector. Emission standards for "industrial wastes", including SO_2, were first introduced in 1973 through the *Pilot Emission Standards* (GBJ4-73) and then revised in 1991, 1996, and 2003 by the *Coal-fired Power Plant Emission Standards for Air Pollutants* (GB13223-91), *Power Plant Air Pollutant Emissions Standards* (GB13223-1996), and *Power Plant Air Pollutant Emissions Standards* (GB13223-2003), respectively. While the emission performance standards for electric power plants in China are not as stringent as standards imposed in many other countries, the updated 2010 standard is similar to the standards of developed countries and will establish more stringent requirements for emissions from coal-fired electric power plants.

Sulfur Dioxide Total Emissions Control

Beginning with the 9^{th} Five-Year Plan, the government established a limit on total national emissions of SO_2. In 2000 – the final year of the 9^{th} Five-Year Plan – the SO_2 total emissions control target was 27.1 million tons (24.6 million metric tons), of which electric power plants and industrial emission sources were authorized to emit up to 24.3 million tons (22 million metric tons). The government also implemented a series of laws, policies, and standards for the SO_2 total emissions control target, including the "Two Control Zones" to reduce total SO_2 emissions and SO_2 concentrations in ambient air, as well as the frequency and severity of acid rain. The electric power plants and industrial emission sources easily met the SO_2 total emissions control target in 2000, emitting 17.3 million tons (15.7 million metric tons). The national total was 22 million tons (19.95 million metric tons) of SO_2.

During the 10th Five-Year Plan period, the government reduced the SO_2 total emissions control target, requiring a 10 percent reduction from 2000 emission levels by 2005. However, the recovery from the Asian financial crisis and joining the World Trade Organization led to rapid and unexpected growth in electricity generation and industrial output – the average annual growth in GDP reached 9.5 percent. Although the electric power sector installed a significant amount of flue gas desulfurization (FGD) equipment, the levels were inadequate to effectively reduce SO_2 emissions at the high rate of economic growth and industrial output. As a result, SO_2 emissions in 2005 were 28.1 million tons (25.5 million metric tons), a 27.8 percent *increase* over 2000 emission levels.

For the 11th Five-Year Plan period, the government established a 2010 SO_2 total emissions control target of 25.3 million tons (23 million metric tons) – 10 percent below 2005 emission levels. The government also strengthened the management and reporting of pollution abatement efforts. The approach for the 11th Five-Year Plan period marks a new stage in SO_2 emission control efforts – the total emissions control targets are binding and have the force of law. SEPA assigned responsibility for reducing SO_2 emissions by requiring authorities from provincial and municipal governments and the six major electric power companies to sign a legally binding *Total Sulfur Dioxide Reduction Letter of Responsibility*. In addition, the government has implemented a number of measures to encourage the installation and use of FGD equipment.

Market-Based Policies

China has some experience using market-based instruments to promote energy saving and pollution abatement. These measures include "green" pricing, preferential dispatch, and a levy on SO_2 emissions.

In 2004, China introduced price premiums for electricity generated by coal-fired electric power plants with FGD equipment. The price premium of \$0.002 (0.015 RMB)[3] per kWh is meant to subsidize the additional fuel costs necessary to power the FGD equipment. However, the policy faced some challenges, such as electric power plants installing, but not operating, the FGD equipment. In addition, ambiguity about eligibility for the price premium limited the installation of FGD equipment on existing electric power plants. So, in 2006 the National Development and Reform Commission (NDRC) and SEPA jointly issued the *Coal-Fired Electric Generating Units Desulfurization Operation and Management Plan (Draft)* that provided comprehensive and systematic measures to address some of the challenges. The Plan clarified some elements of the original program and included requirements for the construction and operation of FGD equipment at new and expanded coal-fired electric power

3 All figures assume a currency exchange rate of 7.5 Chinese RMB per US dollar.

plants, restrictions on the sulfur content of coal used in electric power plants, and requirements to install continuous on-line emission monitors. In addition, the plan set penalties for not operating FGD equipment. Under the new approach, the price premium is granted for electricity produced only when FGD equipment is in operation. If the equipment is in operation less than 90 percent of the time during which electricity is being generated by the power plant, a fine is levied for each kWh of electricity generated during the time when the FGD equipment is not in operation. If the FGD equipment is in operation between and 80 and 90 percent of the generation time, the fine is $0.002 (0.015 RMB) per kWh. If the FGD equipment is in operation less than 80 percent of the generation time, the fine is $0.01 (0.075 RMB) per kWh.

In 2006, China reformed the dispatch policies to provide preference to “cleaner” electricity, including renewables, nuclear, natural gas, and high-efficiency coal combustion. Other coal- and oil-fired electric power plants are dispatched only after the preferred power plants are at full capacity. Priority is also given to larger electric power boilers over 200 megawatts (MW) while smaller electric power boilers – below 135 MW – are restricted from selling electricity into the electric grid.

The SO_2 pollution levy system is another important component of the air pollution and acid rain control approach. In 2004, the levy for SO_2 emissions from electric power plants was raised from $24 per ton (200 RMB per metric ton) to $76 per ton (630 RMB per metric ton). The levy was increased again in 2007 to $152 per ton (1260 RMB per metric ton)[4], slightly higher than the average cost to control emissions.

2.3 Energy Efficiency Policies and Programs in China

China has long had a policy of promoting conservation through policies and goals for the electric power sector, such as enhanced conservation of coal from combustion efficiency improvements and cogeneration, increased efficiency of the electric transmission and distribution system, reduced on-site power requirements at electric power plants, and increased use of cleaner electricity generation (e.g., hydroelectric, nuclear, and gas).

The electric power sector has made great progress toward these goals. During the 10th Five-Year Plan period, the coal required to produce each kWh of electricity fell from 13.8 ounces (392 grams) to 13.1 ounces (370 grams), and losses from transmission lines fell from 7.7 percent to 7.2 percent. Even small improvements in efficiency can have a significant impact – a one ounce (28.3 grams) decrease in the average amount of coal required to produce each kWh of electricity across the entire electric power sector can save 63.9 million tons of coal (58 million metric tons) annually.

For the 11th Five-Year Plan period, China has established the following energy savings goals: improve the efficiency of electricity generation from 13.1 ounces (370 grams) of coal per kWh to 12.5 ounces (355 grams) per kWh; reduce on-site power consumption from 5.9 percent to 4.5 percent; build 40 gigawatts (GW) of cogeneration capacity; reduce electric transmission and distribution losses from 7.2 percent to 7.0 percent; and increase the

[4] In June 2007, China’s State Council issued the *Energy Saving and Emission Reduction Comprehensive Work Program*, which raised the levy from .63 RMB per kilogram to 1.26 RMB per kilogram.

proportion of electricity generated by hydropower, nuclear, renewables, and natural gas. There are four policies intended to help the electric power sector achieve these goals:

