Emissions Trading to Improve Air Quality in an Industrial City in the People's Republic of China

Richard D. Morgenstern, Piya Abeygunawardena, Robert Anderson, Ruth Greenspan Bell, Alan Krupnick, Jeremy Schreifels, Cao Dong, Wang Jinan, Wang Jitian, and Steiner Larsen

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RESOURCES FOR THE FUTURE

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1. Introduction

Can emissions trading or other instruments that harness the power of the market be effective tools for advancing sustainable development and improving environmental quality in the People's Republic of China (PRC)? Can such instruments reduce emissions at lower costs than conventional administrative approaches in a planned-market economy in which monitoring and enforcement systems still are in their infancy and state-owned enterprises are the dominant polluters?

Studies by the Asian Development Bank (ADB) and other groups of the potential application of market-based instruments (MBI) to enhance air quality in the PRC have been under way for more than a decade. Beginning in the early 1990s, the ADB encouraged a few one-off emissions trades in the PRC to offset air pollution from new coal-fired power plants.[1] The PRC's Tenth Five-Year Plan (10th FYP), from 2000–2005, calls for major emissions reductions, although it does not prescribe any specific ways to achieve them. This paper reports on efforts, endorsed by a number of senior Chinese officials and supported by the ADB, to extend the pilot type of emissions trades to establish a demonstration of a cap-and-trade system to meet the goals of the 10th FYP. This system is a form of trading that sets a cap on emissions for enterprises in an area and lets them trade emissions authorizations (also called allowances or permits).

In Spring 2001, the ADB awarded a contract to Washington, DC-based Resources for the Future (RFF), in cooperation with the Chinese Research Academy of Environmental Sciences (CRAES) and the Norwegian Institute for Air Research (NILU), to strengthen the institutional capabilities of the provincial agencies to facilitate MBI implementation.[2] Demonstration of an emissions trading program in Taiyuan, the capital of Shanxi Province, was envisioned as a key step in the process.

With air quality that, at one time, had earned it the dubious distinction of being first on a World Bank list of the most polluted cities in the world and significant pressure from the central government in Beijing to improve air quality, Taiyuan's municipal officials understandably were eager to participate in the study. The challenges involved in introducing a rigorous environmental management system, including emissions trading, in Taiyuan brings to mind the adage, "Rome wasn't built in a day," which also would apply to most other environmental policy changes. Establishing a full-scale emissions trading system is akin to assembling a complex mosaic. It involves addressing a large number of technical issues, such as emissions monitoring, as well as policy-relevant and sometimes politically sensitive issues, such as designing and managing the trading system within the appropriate legal framework. The exercise is not merely a matter of mechanically assembling pieces into a working whole. In addition, a variety of stakeholders and constituents must understand how such a program works, agree that it is in their interests to be part of the effort, and be trained to do their share in making it a reality.

To understand both the challenges and the proposed means of addressing Taiyuan's air quality problems, a number of issues must be examined. Section II of this paper explores the background for the project by addressing three key areas of focus: emissions trading, Taiyuan, and sulfur dioxide (SO_2) emissions. Section III examines the institutional context for the emissions trading system. Section IV considers the rationale for the cap-and-trade type of program selected for the demonstration. Section V outlines the design of the proposed emissions trading system, and Section VI offers a series of concluding observations.

2. Background

Heavy reliance on relatively uncontrolled coal combustion as a source of heat and power has created serious environmental problems in China. The toll on human health alone is estimated to cost approximately 2 percent of China's annual GDP.[3] Particulate matter (PM) and SO_2 are the major pollutants of concern, although, with recent progress in reducing PM emissions, attention increasingly is shifting to the control of SO_2. In many urban areas, particularly the coal-rich northern provinces and heavily industrialized central and southern provinces, high SO_2 concentrations—along with fine particles created by the atmospheric transformation of SO_2 into sulfates—represent a serious public health threat.

The PRC shares in common with most of the developing world various challenges in implementing effective environmental protection. These include limited resources and regulatory experience and a heavy national policy push toward economic development. Consequently, the Chinese government and its advisers lean heavily toward solutions that incorporate economic and administrative efficiency, devoting considerable energy to developing frameworks for economic incentives. An early example is the pollution levy system. Piloted in 1978 and formally adopted in 1982, the pollution levy system is in use in most provinces. Under the theory of a levy system, firms facing high costs to reduce pollution would opt to pay the levy, while firms facing lower costs would opt to treat the pollution until the point at which the additional cost of pollution abatement equaled the per-ton value of the levy.

Originally, the levy system was applied only to emissions concentrations that exceeded the national standards. The funds from the levy were used to finance the Environmental Protection Bureaus (EPBs) and to create a mechanism for financing a portion of pollution control, but not to enforce pollution standards. In 1993, the government initiated a pilot in two provinces and nine cities in which the levy rate was increased fivefold, and the levy was applied to total emissions. In 2000, the basis for calculating the levy nationwide was changed to total emissions.

However, even with recent increases, the levy still is estimated to be no more than half of typical marginal costs to abate emissions. The low rate, 80 percent of which is recycled back to enterprises for pollution control investment, creates only limited incentives to reduce emissions.[4] Enforcement is another issue. Although the central government has established uniform emissions standards, local governments are in charge of collecting the fees. Revenue collections tend to be sensitive to local environmental and economic conditions.[5] Emissions fees in the late 1990s generally were collected only from profitable enterprises and, reportedly, the fee amount still can be negotiated with local EPBs.[6]

2.1 Why Emissions Trading?

One option that might facilitate reduced emissions could be to increase the levy as high as the estimated marginal abatement costs, if possible. A similar approach recently was announced in Beijing, which is undertaking a large number of reforms to reduce pollution prior to the 2008 Beijing Olympics. In fact, RFF explored this option with officials in both Shanxi Province and Taiyuan. However, it soon became clear that reforming the current levy system while introducing large rate increases to encourage further pollution abatement would not be politically acceptable. In contrast, introducing emissions trading in tandem with the recently enshrined system for Total Emissions Control (TEC) was seen as more acceptable, particularly to the local enterprises, which feared the imposition of higher taxes via increased pollution levies. For more on this, see below.

Economic theory suggests that, from an efficiency point of view, augmenting the levy system with a strengthened command and control system is not likely to achieve maximal additional emissions reductions.[7] In general, command and control systems force firms to take on similar shares of the pollution control burden (that is, a uniform percentage reduction) or install specific technologies, regardless of cost. Even though such approaches may have some advantages—if they are easier for the regulated firms to understand and can be enforced more easily (both contentious issues)—they can be quite expensive. Emissions trading has the potential to achieve the same objectives at a lower overall cost. Recent analyses have documented savings from the use of emissions trading to manage acid rain in the United States at 40 percent or more below the cost of conventional approaches.[8] In contrast to the levy system, which in theory relies on price signals to induce reductions in emissions, a trading system sets emissions quantity targets, distributes permits to the polluting firms, and allows trading of the permits among firms in the system.

Under emissions trading, sources with higher marginal abatement costs can pay sources with lower marginal abatement costs to perform the emissions reductions required of the higher-cost sources. This has important efficiency and distribution implications. Society benefits from the transaction because it achieves the required emissions reductions. Higher-cost sources benefit by saving money; they pay lower-cost sources less than it would cost to make the reductions on their own. Lower-cost sources benefit by receiving compensation from higher-cost sources for their excess reductions. This compensation helps offset the costs of control technologies or process changes. Emissions trading also creates flexibility in the timing of compliance, smoothing out pollution control investment needs through emissions banking, a form of intertemporal trading. For all these reasons, emissions trading has the potential to be an attractive instrument for environmental management, particularly in a country like the PRC, which has set extremely high pollution reduction goals that necessarily would involve making major new pollution control investments as part of the 10^{th} FYP and beyond.

Economic theory strongly supports using market solutions to address environmental problems. However, whether these solutions can work in countries in which legal and institutional arrangements to ensure compliance still are in their formative stages is an open question.[9] For example, it is not clear that state-owned enterprises (SOEs) have any real incentive to pursue cost-effective emissions reduction strategies such as emissions trading. SOEs are accustomed to negotiating their compliance with government agencies ad hoc and case-by-case and have not been subjected to aggressive enforcement.

2.2 Why Taiyuan?

Provincial officials selected Taiyuan, the capital of Shanxi Province, as the site for this project. Taiyuan is a heavily industrialized area and one of the most polluted cities in Shanxi Province. Industry accounts for approximately 70 percent of provincial GDP, which is based largely on coal mining, coke production, iron and steel and other metallurgical industries, construction materials (cement), chemical manufacturing, and ceramics. The province produces approximately one-third of the nation’s total coal. Approximately 70 percent of the annual production of energy resources in the form of coal, coke, and electrical power are exported outside the province for sale. State-owned enterprises account for approximately 70 percent of the industrial output, although a number of these enterprises are moving to privatize.

Taiyuan is located 500 kilometers (km) southwest of Beijing. It consists of the central city, the autonomous subcity Gujiao, three counties, and six districts. It has a population of 2.7 million and covers 6,909 square km. Approximately two-thirds of the population lives in the 2 percent of the land area that comprises the city proper. Topographically, Taiyuan is surrounded by mountains on three sides, creating a Los Angeles-type of smog trap in which air pollutants tend to accumulate.

In 2002, reported annual daily SO_2 concentrations in Taiyuan averaged 0.2 milligrams per cubic meter (mg/m^3), more than three times the PRC's Class II annual standard ($0.06 mg/m^3$). Although subject to considerable year-to-year variation, official figures suggest that the trend in SO_2 concentrations has been relatively flat over the past decade (Table 1). The local Taiyuan government has set emissions targets in its response to China's national 10th FYP, which calls for dramatic reductions in SO_2 emissions by 2005. Given recent economic growth in the region averaging 10 percent per year and apparent reasonably stable air quality, the considerable effort already devoted by the government and regulated entities to environmental improvement appears to be paying off. At the same time, the relatively high SO_2 levels indicate the magnitude of the challenge that lies ahead as Shanxi strives to increase its economic output while meeting the major emissions reduction goals established in the 10th FYP.

Table 1

Annual Average Daily SO_2 Concentrations in Taiyuan, 1991–2000 *(mg/m^3)*

1991	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*
0.277	0.303	0.153	0.169	0.211	0.212	0.248	0.276	0.272	0.200

Source: Taiyuan Environmental Protection Bureau

In addition to its high SO_2 levels, Taiyuan was selected as the location of the demonstration for several other reasons:

- Since the ADB had just made a major loan to the province (and the city) for investments in air pollution control technologies, the pilot would provide a unique opportunity to integrate these efforts in an improved air quality management system.
- Provincial and local officials expressed strong interest in participating in a demonstration.
- The local government and other local institutions have available a high degree of technical support.
- A number of large enterprises expressed interest in participating in a demonstration.
- A variety of technical factors make Taiyuan an attractive site, including the availability of extensive monitoring data and ongoing research and modeling activities in the area.[10]
- There is good reason to believe that, by using a trading program, abatement cost savings would be significant because sources have what economists term "heterogeneity in abatement costs." This last reason requires some explanation.

The extent of heterogeneity of marginal abatement costs among enterprises and the presence of economies of scale in pollution abatement are critical determinants of the suitability of an emissions trading system to address a particular environmental problem in a particular area.[11] As noted, emissions trading has the potential to smooth out (or homogenize) differences among plants or locales in marginal abatement costs. Such cost heterogeneity may exist because of inherent differences in technical control options, fuel types, or other factors relevant to individual emissions sources. Cost heterogeneity also may exist—at least temporarily—because of the time-related variations in implementing reductions stipulated in the regulation. Thus, if the regulation calls for a 50 percent emissions reduction staged in 10 percent increments over five years, some sources may install a control technology yielding the full 50 percent reduction early in the five-year period, while others may wait until the fourth or fifth year. In that case, there would be an opportunity for the two to engage in emissions trading during the five-year transition period.

Another rationale for emissions trading is associated with economies of scale in pollution abatement. Suppose there are two identical sources, and one has control technology that can achieve 100 percent reduction in emissions at the same cost as the second source, which can achieve only a 50 percent reduction. If both sources were required to reduce emissions by 50 percent, it would make sense for one of the sources to reduce its emissions completely and sell the excess reductions to the other source. While situations involving large economies of scale in pollution abatement are uncommon, they have been recorded in the literature.[12]

Researchers have documented considerable cost heterogeneity among different industrial sources of SO_2 emissions in the PRC. For example, a recent study in the neighboring province of Shaanxi estimated potential cost savings of 50 percent or more for SO_2 reductions from the use of market-based instruments compared to additional command and control regulations.[13]

A relatively manageable number of large sources make up most of Taiyuan's direct SO_2 emissions. These sources span several industries. Furthermore, according to a control cost survey administered by the RFF team (Table 2), there is considerable abatement cost heterogeneity among the sources. The Taiyuan government also considers the sources to have relatively strong management.

Table 2

SO_2 Control Measures Planned or in Use in Taiyuan, 2001–02

Control measure	*Status*	*Where applied*	*Cost-effectiveness (RMB/ton) (US$)*
Close small boilers	Done	City-wide	Unknown
Wet method	In use	Taiyuan District Heating, Xishan thermal plant, Jinxi	500–1,100 ($60–130)*
Lower sulfur coal (~1.3%)	In use	Taiyuan #1, #2, Taiyuan Iron and Steel, others	667 ($85)
Add limestone to fuel	Planned	Coal gasification power plant	1,070 ($130)
Full FGD[1]	Planned	Taiyuan #1, #2	1,300–1,667 ($150–200)*
Simple FGD	In use	Taiyuan #1	2,000 ($240)**
Coal washing	Limited use	Coking plants	2,800 ($340)

[1]FGD = flue gas desulfurization

* As estimated by plant officials.