- *Replace small, inefficient coal-fired electric power generating units*: in 2005, there were more than 115 GW of small coal-fired electric power generating units, defined as 100 MW or less. These small, inefficient electric power generating units were 29.6 percent of the national electric generation capacity and consumed over 440 million tons (400 million metric tons) of coal. In an effort to improve the efficiency of electricity generation, the State Council issued requirements and incentives to shutdown small, inefficient electric power generating units and replace them with larger, more efficient electric power plants.
- *Promote cogeneration and cleaner electric generation technologies*: China is making great strides to increase the use of cogeneration to produce heat and electricity in urban areas. Currently, cogeneration facilities larger than 60 MW provide 69.8 GW of capacity – 18 percent of China's national electric generation capacity. By 2010, centralized heating will provide 40 percent of China's heating needs and cogeneration facilities will represent 20 percent of the national total electric generation capacity. China is also pursuing electric generation technologies with higher efficiency and lower emissions, including large-scale circulating fluidized bed (CFB) boilers, integrated gasification combined cycle (IGCC) units, and combined cycle units.
- *Enhance the electric grid*: Improvements to the electric grid include advanced technologies (e.g., low-loss transformers) and high-voltage transmission lines to reduce the amount of electricity lost to transmission and distribution. China is also improving the dispatch and scheduling system to give preference to renewable energy sources and efficient, low-polluting electric power plants.
- *Improve end-use energy efficiency*: China is providing incentives and education to change electricity consumption patterns and improve energy efficiency. Energy efficiency is a proven, cost-effective way to reduce the growth in demand for electricity, thereby improving the reliability of the electric grid, avoiding emissions, and saving money. Key programs include promoting the use of energy-efficient equipment and advanced technology – green lighting, variable-voltage variable-frequency motors, and high-efficiency air conditioning. China is also piloting other energy efficiency programs and developing coordinated policies, such as improved electricity forecasting and scheduling, and time-of-use pricing.

2.4 Sulfur Dioxide Pollution Abatement Programs for the United States' Electric Power Sector

The US Clean Air Act and subsequent amendments include a number of specific programs to control emissions from electric power plants and other stationary sources. Like China, the US implements technology mandates and emission performance standards designed to provide local air quality protection. However, the preeminent program to provide broad, regional emission reductions from the electric power sector is an air emissions cap and trade program. Cap and trade limits total cumulative emissions from a group of emission sources (e.g., the electric power sector) in a given geographic area for a specific time period (e.g., calendar year). Each emission source is allocated a quantity of tradable allowances – authorizations to emit a specific quantity of a pollutant (e.g., one ton of SO_2) – that, in aggregate, are equal to the cap. Each emission source has the flexibility to develop a compliance strategy that accounts for the facility's design, operational, management, and financial conditions. The strategy to lower compliance costs may include conventional pollution control equipment, process changes, fuel substitution, the purchase of allowances from another emission source, or some combination of these options.

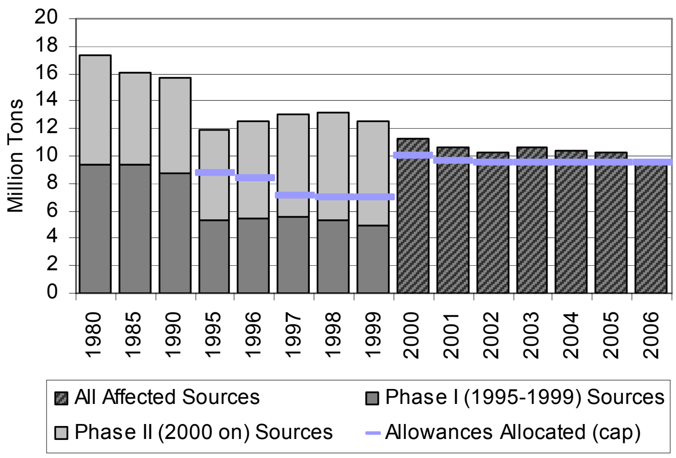
United States Acid Rain Program

The US effort to control SO_2 emissions from the power sector centers on the Acid Rain Program. The program was designed to reduce the adverse ecological effects of acid rain by requiring substantial reductions of SO_2 and NO_X emissions from the electric power sector in the contiguous US. Today, it covers approximately 3,550 electric power generating units.

Under the Acid Rain Program, electric power plants in the US reduced emissions by almost 40 percent from 1990 levels and reduced emissions faster than required. As Figure 4 illustrates, emissions from Phase I sources were significantly lower than the allowances available in the first Phase of the program (1995 – 1999), creating early reductions that led to significant improvements in ambient SO_2 and sulfate concentrations and reductions in the frequency and severity of acid rain (see Figure 5). These surplus reductions also provided a smooth transition to Phase II (beginning in 2000) when the program required all affected sources – Phase I and Phase II sources – to offset their SO_2 emissions with allowances.

Another successful result of the Acid Rain Program is the cost of compliance. Emission reductions and resulting human health and environmental benefits of the program were achieved at a fraction of the expected cost. A recent study estimates that the SO_2 program's annual compliance cost is $2.3 billion (17.3 billion RMB) and the NO_X program's cost is $1.2 billion (9 billion RMB). The resulting annual environmental and human health benefits of the Acid Rain Program exceed $142 billion (1,065 billion RMB)[5] (Chestnut and Mills, 2005). This is a benefit-to-cost ratio of more than 40 to one.

Figure 4: Annual United States Acid Rain Program Sulfur Dioxide Emissions (1980 to 2006)

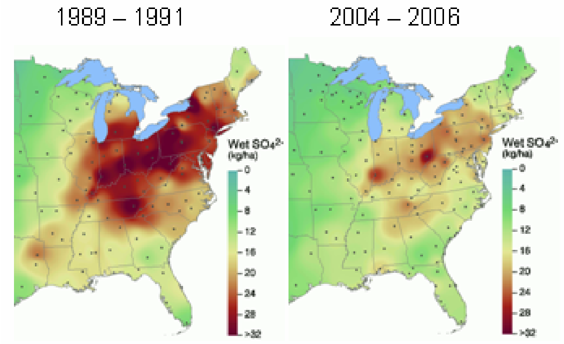


Source: EPA, 2007a

5 All figures are in 2006 dollars.

EPA followed the Acid Rain Program with a NO_X Budget Trading Program in the Eastern US to address summer smog (i.e., ground-level ozone). The program includes the electric power sector and other large industrial sources. The US programs demonstrate that cap and trade can work for addressing national or regional air quality problems, for controlling emissions from the electric power sector and large industrial emission sources, and for addressing annual or seasonal pollution problems. EPA has learned several important lessons from 18 years of experience designing and implementing cap and trade programs.

Figure 5: Annual Average Wet Sulfate Deposition in the Eastern United States



Source: EPA, 2007a

United States Acid Rain Program Lessons Learned

1. Cap and trade works incredibly well to cost-effectively control SO_2 and NO_X emissions from the electric power and industrial sectors. Acid Rain Program emission sources reduced SO_2 and NO_X emissions significantly in a highly cost-effective way while achieving near perfect compliance (greater than 99 percent each year).
2. Cap and trade allows the government to focus on setting emission reduction goals, developing ground rules for reporting and program operation, and overseeing the program. Emission sources are responsible for finding effective approaches to reduce emissions. The flexibility of cap and trade programs provides emission sources with a continuous incentive to reduce emissions, either to avoid using allowances or to free them up for sale. This has led to innovation, with emission sources adopting a wide range of new compliance techniques and developing new types of control arrangements.
3. Complete, accurate, and transparent emission data are the foundation of an effective cap and trade program. Strong emission monitoring, reporting, and data audit and verification programs are essential for a credible and effective program.
4. Emission sources must develop long-term compliance and investment strategies to cost-effectively reduce emissions. Effective planning requires certainty regarding the future level of the cap and the number of allowances the emission source will receive.
5. Clear, simple rules are easier and less costly to implement. Complexity can create uncertainty and unnecessary burdens that may lead to delays, lost opportunities, and, ultimately, higher costs.
6. Cap and trade programs, or any effective air quality program, must include penalties for non-compliance that are greater than the cost to meet the emissions target. The Acid Rain Program has clear, nonnegotiable, automatic penalties. EPA and state regulators do not have discretion to negotiate or limit the penalties.