** Plus unspecified investment costs.

Source: Project team.

2.3 Why SO_2?

Researchers in China, Europe, and the United States have identified SO_2 emissions as a particularly potent air pollutant, both as a gas and as fine particulates (sulfates). To examine how a major reduction of SO_2 emissions could affect health in Taiyuan, we developed rough estimates of health benefits by:

- Establishing the expected amount of SO_2 emissions reductions implied by a proposed cap on such emissions;

- identifying the key types of damages (morbidity, mortality, other);
- establishing physical relationships between the pollutant emissions and the extent of different types of damages;
- identifying the responses by affected parties to mitigate some (or all) of the damages; and
- placing a monetary value on the physical damages, including the damages to human health.

Our approach relies heavily on a concentration-response function developed by the Harvard Institute for International Development (HIID) in its analysis of health benefits in neighboring Shaanxi Province.[14] The calculations examine what would happen if Class II standards were to be met in Taiyuan. Overall, HIID estimated that attainment of the standards could avert between 402 and 1,886 premature deaths annually. In monetary terms, the annual savings in health costs of such a reduction in air pollution are estimated at renminbi (RMB) 925 million to RMB 4.3 billion.[15]

Given the potentially sizable benefits to the community of attaining the Class II standards, can a practical mechanism be established and implemented to bring about the required emissions reductions? The next section considers the institutional arrangements for air pollution control in China, specifically in Taiyuan.

3. Institutional Context

No environmental policy can exist in an institutional vacuum. Rather, environmental policies—like all others—operate in a context of laws, regulations, government and industry behavior, and even cultural norms. There has been an explosion of environmental law drafting in the PRC over the past decade and a great deal of experimentation with various policy approaches. Of particular relevance to the current institutional context are the PRC Atmospheric Pollution Prevention and Control Law, the 10th FYP, regional and local regulations, practices and targets for improving air quality, and the structure and functioning of the local EPB in Taiyuan.

This section describes national air pollution policies in the PRC; surveys the air pollution control context for Shanxi, specifically for Taiyuan; and reviews the history of the pollution permits system in Taiyuan.

3.1 National Policy

The basic mandate for air pollution control is contained in the PRC Law on Atmospheric Pollution Prevention and Control (hereafter, Air Act).[16] Passed in 2000, the Air Act is a "framework" environmental law. It provides in very broad, general terms the outlines of the Chinese approach to controlling emissions. It identifies "key cities for air pollution control," of which Taiyuan is one. It requires the Taiyuan government to establish plans to control or gradually reduce the total maximum annual load of air pollution emissions for jurisdictions specified by the State Council.[17] The State Environmental Protection Administration (SEPA) has the responsibility to prepare implementing regulations or sublaws, which it must submit to the State Council. The implementing regulations are to include language encouraging the use of emissions trading.

Total Emissions Control (TEC) and Two Control Zones (TCZ) are the two basic state policies to control SO_2 emissions in the PRC. The TEC concept was introduced in the 9th FYP (1996–2000) and formally enshrined in the Air Act in 2000. The TEC plan caps total emissions of 12 air, water, and solid waste pollutants (including SO_2) in key geographical areas. Selected cities are requested to establish rules for TEC to support targets for environmental improvement. The TEC plan also directs that, as industry restructures, it must consider cleaner production techniques and pay attention to the entire production process, not just end-of-pipe pollution. Certain backward production processes and obsolete equipment are targeted for replacement. Priority is to be given to measurement of emissions and enforcement of regulations. Automated air quality monitoring networks are planned for large and medium-sized cities, including Taiyuan, and continuous emissions monitors (CEMs) are mandated for new large emissions sources.

In January 1998, the State Council approved an ambitious plan originally proposed by SEPA to control acid rain and SO_2 emissions in the most seriously affected regions, designated as the "Two Control Zones." Together, the Acid Rain and SO_2 Control Zones cover approximately 11 percent of China's territory and are responsible for 60 percent of China's total SO_2 emissions. China's overall goals for these zones for the year 2010 are to bring all cities into compliance with ambient air quality standards. Shanxi was listed as one of most seriously polluted SO_2 emissions control areas.

The 10^{th} FYP establishes specific targets for pollution control at the regional and local level. Overall, by 2005 the PRC aims to reduce SO_2 emissions nationwide to 10 percent below 2000 levels. For the two Acid Rain and SO_2 Control Zones, SO_2 emissions are targeted at 20 percent below 2000 levels by 2005. Provinces and autonomous municipalities also are allocated their own SO_2 emissions targets under the plan, with the goal of achieving reductions from 1.5 percent to 20.5 percent.

3.2 Air Pollution Control in Shanxi and Taiyuan

The Shanxi EPB estimated that, in the absence of additional policy initiatives, the total SO_2 emissions in Shanxi Province will reach 1.575 million tons by 2005. The goal set in the province's 10^{th} FYP for the same period is 1.1 million tons of emissions. The specific targets for 2005 for major cities in Shanxi Province are shown in Table 3. By far, the largest reductions are slated for the SO_2 control zone of Taiyuan—a full 50 percent drop below 2000 levels.

Table 3

SO_2 Emissions and Total Emissions Control Objectives for Major Cities in Shanxi in 10th FYP

Location	*2000 emissions (tons)*	*2005 TEC level* (tons)
Taiyuan (city plus 3 counties)	295,000	200,000
Taiyuan (SO_2 control zone)	258,000	125,100
Datong	160,000	150,000
Yangquan	140,000	130,000
Shanxi Province	1,575,000	1,100,000

Source: Taiyuan Environmental Protection Bureau.

In response to the demands of the 10th FYP, officials of Shanxi Province are engaged in extensive planning to reduce SO_2 and other pollutants. Power plants are required to upgrade their sulfur removal technologies by, for example, mixing limestone with the coal prior to combustion or by installing flue gas desulfurization (FGD). All boilers with thermal capacity grater than 10 tons of steam per hour are required to use coal with sulfur content of 1 percent or less. In addition, both of the large power plants in Taiyuan have closed several small boilers. The goals of the 10th FYP do not leave much room for adding new industries or sources. However, Shanxi officials expect that new sources will engage in emissions trading to offset their emissions.

3.3 Taiyuan's Early Efforts with Trading and Other Air Pollution Policies

The Taiyuan city government began experimenting with emissions permits and Total Emissions Control (TEC) in the mid-1980s. As early as 1985, Taiyuan established a series of local laws and regulations, including "Total Emissions Control Standards for Air Pollutants." In the mid-1990s, following the principle of "increasing output without increasing pollution, and building new facilities to replace the old ones," the city conducted pilot experiments on emissions trading and emissions offsets. This experience encouraged enterprises to conduct various analyses of the cost-effectiveness of alternative types of emissions controls to examine the options that they had available for low-cost emissions reductions.[18]

In 1993, the Taiyuan city government issued a regulation entitled Rules on Environmental Offsets for Air Pollutants to serve as the legal basis for pilot emissions offsets. In 1998, the city government issued the Administrative Regulation for Total Emissions Control of Air Pollutants in Taiyuan City, which also included a provision for "permit exchange," a form of emissions permit trading. On the basis of this regulation, the Taiyuan EPB began to issue to large enterprises updated permits with TEC-based limits. In 1994 and 1997, 40 key enterprises were issued air pollutant permits by the Taiyuan EPB. Unfortunately, these permits were defined for a limited period (2–3 years), and all have expired. The current mechanism for establishing requirements is emissions "target responsibility agreements," which essentially are a series of written agreements or contracts detailing the responsibilities of city government and enterprises for environmental quality.

The Taiyuan government announced new initiatives for air pollution control in 1999. They require the reduction of coal use in the central urban area by means of fuel switching; closure of certain small boilers; installation of monitoring devices; and emissions controls on larger boilers.[19] With assistance from ADB, the urban gas supply system is being expanded, and the district heating system is slated for modernization using heat from the larger power stations in the city to replace community boilers. The heating sources are in place, but the local service area still is limited. A significant investment will be required to expand the local heat distribution network. The key legislative and regulatory developments pertaining to Taiyuan's emissions permit program are summarized in Table 4.

Table 4

Major Policy and Regulatory Developments Related to Air Emissions Permits

Year	*Activity*
1985	Taiyuan government issues air emissions control management rule requiring facility modifications to meet emissions standards.
1987	National Air Pollution Prevention and Control Law approved.
1991–97	National pilot program for emissions permits supervised by SEPA.
1993	Taiyuan city government issued Rules on Environmental Offsets for Air Pollutants, which started the pilot of emissions trading in Taiyuan.
1995	National Air Pollution law amended.
1996	State Council issues Decision Regarding Several Issues of Environmental Protection (*Guofa* No. 31, 1996). State Council approves Total Emissions Control Plan for Major Pollutants.
1998	State Council approves National Acid Rain and SO_2 Control Zoning Plan. Taiyuan city government issues Administrative Regulation for Total Emissions Control of Air Pollutants in Taiyuan City, including provision for "permit exchange."
1999	Taiyuan city government announces new initiatives for air pollution control and countermeasures. New TEC-based permits issued for major pollution sources.
2000	National air pollution law amendments approved. Updated law includes more stringent enforcement provisions and provisions for emissions trading, but requires national implementing regulations to be effective.

4. Rationale for a Cap-and-Trade System in Taiyuan

This section discusses the rationale for selecting a cap-and-trade form of emissions trading in Taiyuan, rather than emissions "offsets," or an open market trading system.

Three overall reasons underlie the selection of a cap-and-trade system:

1. Such a system provides greater environmental certainty than other approaches.
2. It is consistent with the already-announced TEC policy requiring local governments to set emissions targets, which then can serve as limits for the cap-and-trade policy.
3. There is growing interest at the national and provincial levels in introducing cap-and-trade systems throughout the PRC.

4.1 Forms of Emissions Trading

Initially, three different emissions trading approaches were considered by the project team, the ADB, and the Chinese officials involved in the Taiyuan demonstration: (1) emissions "offsets," (2) an open market trading system, and (3) cap-and-trade. Since structurally different emissions trading programs often are identified in different ways, the names alone are not sufficient to characterize the programs. Rather, it is important to identify their key attributes, such as whether emissions are capped or uncapped.

So long as permits, or "allowances," are given away (typically, grandfathered) rather than sold, industry retains more financial resources than under policies involving levies (or taxes), because payments associated with buying and selling allowances flow from one enterprise to another, not to the government. Enterprises still must finance actions to control emissions, but typically are not required to pay the government for those emissions. Moreover, in choosing emissions control activities, enterprises are free to use the emissions-reducing options that they believe to be most cost-effective, whether end-of-pipe or otherwise. They do not need to seek prior approval from government authorities, as in the case of recycled levy revenues in the PRC. Nor are environmental authorities required to make any calculations of marginal control costs for different enterprises, as they would in deciding on the appropriate size of an increased SO_2 levy.

The least-structured type of emissions trading system involves emissions "offsets." Under an offset program, emissions reductions are allowed in one place to compensate for increased emissions somewhere else. Offsets can be between different plants (an "external offset") or between sources of emissions within the same plant ("internal offsets"). Typically, offsets are approved and implemented on a case-by-case basis. Offsets may involve financial compensation, but this is not an essential element.

Emissions reductions from one source in excess of the proposed emissions increases at another may be required in order to provide for an overall net reduction in emissions. For example, a source may have to reduce 2 tons to offset 1 ton of increases at another source. Offsets can be particularly useful for allowing new or expanded sources of pollution to locate or produce in a region that is not meeting its ambient targets or standards. In these cases, new sources may have the responsibility for obtaining (or paying for) emissions reductions from existing sources. Emissions offsets were among the first market-based instruments used in the United States, in the early years of the U.S. air management program. As noted, the PRC has previously experimented with offset programs in a number of pilot projects, including in Taiyuan.

A more ambitious trading approach is the open market trading system. A pollution source can earn marketable emissions credits by reducing its emissions to levels below a regulatory standard or by making reductions in advance of a prescribed deadline. For example, if an enterprise is subject to an emissions standard, and this standard exceeds its actual emissions, it may sell the amount of pollution reduction implied by the difference, depending on the rules of the particular system. The credits earned may be sold to other sources and used to offset an equal amount of excess emissions, and they may be resold as well; or they may be banked for future use. This approach institutionalizes the offset idea by permitting sources to trade without case-by-case approval. This approach also reduces transaction costs relative to an offset system. It has been implemented in a handful of states in the United States. The main difficulty with open market trading systems is meeting an aggregate emissions reduction target, because it may be difficult to monitor all of the credit-generating activities and no overall limit on emissions is built into the design.

Still more ambitious is a cap-and-trade system, of which the U.S. SO_2 allowance trading system under its Clean Air Act is the canonical example. Sources may trade pollution reduction responsibilities among themselves to meet an aggregate emissions cap set by the federal government in the given area. In this system, emissions credits (or allowances) are allocated without reference to a regulatory standard (although sources still *are* required to comply with certain standards regardless of the number of allowances they possess). Instead, the regulatory agency decides on the aggregate level of allowable emissions for all the parties participating in the program (the "cap"), and then it allocates to each party a portion of this amount in the form of "allowances" that can be traded. Each allowance gives a source the right to discharge one unit of the pollutant in question. The allocation may be made according to parties' historical performance (for example, emissions, fuel use, output), by auction, or by other means. Once allowances are allocated, parties are prohibited from emitting more pollution than their allocation, unless they purchase additional allowances from another party.