7. Cap and trade programs are administratively efficient. The use of information technology to manage allowance holdings and transactions and to collect, quality assure, and manage emission data reduces the number of administrative staff required to run the programs.
8. Emission sources and the government share the same goals – to reduce emissions without harming the economy and protecting environmental quality through 100 percent compliance with key program requirements. EPA provides training, reference documents, workshops, and technical assistance to emission sources to ensure that the sources understand their obligations under the Acid Rain Program. This close, collaborative working relationship has led to positive interactions, strong support for the programs, and compliance rates exceeding 99 percent.
9. Cap and trade programs work best on a regional or larger scale. By requiring significant reductions of regional pollution that is often transported across state boundaries, cap and trade programs may also, and often do, improve local air quality. However, eliminating high, localized concentrations of emissions is not the primary purpose of cap and trade programs. To protect local air quality, cap and trade programs should complement, not compete with, state or local programs.
10. The lower compliance costs of the Acid Rain Program enabled EPA to require greater emission reductions than would be possible with costlier technology mandates or emission performance standards.
11. The need to achieve significant reductions quickly must be balanced with the ability of emission sources to install the necessary emission controls in time to meet those requirements. Implementing the emission cap in two or more phases provides industry with additional flexibility and reduces the cost of achieving the environmental goals.
12. Cap and trade programs do not create barriers for the construction or expansion of coal-fired electric power plants.

2.5 Energy Efficiency Policies and Programs in the United States

Improving the energy efficiency of homes, businesses, and power plants, is one of the most cost-effective means available for reducing emissions from power plants, while lowering energy costs to consumers and improving the reliability and security of the nation's energy system. Because much of the energy consumed in buildings, appliances, electronics, and industrial plants is produced by power plants that burn fossil fuels (coal, oil and natural gas), improvements in energy efficiency can reap large air quality, energy security, and economic benefits.

In the US, the term "energy efficiency" commonly refers to the ability to provide the same level of goods or services (e.g. lighting, heating, cooling, or other energy services) with less energy. The concept incorporates technology and management to increase the efficiency by which energy is consumed and reduce the need for the supply of electricity. Cost-effective technologies, programs, and policy tools are widely available to greatly improve energy efficiency across all electricity customers – residential, commercial and industrial, institutional, and government – as well as supply-side generation.

The US approach to energy efficiency policy and programs includes a portfolio of tax policies, product standards, building codes, government facility-targeted efforts, and informational programs. This approach complements energy efficiency strategies at the state, regional, and local level that employ many of these tools, as well as tactics that address specific local conditions, demographics, and market barriers. Energy efficiency policies and programs are pursued at all levels of government as well as by electric and gas utilities, non-governmental organizations, consumer groups, and other stakeholders. Some of the policies and programs, such as ENERGY STAR, take a voluntary approach to promoting energy efficiency, showing end users how energy efficiency can provide significant benefits. Other policies and programs take a mandatory approach, including energy efficient appliance standards that keep poor-performing products out of the marketplace when there are cost-effective, higher-performing alternatives available.

Key major categories of end-use energy efficiency policies and programs include:

- Tax incentives (federal and state)
- Codes and standards (appliance, equipment, and buildings)
- Government facility programs
- Federal informational and voluntary programs
- Utility and non-utility programs
- Utility regulatory approaches

In addition, two key opportunities to address energy efficiency in electricity generation and delivery are:

- Strategies to promote combined heat and power (i.e., cogeneration)
- National standards for electricity distribution transformers

United States Energy Efficiency Policies and Programs Lessons Learned

1. Multi-pronged approaches that incorporate incentives (e.g., favorable tax treatment) and regulatory approaches (e.g., mandatory codes and standards) are often necessary to achieve results.
2. Energy efficiency programs that employ open and transparent processes build stronger stakeholder relationships, ensuring a longer-term commitment to the program's mission and improved access to hard-to-find market information.
3. With efforts taking place at the Federal, State, regional, municipal, and utility levels, the need for increased communication and coordination among program designers, implementers, and policy makers is critical.
4. Programs based on incentives to purchase energy efficient products provide rapid results, but the results may not be sustained after the incentives are removed. Programs based on transforming the market take longer to achieve results because they involve stakeholders throughout the supply and market chain and require information and education. However, the results of market transformation policies are generally superior and are sustained after the programs end.
5. Consumer confidence in any energy efficiency program is a critical success factor. Programs that promote energy-efficient products and/or services need to develop specifications and verification systems to ensure that only high-quality products and services are identified as energy efficient.

6. Where appropriate, international coordination and harmonization of standards and testing procedures can accelerate the development, purchase, and use of energy-efficient technologies. Harmonization of these program components is mutually beneficial for government and industry because it ensures comparability of efficiency claims and specifications worldwide and minimizes manufacturers' cost of compliance/participation for globally manufactured and marketed products.

2.6 Sulfur Programs for Mobile Sources in the United States

The US has also focused on lowering sulfur-related PM emissions from the transportation sector. The source of these emissions is sulfur contained in gasoline and diesel fuel. In order to reduce these emissions, the US and other countries have adopted a "systems" approach that addresses both fuel quality and vehicle emission standards at the same time. Reducing the sulfur content of transportation fuels produces immediate benefits and enables the use of advanced catalysts in cars and heavy-duty vehicles, and particle-trapping filters on heavy-duty diesel vehicles.

The US has implemented programs under authority of the US Clean Air Act which reflect the systems approach to clean fuels and vehicles:

- Reduced sulfur content of gasoline to an average of 30 parts per million (ppm) in conjunction with Tier 2 emission standards for light-duty cars and trucks.
- Reduced sulfur content of on-highway diesel fuel to 15 ppm in conjunction with new emission standards for heavy-duty diesel vehicles.

As new vehicles with advanced controls enter the fleet, it is critical to ensure that low-sulfur fuel is available in the marketplace. Sulfur levels in fuel can affect the efficiency of catalysts used to control emissions. In addition, diesel particle filters that can dramatically reduce fine particle emissions from diesel trucks, buses, and construction machinery require low-sulfur diesel fuel. If the appropriate fuel is not available, there is a risk of vehicle breakdown due to engine failure and/or reduced performance of emission control devices that are very sensitive to the sulfur levels in the fuel.

Experience in the US has demonstrated that the technologies to reduce sulfur levels in gasoline and diesel are cost effective, widely available, and used extensively throughout the world. In addition, the benefits of introducing these clean fuel and vehicle programs have consistently and significantly outweighed the costs. The low-sulfur diesel fuel portion of EPA's Heavy-Duty Highway Diesel Rule of 2001 requires a 97 percent reduction in the sulfur content of highway diesel fuel, from a level of 500 ppm to 15 ppm. For the foreseeable future this new Ultra-Low Sulfur Diesel (ULSD) will cost refiners an additional $0.04 and $0.05 per gallon (0.08 to 0.1 RMB per liter) to produce and distribute. ULSD enables advanced pollution control technology for heavy-duty trucks and buses so that engine and vehicle manufacturers can meet the 2007 emission standards. As a result, each new truck and bus will be more than 90 percent cleaner than 2006 and older models. By addressing diesel fuel and engines together as a single system, this program will provide annual emission reductions equivalent to removing the pollution from more than 90 percent of today's trucks and buses, or about 13 million trucks and buses, when the current heavy-duty vehicle fleet has been completely replaced in 2030. Once this action is fully implemented, environmental benefits will include annual reductions of 2.6 million tons (2.36 million metric tons) of smogcausing NO_X emissions and 110,000 tons (99,790 metric tons) of PM. By 2030, this program will result in more than $70 billion (525 billion RMB) of annual environmental and public health benefits at an annual cost of approximately $5 billion (37.5 billion RMB). Health benefits will include the annual prevention of 8,300 premature deaths, 5,500 cases of chronic bronchitis and 17,600 cases of acute bronchitis, 1.5 million lost work days, and 7,100 hospital visits.