4.2 National Policy Context for Emissions Trading

A cap-and-trade system for Taiyuan is consistent with national efforts already underway to introduce a market-based approach to controlling SO_2 emissions. As early as the 1980s, the PRC began discussing emissions trading pilots in combination with air quality management projects. For example, SEPA has carried out several academic case studies on the transfer of emissions allowances among enterprises. SEPA's next step was to conduct pilot experiments with emissions trading. SEPA's interest in emissions trading continued to grow in the 1990s as it began working with international partners to help build local capacity on emissions trading. The Total Emissions Control (TEC) approach was discussed extensively in the period of the 9th FYP.

In 1994, SEPA carried out emissions trading policy pilots in six cities: Baotou, Kaiyuan, Taiyuan, Liuzhou, Pingdingshan, and Guiyang. The pilots introduced flexibility into the emissions control requirements and enabled enterprises to transfer allowances within an enterprise, pay an environmental compensation fee to obtain additional emissions allowances, invest in non-point-source pollution controls to obtain additional emissions allowances, and sell surplus allowances to other sources that hold insufficient allowances. In these pilots, the trading—in the form of offsets—was heavily influenced by institutional and political considerations and was not strictly market driven. Rather, it worked in combination with new, expansion, and technical innovation projects arranged by local EPBs.

SEPA also partnered with the U.S. Environmental Protection Agency (EPA) to increase the knowledge and understanding of emissions trading. In 1999, SEPA and the U.S. EPA initiated cooperation on a study to explore the feasibility of introducing nationwide SO_2 emissions trading in the Chinese power sector.[20] This study explored the theory, methods, legal bases, and conditions of emissions trading and considered special conditions in the PRC. Through workshops, training activities, and personnel exchanges, a number of Chinese management and research personnel studied emissions trading in depth.

Parallel to the Shanxi project, the U.S. nongovernmental organization (NGO), Environmental Defense, has worked for five years on another trading effort. It has taken place in two industrial cities: in Benxi to draft tougher air pollution legislation based on the U.S. acid rain model, and in Nantong to develop a demonstration SO_2 trade whereby a light manufacturer can expand operations in exchange for contributing funds for pollution control to a local power plant. The Nantong trade is quite similar to an emissions offset. Environmental Defense is also working with the PRC's largest power generator, State Power of China, to develop a trade.

In 2002, to gain more experience and facilitate nationwide adoption of emissions trading, SEPA organized pilot programs in seven provinces. After one year of preparatory work, some provinces have already reported some initial success. For instance, two power plants in Jiangsu have reached an agreement to trade SO_2 allowances in order to meet TEC limits. SEPA expects to strengthen and expand these pilots. Finally, at the end of this process, SEPA endorsed the Taiyuan demonstration and clearly signaled the importance of this demonstration to the overall policy structure.

5. Design of a Cap-and-Trade System

Although the economic rationale for a cap-and-trade system—to reduce the costs of meeting SO_2 emissions goals—is compelling, it is certainly true that "the devil is in the details." For an emissions trading program to be successful, a number of policy and administrative issues must be sorted out.[21] Governmental decisions must address such matters as the overall pollution reduction to be achieved, the deadline to meet the goal, the actual sources of emissions to be included in the program, the initial permit allocation plan, and the creation of proper incentives for compliance. Administrative elements include designs for compliance, emissions measurement and monitoring, enforcement, emissions reporting, and allowance tracking systems. However, each of these also includes policy aspects. Table 5 summarizes the key design elements.

Table 5 Summary of Key Design Elements

Policy-level design elements	
1. Environmental goals	
Emissions level for cap	Maximum emissions limit or cap for the trading program
Timing (beginning year, target year, phase-in)	Timing of emissions reduction requirements
Capturing environmental impacts from emissions trading	Environmental implications to using emissions trading
2. Scope and applicability of trading program	
Affected sources	Source categories to include in trading program
Trading area	Geographic scope or area covered by trading program
New sources	Incorporating new sources
3. Allowance distribution vs. auction or sale	
How sources obtain allowances	Different sources for sources to obtain allowances
Prices	Prices of the allowances
Banking	Whether sources will be allowed to save allowances for use in future compliance years
4. Policy interactions	
Relationship with discharge standards	Whether emissions trading system will interfere with other discharge standards
Relationship with pollution levy	Whether pollution levy will restrict or interfere with emissions trading system
Administrative design elements	
1. Emissions quantification, reporting, and verification	
Emissions quantification	Standards for emissions measurement
Emissions reporting	Reporting standards for emissions data
Verification	Validating emissions data including quality control checks of methods used and equipment (monitors)

2. Allocations and auctions	
Defining and allocating allowances	Define allowance
	Establish an allowance distribution method
	Allowance accounts
	Who can hold allowances
Auction	Annual auction procedures
3. Legal authority and responsibility	
Authority and roles	Program administration
	Legal framework (within which emissions trading laws can be developed)
Compliance	Procedure for compliance determination
	Authority to enforce noncompliance at the source level
	Noncompliance penalty
4. Information systems	
Tracking systems	Emissions tracking
	Allowance tracking
	Allowance transfers

5.1 Policy Design

To develop its regulation on emissions trading—which was issued in October 2002—the Taiyuan city government had to make decisions on a wide range of policy issues. One decision that was not within the city government's discretion was the SO_2 emissions goal; that had been set in the Economic Development Tenth FYP for Taiyuan. As noted above, that plan set the SO_2 emissions goal for 2005 at 125,100 tons, a 50 percent reduction from the 2000 emissions level.

It is notable that only smokestack emissions count in this exercise. Fugitive emissions (emissions from other parts of the plant that are not discharged through the stacks)—which can be a very large fraction of total emissions from coke plants, iron and steel plants, and other heavy industrial sources—were excluded from the emissions inventory. Counting them in the cap likely would have environmental benefits and would result in a more realistic and comprehensive cap being set. However, because of the difficulty of accurately estimating fugitive emissions, it was decided not to include them in the program at this time.

A program could include one or a combination of the following: all sources, large industrial and other point sources, only the largest sources, and/or already permitted point sources. The Taiyuan EPB decided to include only the 23 coal combustion sources that had been given emissions quotas or targets for 2001. While Taiyuan has other large sources of SO_2 emissions (such as the glass company and some other users of sulfuric acid [H_2SO_4]), the EPB recommended initially limiting trading to combustion sources. Emissions from the 23 enterprises that were proposed for the demonstration account for approximately 50 percent of the total SO_2 inventory in Taiyuan (not counting fugitive emissions). As noted earlier, these 23 sources also are regarded as having relatively strong management.

The decision on the geographic scope of the trading area follows from the decision to include the 23 sources. The Taiyuan EPB decided to include just the city proper. They considered but rejected including the autonomous municipality of Gujiao as a part of the Taiyuan SO_2 control zone, because doing so would have required an additional level of administrative coordination.

Often, how allowances are distributed is one of the most controversial elements of a trading program. The reason is that the allowance represents a valuable economic asset to an enterprise. Allowances were given away in U.S. programs, but recent research suggests that they should be at least partly auctioned.[22] Alternately, they could be sold at a predetermined price, although this method would not be as efficient and would, like auctions, likely invite resistance from the firms. These different options also imply different degrees of administrative complexity. In general, if the permits are given away, the receiving enterprises may reap benefits upon selling their permits. In contrast, if the permits are sold, the revenues may be generated for use by the government.

In discussions, most government officials felt that the sale of emissions permits at fixed prices or through an auction probably would not be a feasible allocation mechanism at this time. They noted that sources have limited financial resources due to relatively depressed economic conditions and low profit margins. Taiyuan EPB officials focused on the possibility of allocating most emissions allowances to sources in proportion to historic quotas, but reserving 10 percent to 15 percent of the allocation for new growth.

The RFF team and local officials engaged in extensive discussions and analyses to establish the following principles:

- In general, the 2005 SO_2 reduction goal for each source is 50 percent of its 2000 reported SO_2 emissions. A uniform annual reduction (equal percentage) is to be applied to each source from 2001 to 2005.
- If participating enterprises are SO_2 control point sources in Taiyuan's 10th FYP and their 2005 SO_2 emissions specified in the plan already are lower than 50 percent of their 2000 reported emissions, their planned 2005 SO_2 reduction goals are used.
- If sources are listed in the 2001 environmental responsibility contract system, their 2001 contract emissions are adopted as the baseline. A uniform annual reduction (equal percentage for each source) is applied to each source from 2002 to 2005.
- If sources' SO_2 emissions specified in their 2001 environmental responsibility contracts already are lower than 50 percent of their 2000 reported emissions, their 2005 reduction goals are set at 20 percent below 2001 permitted emissions. Each source is required to reduce 5 percent of its 2001 permitted SO_2 emissions every year, beginning in 2002.

Another key policy decision is whether sources can "bank" (save) unused allowances for future use or sale. Banking can provide firms needed flexibility in developing control strategies. The U.S. experience shows that banking can be done without environmental detriment. Indeed, experience with banking has shown that firms tend to bank, in the aggregate, a significant number of tons each year, resulting in fewer emissions than allowed by the cap, and, thus, correspondingly more rapid environmental improvement. Experience also shows that most firms will keep some emissions in the bank as insurance against future need—a pattern that tends to create additional environmental improvements.

Item 20 of the Administrative Regulation for Total Emissions Control of Air Pollutants in Taiyuan City allows banking so long as prior approval is obtained from the EPB. Although EPB and company representatives had varying views on this issue, ultimately, a banking provision was included in the demonstration program.

5.2 Administrative Design

Parallel to handling the policy design issues, a wide range of administrative design issues were considered. The administrative elements cover important details of the trading system, including compliance, monitoring, enforcement, reporting elements, legal issues, and information systems. Many of these decisions, which are examined below, are needed for *any* emissions-based regulatory system to function properly, not merely an emissions-trading system.

It is beyond dispute that regulators and the public must be assured that real, not imaginary, pollution reductions are being traded. Thus, it is essential that tight procedures be implemented for determining the actual quantity of emissions. The best approach would be to have continuous emissions monitors (CEMs) installed in each emitting stack. Indeed, some major sources in Taiyuan already use CEMs to track their emissions, but these devices are used either for purposes internal to the plant or intermittently by EPB inspectors in their periodic inspections. Standards need to be developed to ensure that CEMs are installed, operating properly, and calibrated regularly.[23] There is, in fact, strong interest in improving monitoring capabilities in Taiyuan. Evidence of this commitment is the recent request by Chinese officials to the ADB to use recent loans to purchase additional CEMs.

Another improvement would be to ensure that the information obtained from monitoring is easily available to regulators. A central database for CEM data is under development by the Taiyuan EPB. It will include online data transfer. Alternately, other techniques, such as direct or indirect measurement through fuel use and sulfur content calculations, could be used. However, the accuracy of periodic direct measurements depends on a number of assumptions, including operating conditions, production levels, and control equipment operation. The accuracy of indirect emissions measurement depends on the quality and quantity of fuel type information. Ensuring that data quality is high is an important task for any type of environmental program and could be challenging to governments with limited data collection experience and authority.

One government institution needs to take primary responsibility for the administration of the program. The obvious institution to do this is the Taiyuan EPB, because it is responsible for emissions regulation and already has in place the beginnings of the necessary monitoring and enforcement infrastructure. The role for the provincial EPB and the relationship between the provincial EPB and the Taiyuan EPB are critical issues. Unfortunately, neither EPB is an independent body and may not possess the requisite jurisdiction to act in case of violations. In particular, because power plants are regulated from a provincial (and even national) level, procedures and regulations for addressing power plant regulation need to be developed within the local permit exchange system.

No environmental regulatory program works without a system to ensure compliance. A strong compliance program has many aspects, all of which are designed to ensure that sources will play by the rules and be treated fairly through a set of procedures that are clear, transparent, and consistently applied. As part of the demonstration activities carried out in Taiyuan, a number of technical programs have been put in place to help manage disputes and to encourage enterprises to follow the rules.

- *Emissions Tracking System (ETS).* EPB needs information to determine whether enterprises are operating within the parameters of the system, including whether their SO_2 emissions are less than or equal to the allowances they hold. The ETS was developed to integrate technical monitoring information collected by the Taiyuan EPB with additional data on coal purchases, new SO_2 control measures undertaken, enterprise-level output, and other factors. Enterprises will be able to submit their data in electronic (or paper) format, and the Taiyuan EPB will be able to generate reports specifically tailored to its regulatory needs.

- *Allowance Tracking System (ATS).* ATS will ensure the functioning of the trading system. This system can report and verify trades.

- *Provision for reconciliation*. In the process of buying and selling allowances, enterprises normally will need to reconcile their emissions and permit holdings. Thus, they may need to buy additional allowances or sell some to be sure that their emissions do not exceed the allowances held. Procedures for reconciliation were written into a "Procedures Guide" as part of the project.

- *Appeals process.* Disputes will arise in any environmental program. To resolve disputes, it was proposed that a mediation committee be established. The committee could consist of senior government officials and key enterprise managers, plus perhaps members of the academic community, the public, and the media.