United States Sulfur Programs for Mobile Sources Lessons Learned

1. Refiners and other parties throughout the fuel production and distribution industry require significant lead time to modify facilities to produce and distribute low-sulfur fuels. Providing lead time and phasing in more stringent requirements over time allows for a smooth transition to low-sulfur fuels.
2. Low-sulfur fuels allow existing vehicles to be retrofitted with devices such as advanced catalysts and diesel oxidation catalysts that can reduce emissions of pollutants such as NO_X and $PM_{2.5}$ by more than 90 percent.
3. One organization should have the authority to issue both fuel quality and vehicle emission standards. In the US, this authority is vested in the EPA under authority of the US Clean Air Act. This authority ensures that clean fuel is available in the marketplace when needed by newer, cleaner vehicles.

3. Costs and Benefits of Energy Saving and Pollution Abatement Policies in China's Electric Power Sector

3.1 The Energy Saving and Pollution Abatement Scenario

By the end of 2005, coal-fired electric power plants represented 75.7 percent of total electricity capacity, 81.8 percent of national electricity generation, 50 percent of national coal consumption, and 52.1 percent of national SO_2 emissions. Because of its role as a major energy consumer and pollution source, the electric power sector is the focus of energy saving and SO_2 pollution abatement efforts.

China's National Economic and Social Development 11th Five-Year Plan and the *National Acid Rain and Sulfur Dioxide Pollution Prevention Plan* require that China's electric power sector reduce 2010 SO_2 emissions to no more than 11 million tons (10 million metric tons) – 25 percent below 2005 levels. The major pollution abatement measures are installing FGD equipment at new and existing electric power plants, shutting down small, inefficient boilers (closure of approximately 50 GW of electric capacity), and encouraging the use of low-sulfur and washed coal. The *National Energy Development Plan* requires an improvement in average generation efficiency from 13.1 ounces (370 grams) of coal required to generate one kWh of electricity to 12.5 ounces (355 grams) of coal per kWh. The primary measures for achieving the energy efficiency goal are shutting down small, inefficient boilers, reducing on-site electricity consumption (from 5.9 percent to 4.5 percent of generation), reducing transmission and distribution losses (from 7.18 percent to 7 percent of generation), and adding 40 GW of cogeneration facilities.

The JES assessed the costs and benefits of installing FGD equipment on existing electric power plants and the shutdown of small, inefficient boilers. Relative to the "business-as-usual" scenario, the JES analyzed the installation of an additional 167 GW of FGD equipment on existing electric power plants, leading to SO_2 reductions of 6 million tons (5.4 million metric tons). The shutdown of an additional 50 GW of small boilers will lead to SO_2 reductions of 2.3 million tons (2.1 million metric tons). These two measures will achieve 90 percent or more of the emission reduction goals in the 11th Five-Year Plan. In addition, the shutdown measures will save 32 million tons (29 million metric tons) of coal, ensuring to achieve the energy efficiency goals of the 11th Five-Year Plan.

The 11th Five-Year Plan Environmental Targets

The energy saving and SO_2 emission targets of the 11th Five-Year Plan are presented in Table 1 and Table 2, respectively.

Table 1: The 11th Five-Year Plan Energy Saving Targets for the Electric Power Sector

Energy Saving Requirements	Notes
Electric Power Sector 2005 (actual) 13 ounces of coal/kWh (370 grams/kWh)	National Economic and Social Development 11th Five-Year Plan and National Energy Development 11th Five-Year Plan
2010 (target) 12.5 ounces of coal/kWh (355 grams/kWh)	Equivalent to saving 23 million tons (20.9 million metric tons) of coal

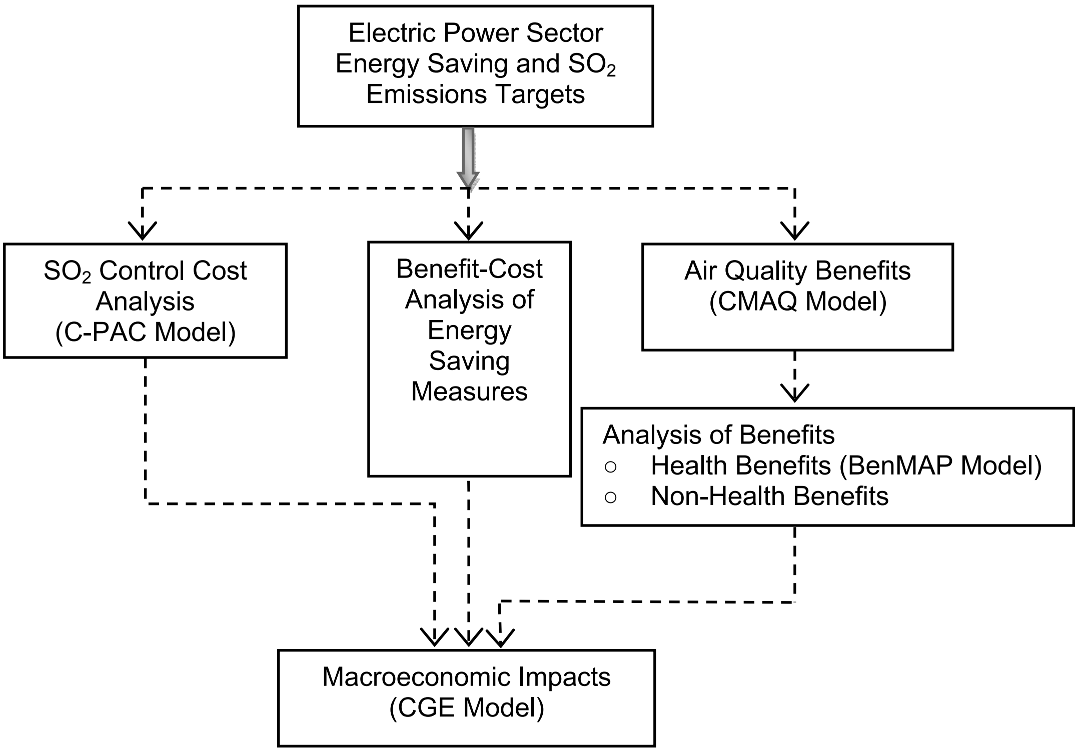
Table 2: The 11th Five-Year Plan Sulfur Dioxide Emission Targets for the Electric Power Sector

SO_2 Emission Levels	Notes
Electric Power Sector 2005 (actual) 14.7 million tons (13.3 million metric tons) 2010 (emission cap) 11 million tons (10 million metric tons)	• National Economic and Social Development 11th Five-Year Plan, National Environmental Protection 11th Five-Year Plan, and National Acid Rain and Sulfur Dioxide Pollution Prevention Plan. • During the 10th Five-Year Plan period, China implemented a number of emission reduction measures, including installing FGD equipment on 30 GW – 12 percent of total installed electric power generation capacity. • Forecasts of 2010 SO_2 emissions consider continuity of policies from the 10th Five-Year Plan and new electric power generation brought online during the 11th Five-Year Plan period. Approximately 250 GW of new electric power generation capacity is expected during the period. In the absence of additional controls on new and existing units, SO_2 emissions from the electric power sector are estimated to grow to approximately 24.3 to 26.5 million tons (22 to 24 million metric tons). • Assuming that the emission of air pollutants from transportation sectors, other industrial sectors, households remain the level of 2005.