To ensure that enterprises involved in emissions trading follow the rules, governments at all levels need to send a strong and consistent message about its commitment to enforcement. Expressed in terms of an economic framework, the "cost" of violating an emissions limit must be higher than the "benefit" the violator gains by noncompliance. One way to manage this problem would be to impose cash penalties, such as a fee on each unit of emissions exceeding the allowances held. The compliance penalty could be made at least as high as the cost of coal washing. Currently, coal washing costs approximately RMB 2,800 per ton of SO_2.[24] Setting the penalty at a slightly higher level than the cost of coal washing would ensure that compliance is less costly than paying the penalty for emissions in excess of one's quota. Another approach might be public disclosure and civil or criminal prosecution of violators.

Additional reforms are necessary. Penalties must be collected in a timely fashion to link the pain with the violation and ensure timely compliance. Enforcement officials must not be constrained by fears that they will run afoul of powerful interests or that, in taking an aggressive enforcement posture, they will endanger their own salaries and social benefits. This is a critical issue in the PRC, in which the EPBs are not independent of the local People's Congress and the political apparatus.[25]

Stakeholders widely acknowledged that penalties for noncompliance should be higher than the marginal cost of compliance. At the same time, they wanted penalties set at "realistic" levels. Although the Administrative Regulation on SO_2 Emissions Trading in Taiyuan City set sufficient penalties—RMB 3,000 (US$364) to RMB 8,000 (US$968) per ton—the regulation limits total penalties to no more than RMB 30,000 (US$3,630), which is undoubtedly too small to induce full compliance with the program, a fact pointed out in meetings by local industry.

The need for effective penalties raises the larger issue of the interface between the existing pollution levy system and the penalty system, as well as that between the pollution levy system and the emissions trading system. Levies are paid on every unit of SO_2 emissions, whether these emissions exceed the enterprise's quotas or not. However, these levies currently are too low relative to the cost of reducing SO_2 emissions to significantly discourage emissions.

As work proceeds on emissions trading, some difficult decisions must be made about the levy system. A small levy that is used for raising revenue, such as now exists, presents no obstacle to the successful functioning of an emissions trading system.[26] However, technically, a levy system with fees high enough to change polluting behavior duplicates a trading system. At any one time, either the price of a unit of emissions set in the market or the levy rate will be binding. The PRC could use one of the following options to address this problem:

1. Recognize that the levies are very low and allow the two systems to coexist;
2. Eliminate the levy charge on SO_2 to all participating enterprises, but auction or sell SO_2 emissions allowances at an administered price and rely on penalty collections for paying EPB expenses; or
3. Give away allowances but impose a small surcharge for each allowance equal to the current levy rate. The difficulty, of course, is that it is not possible to discontinue the levy without prior approval from SEPA.

Another issue that the PRC must face is the integrity of a trading system. By its very nature, emissions trading allows different enterprises to emit different levels of pollution. For those who are not fully knowledgeable about the program, these differences may create misunderstandings about whether firms are being treated fairly and equitably. In addition, there must be confidence in the general population and among the regulated community that trades are legitimate; that the grant of discretion to a particular plant is not based on favoritism; and that the program does not enrich plant owners or operators, regulators, or other vested interests at the expense of the environment.

Perhaps the best way to examine this issue is to think about the U.S. SO_2 emissions trading system. In the United States, decisions about allowance allocations, information on actual trades, and virtually the entire program are subject to public inspection. This helps insure that there is no cheating, that everyone is treated fairly, and that interest groups (including neighborhood groups, NGOs, and competitors) have confidence in the program. A campaign to inform the public about the program may reduce suspicions that the program has been instituted to benefit favored units, enterprises, or individuals, or to punish others.

Transparency also would help the enforcement aspect of the program in China, for example, by establishing a disclosure system so that an informed public and environmental NGOs can, in effect, help keep the program honest. After the SARS epidemic of 2003, some PRC provinces, particularly those with the most negative publicity about SARS, began experimenting with limited transparency concerning government programs, but considerable improvements are needed to result in effective program enforcement.

An effort toward greater transparency would be consistent with China's current emphasis on increasing public environmental awareness and related efforts. Article 15 of the new Air Act has provisions calling for greater transparency in setting the TEC and issuing emissions permits.

With the assistance of CRAES, the World Bank is working on a disclosure system for the PRC, using color coding and public disclosure as the means to channel public pressure for environmental compliance. A limited form of public disclosure, whereby an air quality (ambient) index is being made available to the public on a "real-time" basis, already is being used in many PRC cities. Moreover, the Chinese media increasingly have used public disclosure to pressure polluting units to control their pollution. Many large cities have "green" newspapers and "green" reporters for television and radio. Last year the Taiyuan EPB reported in a newspaper the efforts that sources were making to reduce emissions. This year the EPB plans to prepare a report for the government and enterprises that discusses emissions and facility utilization. Nevertheless, green newspapers and media outlets are all owned and directed by the government, which clearly limits their ability to serve as independent observers.

Over the course of this project, stakeholders, including local officials and enterprise representatives, raised a number of additional issues: (1) emissions trading might not be feasible because of the high percentage of emissions discharged from a relatively small number of sources; (2) poor economic conditions may hinder trading; and (3) a stronger demonstration of high-level government support is necessary before emissions trading can proceed. Each of these issues is considered below.

1. A few large sources and many small sources might present significant challenges to an emissions trading system. In Taiyuan there are two very large sources and a small number of other sources with substantial emissions. The remaining sources, although numerous, are relatively small. Participants feared that this size distribution of the sources might create a problem for emissions trading. It is certainly possible that the "market" could be distorted by an attempt by one or two large firms to monopolize the emissions market. The RFF team suggested that the Taiyuan authorities monitor trades closely for such behavior. Size alone, however, is not the major factor in market distortion. Rather, the key measure is the difference between the number of allowances granted to a source and its current emissions. This difference need not be greater for large sources than for small sources. For instance, a skewed size distribution exists in Los Angeles. Nevertheless, monopoly behavior has not been an issue in the California-based Regional Clean Air Incentives Program (RECLAIM) program, in which a few power plants dominate in terms of quantity of emissions, although there may have been such an issue in New Jersey.[27]
2. Poor economic conditions within the firms might lead to resistance to emissions trading. Concern has been expressed about the economic health of the Taiyuan enterprises and whether this would affect their interest in participating in an emissions trading program. For an emissions trading program to be successful, clear regulatory goals for reduction of emissions and adequate enforcement must be present. The environmental authorities in Taiyuan and Shanxi Province must make it absolutely clear to sources that they will, in the aggregate, need to reduce emissions by specified amounts. If sources are not in actuality required to meet their regulatory requirements and the regulation is not effectively enforced, then neither emissions trading nor any other approach will succeed. However, if enterprises and firms are facing genuine regulatory requirements, a trading system can reduce compliance costs to below those that would be incurred if all sources were required to meet

the same reduction goals in the same time frame. Thus, firms might be expected to support the trading program to the extent that the government is serious about reducing emissions.