3.2 The Analytical Approach

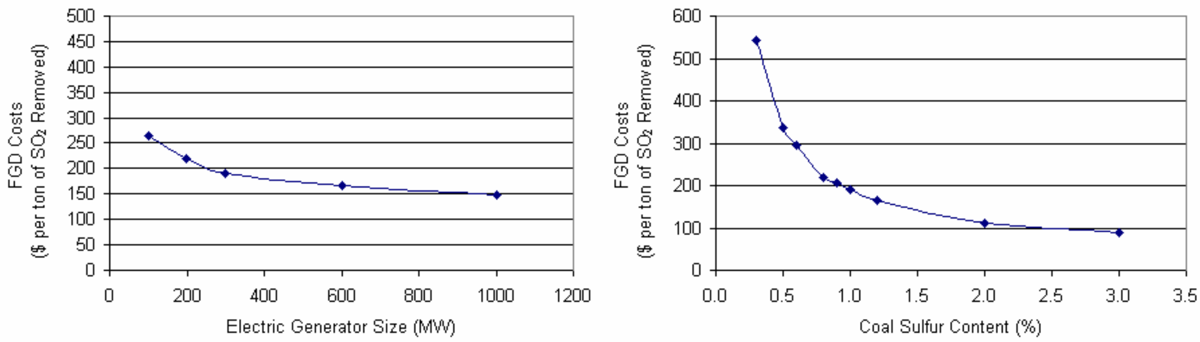
The JES provides an integrated assessment of the costs of installing FGD on existing electric power plants and shutting down small, inefficient boilers, the air quality benefits from the additional control technologies and improved generation efficiency, the health benefits of improved air quality, and the resulting macroeconomic impacts (see Figure 6).

Figure 6: Benefit-Cost Modeling Approach for Evaluating the Environmental Goals of China's 11th Five-Year Plan



The costs of controlling SO_2 emissions are based on national estimates of installation, operation, and maintenance costs of FGD equipment. Specific costs include operating inputs (water, electricity, sorbent), labor costs, depreciation, and maintenance costs. The installation cost per ton of SO_2 removed varies by the size of the electric power plant and the sulfur content of the coal consumed (see Figure 7). The China Pollution Abatement Cost (C-PAC) Model was used to compare the costs of control through technology mandates (the approach used in the 11th Five-Year Plan) and a cap and trade program.

Figure 7: Cost of Desulfurization Equipment in China by Generating Capacity and Coal Sulfur Content



Both the SO_2 pollution abatement efforts and the small-boiler shutdown program reduce SO_2 emissions and, as a result, ambient concentrations of SO_2 and $PM_{2.5}$. The Community Multi-scale Air Quality Model (Models-3/CMAQ) was used to model the air quality impacts. Health and non-health benefits, including reduced damage to crops, buildings, and infrastructure from improved air quality, were calculated using the BenMap Model. The model used concentration:response co-efficients for calculating non-health benefits. The macroeconomic impacts were assessed with a computable general equilibrium model. To assess the energy saving costs and benefits, the JES focused on the small-boiler shutdown policy because other studies conclude that the small-boiler shutdown policy provides the greatest energy savings and SO_2 reductions relative to the other energy saving measures (e.g., increased cogeneration, enhanced electric grid, reduced on-site power consumption). An additional benefit of the small-boiler shutdown is the potential for higher-value reuse of the land currently occupied by the small, inefficient electric power plants.

3.3 Energy Saving and Pollution Abatement Policy Impacts

Electric Power Sector Impacts – Sulfur Dioxide Emission Reductions

To achieve the SO_2 reduction goal of the 11th Five-Year Plan, the electric power sector must install FGD equipment on 167 GW of electricity generation. The present value of this investment in pollution controls is $4.8 billion (36.2 billion RMB). The annualized costs, including construction, operation, and maintenance, of these controls is $950 million (7.15 billion RMB) with SO_2 reductions of 6 million tons (5.4 million metric tons). The average cost of control is $160 per ton (1,326 RMB per metric ton) of SO_2 reduced.

The cost of installing and operating the FGD equipment will not be a significant burden for many electric power companies. In fact, the FGD equipment will often provide significant financial benefits for the plants. For example, for each ton of SO_2 controlled, the power plant will avoid the pollution levy of $152 (1,260 RMB per metric ton), will often receive revenues from the sale of gypsum (a byproduct of some FGD equipment), and generate additional revenues from the “green” pricing premium of $.002 (0.015 RMB) per kWh of electricity generated while an FGD is in operation. For some electric power plants, the additional financial benefits are greater than the costs of SO_2 emission control.

A cap and trade approach provides a more cost-effective way to achieve the SO_2 pollution abatement goal. By allowing the power sector to determine the most cost-effective approach for reducing emissions, the emission reduction goal can be achieved while providing incentives for innovation and creating a market for reducing pollution. Based on the situation in 2007, the installation of FGD on an additional 128 GW of electric generation capacity will cost $765 million (5.74 billion RMB) – an average cost of $160 per ton (1,326 RMB per metric ton) of SO_2 controlled. A limited examination of a cap and trade approach in the JES showed that cap and trade could achieve the same level of emission reductions but only necessitate the installation of FGD on an additional 101 GW of electric generating capacity at a cost of $640 million (4.8 billion RMB) – an average cost of $134 per ton (1,108 RMB per metric ton) of SO_2 controlled. The cap and trade approach would save $125 million (940 million RMB) in operating costs – a cost savings of approximately 16 percent. The actual savings will be significantly larger because the brief JES analysis only assessed the installation of FGD equipment to lower SO_2 emissions. It did not assess other options to reduce SO_2 emissions (e.g., coal washing, fuel switching, alternative technologies). Based on the US experience, if these and other options were included and electric power plants had the flexibility to deploy the most cost-effective approach, the costs would be significantly lower.

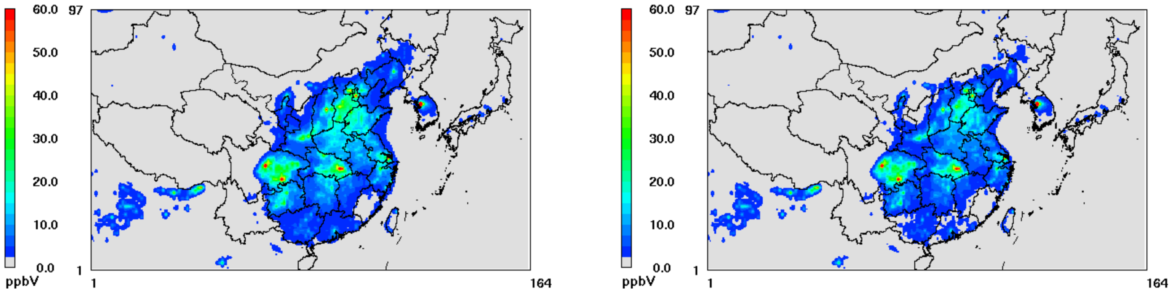
Air Quality, Health, and Environmental Benefits – Sulfur Dioxide Emission Reductions

The achievement of the SO_2 emission targets of the 11th Five-Year Plan will reduce the geographic area impacted by high SO_2 concentrations. By 2010, the cities that do not meet the Class I standards for annual SO_2 concentrations will decline from 17.3 percent of cities to 12.6 percent, a 27 percent improvement. The cities that do not meet the Class 2 standards will decline from 1.88 percent to 1.08 percent, a 42 percent improvement. While SO_2 annual concentrations decrease by more than ten percent in the majority of regions, Henan, Shanxi, and Shaanxi Province have declines of up to 30 percent. Nationally, $PM_{2.5}$ concentrations will decline by an average of approximately 5 percent.

Figure 8: Projected Annual Average Sulfur Dioxide Concentrations in China (2010)

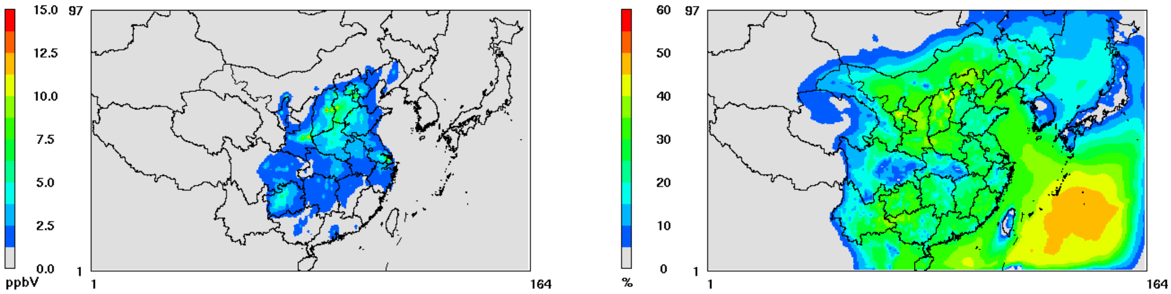
Ambient SO_2 Concentrations

Business-as-usual Scenario *Energy Saving and Pollution Abatement Scenario*



Reduction in Ambient SO_2 Concentrations

Parts per billion *Percent*



The benefits of the emission reductions from the installation of FGD equipment amount to $4.7 billion (35.4 billion RMB), including improved health, improved crop yields, and less damage to buildings and infrastructure. Each one ton reduction of SO_2 yields $793 (6,556 RMB per metric ton) of benefits. This is a benefit-to-cost ratio of 5 to 1[6].

Energy Saving Benefits and Costs

The small-boiler shutdown policy of the 11th Five-Year Plan can save approximately 32 million tons (29 million metric tons) of coal and reduce SO_2 emissions by 2.4 million tons (2.1 million metric tons) annually. The substitution of small, inefficient electric power plants with larger, more efficient electric power plants will also release land that can be used for other

[6] Relative to the US study, the benefit-cost ratio for China is not as large. This is due to several factors, including: a) the public willingness to pay for lower health risks differs in China and the US, b) the US study included more forms of health benefits and economic impacts (e.g., fewer lost work days due to illnesses, fewer cases of asthma), c) medical costs are higher in the US, therefore the benefits from reduced medical expenses are greater, and d) the US study evaluated a diversity of SO_2 emission control options using a cap and trade approach that lowered compliance costs.

higher-value purposes. Therefore, even if the benefits from environmental quality improvements and health, as well as non-health are not taken account of it, this measure will probably have net benefits.

Other energy saving measures also provide net benefits. Measures to reduce on-site electricity demands at electric power plants will reduce coal consumption by 1.2 million tons (1.1 million metric tons); reduced electric transmission and distribution losses will reduce coal consumption by 154,300 tons (140,000 metric tons); and the increased use of cogeneration facilities to produce heat and electricity will reduce coal consumption by 6.6 million tons (6 million metric tons).

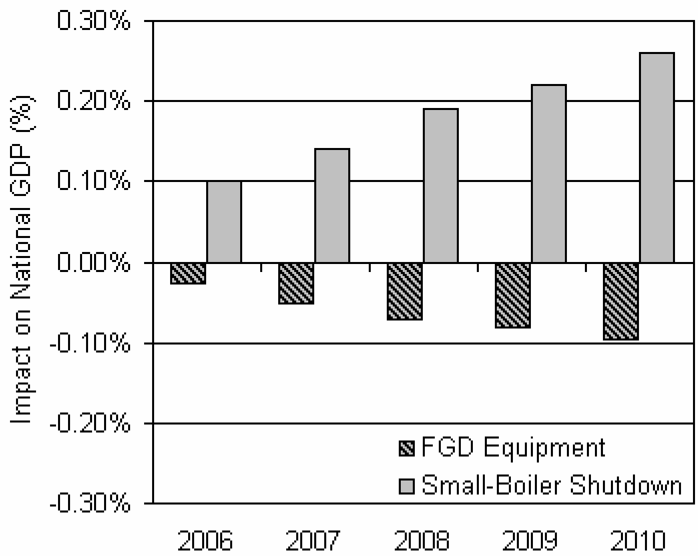
The 11th Five-Year Plan Energy Saving and Sulfur Dioxide Targets Benefits and Costs Summary

The SO_2 pollution control policy of the 11th Five-Year Plan results in the installation of 167 GW of FGD equipment and yields a benefit to cost ratio of 5 to 1 with quantifiable benefits of $4.7 billion (35.4 billion RMB) and costs of $950 million (7.15 billion RMB) to reduce SO_2 emissions by 6 million tons (5.4 million metric tons). The small-boiler shutdown policy will lower SO_2 emissions by another 2.4 million tons (2.1 million metric tons). The cost of new generation capacity to replace the small-boilers is offset by cost savings from reduced coal use and other factors that lead to the conclusion that the total SO_2 reductions occurring from both policies together is likely to have a greater benefit to cost ratio than 5 to 1.

Macroeconomic Impacts

The macroeconomic impact of achieving the goals of the 11th Five-Year Plan is estimated to be a reduction in GDP of less than 0.1 percent in 2010 (see Figure 9). However, accounting for the effect of the energy saving policies and the utilization of land made available from the closure of small boilers would further offset the cost of the abatement policies. The combination of policies may even have a positive effect on GDP.

Figure 9: The Impacts of Sulfur Dioxide Pollution Abatement Policies on GDP (2006 - 2010)



4. Costs and Benefits of the United States Clean Air Interstate Rule

In 2005, the EPA finalized the Clean Air Interstate Rule (CAIR) – a cap and trade program to reduce air pollution in 28 Eastern states and the District of Columbia. CAIR is one of the largest EPA initiatives ever undertaken and will go a long way in helping local governments meet federal air quality standards. The rule is based on multi-pollutant control concepts that EPA first introduced nearly a decade earlier.

Emissions of SO_2 and NO_X from electric power plants contribute to the formation of fine particles and acid rain. In addition, NO_X contributes to the formation of ground-level ozone. Currently, there are 132 areas in the US that do not meet the 1997 ambient air quality standards for $PM_{2.5}$ or ozone, affecting some 160 million people or roughly 60 percent of the US population. Along with other EPA actions, CAIR is designed to help these areas meet the applicable air quality standards.

4.1 Clean Air Interstate Rule Emission Reduction Requirements

The emission reductions required by CAIR occur in two phases (see Table 3) and cover power plants in the Eastern US. The first phase begins in 2009 for NO_X and 2010 for SO_2. The second phase begins in 2015 for both pollutants. In addition to the annual cap for NO_X, a five-month ozone-season cap is established for certain states in 2009 and 2015.

Table 3: United States Clean Air Interstate Rule Emission Caps

	2009 (NO_X)/2010 (SO_2)	2015
SO_2	3.7 million tons (3.35 million metric tons)	2.6 million tons (2.36 million metric tons)
NO_X (annual)	1.5 million tons (1.36 million metric tons)	1.3 million tons (1.18 million metric tons)
NO_X (seasonal)	570,000 tons (517,100 metric tons)	480,000 tons (435,450 metric tons)

Sources: 70 Federal Register 25523-26231
70 Federal Register 25416

4.2 Electric Power Sector Impacts

When the second phase of the program begins in 2015, the annualized cost of CAIR is estimated to be about $4.4 billion (33 billion RMB) per year.[7] The present value of the capital investment in pollution controls for CAIR, beginning with the first phase of the program through 2020, is estimated to be approximately $20.3 billion (152 billion RMB). Much of these costs will be passed along to consumers in cost-of-service power regions, which represented roughly 63 percent of the market for electricity generation in 2004. For the region affected by the rule, EPA expects retail electricity prices to increase by roughly 1.8 to 2.7 percent (Adamantiades et al., 2005).

The reductions achieved under CAIR will be met largely through the installation of pollution controls on coal-fired units, not through shifting to other fuels. This ensures a continued reliance on our abundant coal resources to produce electricity, but it will be in a cleaner and more efficient way. In fact, EPA anticipates that new coal power plants will be cost-effective, even with the aggressive cap levels of CAIR.

[7] All figures are in 2006 dollars.

The emission reduction requirements of CAIR are anticipated to result in a total of over 220 GW of installed FGD units and over 170 GW of installed NO_X selective catalytic reduction (SCR) units by 2015. By 2020, about 80 percent of all the electricity generated by burning coal in the US will come from sources with advanced pollution control equipment for SO_2 and NO_X – FGDs, SCRs, or both (Adamantiades et al., 2005). These controls will be installed where it is cost-effective. However, other compliance options include switching coal types, shifting generation to more efficient and cleaner units, and buying excess allowances from other sources.

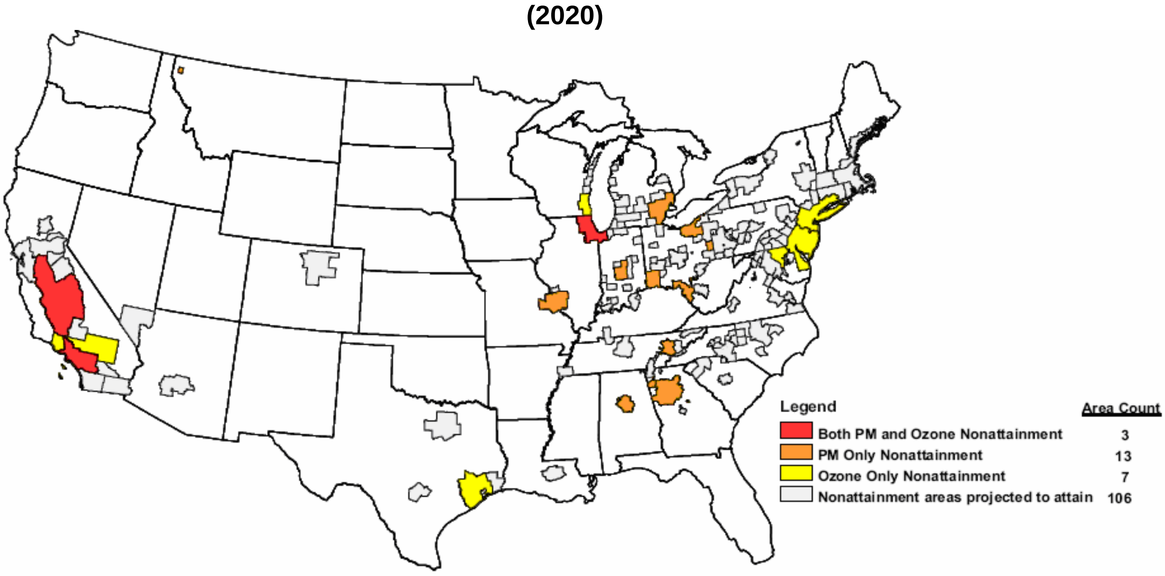
While the costs and impacts are significant, the analysis estimates that the macroeconomic impact on the US GDP is less than 0.04 percent in 2015. In addition, the policy will preserve both low electricity prices and fuel diversity.

4.3 Air Quality, Health, and Environmental Benefits

By 2015, CAIR will reduce SO_2 emissions by 5.4 million tons (4.9 million metric tons), or 57 percent, from 2003 levels in states affected by the rule. At full implementation post-2015, CAIR will reduce power plant SO_2 emissions in affected states to just 2.5 million tons (2.3 million metric tons), 73 percent below 2003 emissions levels. CAIR also will achieve significant NO_X reductions across states covered by the rule. By 2015, CAIR will reduce power plant NO_X emissions by 2 million tons (1.8 million metric tons), achieving regional emissions of 1.3 million tons (1.18 million metric tons), 61 percent below 2003 levels.

The emission reductions required by CAIR will translate into major improvements in air quality in the CAIR region. The rule will help cities and states in the East meet the 1997 National Ambient Air Quality Standards for ozone and $PM_{2.5}$. CAIR, in conjunction with existing power sector controls, recent mobile source rules, and state regulatory actions already undertaken, will reduce the number of ozone nonattainment areas in the US from 127 in 2007 to 10 by 2020. For fine particles, nonattainment areas in the US will decrease from 39 areas in 2007 to 16 areas in 2020 (see Figure 10) (EPA, 2007b). In addition, CAIR will help those remaining areas move closer to attainment. State efforts to address any residual nonattainment issues will become much easier as a result of CAIR.

Figure 10: Projected Ozone and Fine Particulate Nonattainment Areas in the United States (2020)



Source: EPA, 2007b

The public benefits of the emission reductions are significant. EPA estimates the annual benefits for human health and welfare to be $104 billion to $122 billion (780 billion RMB to 915 billion RMB) in 2015. These monetized benefits include the prevention of 17,000 premature deaths, 22,000 non-fatal heart attacks, 12,300 hospital admissions, 1.7 million lost workdays, and 500,000 lost school days annually. There are also benefits to the public that the study was unable to quantify in monetary terms. These include reductions of mercury emissions, acid rain, coastal and estuarine water eutrophication as well as improvements in visibility outside of the selected national parks. For instance, CAIR is expected to result in 11 tons (10 metric tons) of additional mercury reductions in 2015. Because of additional emission reductions post-2015 from CAIR, EPA anticipates even greater annual health and environmental benefits thereafter.

4.4 Clean Air Interstate Rule Costs and Benefits Summary

The Clean Air Interstate Rule represents a significant step toward the attainment of air quality standards in the Eastern US. The impacts on electricity prices and fuel markets are reasonable and energy diversity and reliability will be maintained. The benefits of CAIR outweigh the costs of pollution abatement by more than 20 to 1. The implementation of CAIR will lead to major environmental and health benefits, demonstrating the effectiveness of multi-pollutant approaches (Adamantiades et al., 2005).[8]

5. Policy Recommendations

5.1 Recommendations for Chinese Policymakers

Whether direct pollution controls or market-based approaches, effective air pollution control programs require a strong foundation that includes proper institutions, infrastructure, and incentives. **Policymakers should provide this foundation by implementing a comprehensive program to continuously measure emissions from sources in the power and industrial sectors, verify accuracy of emissions data through electronic and facility audits, and assure compliance with programs through consistent oversight with meaningful incentives**. The effort must include:

- Sound standards for the installation, operation, calibration, and testing of emission measurement equipment (e.g., emission and flow monitors) to ensure accuracy and consistency. The US Acid Rain Program's emission monitoring rules (40 CFR Part 75) provide a useful example.
- Reporting requirements for emissions data (e.g., SO_2 and NO_X) and related data to a central authority. Related data, such as heat input, operating hours, CO_2 emissions, and monitor calibration/test results, improve quality assurance efforts. In addition, collecting data on pollutants that may be the subject of future emissions control (e.g., NO_X) will provide a baseline for establishing a target, provide emission measurement experience, and provide a signal to industry that controls may be required in the future.
- Capacity building efforts to train national, provincial, and local environmental monitoring staff and industry representatives on the uniform application of standards for emission

[8] Original values of the analysis were in 1999 dollars – annualized cost of $3.6 billion, present value of investment in pollution controls of $16.8 billion, benefits of $86 to $101 billion.

measurement, data collection and reporting, recordkeeping, emission verification (e.g., data quality assurance and facility audits), and compliance assessment.

- Strict, consistently enforced compliance mechanisms, including penalties that are a strong incentive to comply instead of paying penalties for non-compliance.
- An evaluation system for bureaucrats who are responsible for environmental programs that gives greater weight to meeting environmental objectives and enforcing emission control programs.
- An assessment system to evaluate how well pollution control programs are achieving their targets and to identify and address issues quickly. This system should build on the existing air quality and acid rain monitoring networks.

Cap and trade programs are extremely cost effective at reducing air emissions from stationary sources over a large region. **Policymakers should implement a national cap and trade program to lower SO_2 emissions from the power sector. Additionally, they should explore its usefulness for lowering SO_2 emissions from other sectors. The cap and trade approach will also provide a cost-effective method for addressing other emissions, such as NO_X, from large stationary sources**. The SO_2 cap and trade effort should include:

- Design of a national program that replaces ineffective and duplicative programs and complements needed local emissions control programs. The aim should be to construct a simple-but-effective program that provides substantial regional emission reductions while protecting local air quality. Effective cap and trade programs provide industry with the flexibility and incentives to reduce SO_2 emissions cost-effectively. To facilitate long-term planning and investment in pollution control, industry needs long-term emission targets (e.g., 10 to 15 years in advance). In addition, a market for emission allowances without trading restrictions and without government intervention will encourage industry to look for the lowest-cost approaches and take on the full responsibility of meeting the environmental goals that the government establishes.
- Stakeholder involvement in the design and implementation of the program. This will help identify potential problems and the appropriate solutions, enhance the credibility of the program, and promote acceptance and compliance with the program.
- Substantial capacity-building efforts to train national, provincial, and local regulators and industry representatives on the design, operation, and assessment of cap and trade programs. Emission monitoring programs foster understanding and support cooperative relationship between regulators and industry, where both have the shared focus of environmental compliance.
- Transparency of emission data and program operation that builds confidence in the enforcement of emissions control programs and provides an added level of scrutiny. The 2007 *Information Disclosure Law* should include emission data from large stationary sources.

Benefit-cost analysis is a valuable tool for examining environmental policies and programs. **Policymakers should develop the capacity to apply benefit-cost analysis to evaluate environmental policies and programs, such as emission targets and ways to**

achieve those targets. In addition, it is important to consider the distributional effects (e.g., productivity and employment changes) of programs and policies with macroeconomic analysis to provide insights into their effects on the Chinese economy. This effort should include:

- A national database of power and industrial sector emissions (e.g., SO_2, NO_X, and CO_2). A high-quality, centralized database will support modeling and air quality management efforts, as well as allow for improved access to data for determining compliance and studying emission trends. It can also improve data consistency, facilitate electronic audits, and improve efficiency of data collection and analysis.
- Modeling tools to credibly estimate the impacts on air quality, health, environment, resource use, and the economic impacts of different types of environmental policies/programs.
- Capacity building to train analysts on the proper design, application, and limitations of benefit-cost and macroeconomic analyses and to explain their value to policymakers.

Policymakers should continue their efforts to promote the construction of more efficient power generation facilities utilizing the best technology options available (e.g., clean coal, cogeneration, supercritical boilers) and to encourage improvements in the efficiency of power delivery. Furthermore, **improvements in end-use energy efficiency should be supported through a portfolio of policy and programmatic strategies, including cost-effective appliance and equipment energy efficiency standards, enhanced building energy codes, cost-effective end-user incentive and technical assistance programs, and implementation of complementary utility regulatory policies**.

The JES illustrates the significant health and environmental benefits from reducing SO_2 emissions. In addition to power plants and industrial sources, mobile sources are an important and rapidly growing source of sulfur-related PM. **Policymakers should adopt a low-sulfur fuels (i.e., gasoline and diesel) policy that requires sulfur levels of 50 parts per million or below**. This would produce measurable reductions in sulfate emissions. In addition, low-sulfur fuels allow for the use of more advanced pollution control technologies (e.g., advanced catalysts, diesel particle filters) that can reduce $PM_{2.5}$ and NO_X emissions by more than 90 percent.

5.2 Recommendations for United States Policymakers

The Clean Air Interstate Rule and Clean Air Mercury Rule provide significant and meaningful reductions of SO_2 and NO_X in the Eastern US and mercury nationwide. However, the lesson of the US Acid Rain Program is that clear, comprehensive legislation is simpler to implement and provides greater certainty for EPA, industry, and other stakeholders. **Policymakers should pursue multi-pollutant legislation to control emissions from the electric power sector**.

As the electric power sector reduces SO_2 and NO_X emissions to meet the goals of the Clean Air Interstate Rule, industrial sources will represent a greater percentage of total emissions. **Policymakers should assess the opportunities to include key industrial sources in the cap and trade programs to reduce SO_2 and NO_X**.

EPA has helped state and local governments to improve local air quality through national and regional cap and trade programs, national mobile source rules, and national standards industrial emission sources. States have focused on local concerns through State Implementation Plan requirements and other rules needed to address local circumstances. **Policymakers should ensure that EPA and States continue to coordinate to ensure that this approach utilizes each government level's comparative advantage to protect public health while minimizing overlap and duplication that will hinder cost-effectiveness.**

There are considerable public health benefits from EPA's regulatory programs. Analysis to quantify these benefits has influenced various programs and enhanced public support. **Policymakers should consider extending benefit-cost analysis by finding ways to quantify the full benefits of protecting the environment (e.g., wildlife and ecological systems) and welfare (e.g., the reduction of haze in urban and rural settings) and using these analyses to inform, or shape, future air programs at the federal and state level**.

5.3 Next Steps

The JES has been a successful, mutually-beneficial program to share analytical tools, information, experience, and lessons. The JES work should continue under the SED framework with future work focused on: (1) designing and implementing an SO_2 cap and trade program for the Chinese electric power sector, and (2) strengthening the capacity of China's government research institutes to conduct economic analyses of environmental goals and policies.

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