3. It is clear that the success of emissions trading in Taiyuan requires a stronger demonstration of high-level government support. Several workshop participants made the point that no environmental program, including an emissions trading program, can succeed in Taiyuan without explicit support from high levels of the city and provincial governments. It has been proposed that the Shanxi Planning Commission convene an advisory group of key government officials and industry managers in Taiyuan to assess the overall demonstration and a working group of technical staff to monitor the detailed operation of demonstration.

6. Overall Conclusions

To put the Taiyuan effort into perspective, it is useful to review the experience of the highly successful SO_2 trading program in the United States. The U.S. program was preceded by many years of theoretical and empirical analyses of appropriate design features for a trading program, as well as more than 10 years of experiments with less sophisticated market-based instruments. While the experiments at the U.S. EPA with offsets and other forms of economic incentives had only limited success, the lessons fed directly into a political debate over how to reduce SO_2 emissions of existing power plants—a debate that in 1990 led to the creation of the SO_2 Allowance Trading Program in the Clean Air Act Amendments. This was followed by a four-year lead-in period in which the U.S. EPA wrote implementing regulations using notice-and-comment rulemaking procedures that required extensive solicitation of public views, followed by the formal establishment of the emissions trading program. The U.S. program was built on an existing, well-established regime for environmental enforcement. Such a regime does not yet exist in the PRC.

Interestingly, the target set in the United States was approximately a 50 percent reduction in SO_2 emissions from baseline, similar to the cap established in Taiyuan (50 percent reduction from 2000 levels). However, in the case of the United States, the reduction was phased in over a longer period, with the majority of reductions scheduled for 2000—a full 10 years after the Clean

Air Act Amendments were signed into law and five years after the program was implemented, rather than over the three- to five-year period contemplated in Taiyuan.

Current conditions in the PRC also are quite different from those that existed historically in the United States. Using law to manage social problems is a relatively new development in China. Generally, throughout Chinese history, personal responsibility has been a more important motivator than the law. However, in recent years, there has been a proliferation of laws, including the legal framework under which an emissions trading program could operate. Many of the laws are written in broad terms and lack detailed guidance, and they have not been tested in practice. Due in part to this lack of detail, local environmental regulators still are struggling with basic issues of how to ensure compliance with environmental requirements and how to achieve regulatory independence. Many of the inherent conflicts of interest of a system in which state-owned industry is overseen by another arm of the state structure are present in the PRC.[28] At the same time, the country has only limited experience with markets for intangible commodities—a category that would include pollution credits.

A major milestone achieved during the period of this demonstration project was the promulgation by the Taiyuan city government of a regulation for the emissions trading program (October 2002). Although some controversial issues remain, such as the cap on penalties, Taiyuan's regulation is notable as the first comprehensive regulation of its kind in the PRC to support a cap-and-trade system on a city-wide basis. The numerous other achievements of the project include:

- Education of government and industry leadership about the benefits of adopting emissions trading;
- Establishment of an administrative framework to support the regulation;
- Development and demonstration of various computer-based tools to facilitate emissions monitoring and verification, and to manage the allowances (Emissions Tracking and Allowance Tracking Systems);

- Capacity building and training on the theory, practice, and management of emissions trading systems for both government and industry, including senior officials and technical and managerial staff; and
- Initial simulation of emissions trading among selected facilities.

The PRC's growing concerns about environmental health, combined with its enhanced financial and technical abilities to address these problems, give hope for future progress. Emissions trading is a particularly attractive option as cities such as Taiyuan increasingly look for options to enhance their environmental management systems and reduce emissions of SO_2 and other critical pollutants. Overall, the participants in the Taiyuan project believe that this work has succeeded in developing the foundation for effective and efficient SO_2 control in Taiyuan and in advancing the emissions trading model to a point that other areas of Shanxi Province can adopt it. High-level officials from Shanxi Province and representatives of the ADB expressed their support for the policy at a public meeting in Taiyuan in September 2003. They also indicated their intention to support continued development of the infrastructure for an effective emissions trading program. The latest indications are that the government is moving aggressively to assist enterprises with the acquisition of CEMs and certain control equipment—key features of an emissions trading program—with the assistance of international lenders. Whether and when this system becomes fully operational and how the inevitable "growing pains" of the system are resolved depend on the interplay of a complex set of local and national factors. What is clear, however, is that the seeds of change have been sown.[29, 30]

Endnotes

1. See P.N. Fernando, Aminul Huq, Piya Abeygunawardena, Robert Anderson, and Ricardo Barba, Emissions Trading in the Energy Sector: Opportunities for the People's Republic of China (Manila: Asian Development Bank, 1999).

2. The U.S. Environmental Protection Agency (EPA) provided extensive assistance in training and capacity building on the design and implementation of emissions trading programs. Key individuals involved in the project, in addition to the authors, are Stephanie Benkovic (EPA), Shawei Chen (formerly RFF), Melanie Dean (EPA), Joe Kruger (EPA), and Xuehua Zhang (formerly RFF). We express special thanks to Dan Millison (ADB), who participated as a consultant in the early phases of the project. The activities described herein were carried out from Mar. 2001–Sept. 2003.

3. See Xie Zhenhua, "Speech to the National Acid Rain and SO2 Comprehensive Control Conference," China Environment Yearbook (Beijing: China Environment Yearbook Press, 1998).

4. A regulatory change in late 2002 phased in new requirements for the use of levy funds. No longer will EPBs be funded with levy collections, nor will firms automatically receive a portion of their payments to use in financing pollution control projects. Rather, a competitive process will be used to allocate levy funds to firms.

5. Wang Hua and David Wheeler, "Endogenous Enforcement and the Effectiveness of China's Pollution Levy System," (Washington, DC: Development Research Group, World Bank, 2001).

6. Barbara A. Finamore, "Taming the Dragon Heads: Controlling Air Emissions from Power Plants in China," (Washington, DC: National Resources Defense Council, June 2000), http://www.efchina.org/documents/TamingtheDragonHeads.pdf.

7. For example, see contrary argument in "When Is Command and Control Efficient? Institutions, Technology, and the Comparative Efficiency of Alternative Regulatory Regimes for Environmental Protection," Wisconsin Law Review 5 (1999): 887, http://www.iulaw.indy.indiana.edu. See also "Toward a Total Cost Approach to Environmental Instrument Choice," in Research in Law and Economics, R. Zerbe and T. Swanson, eds. (Greenwich, CT: JAI Press, 2002).

8. Curtis Carlson, Dallas Burtraw, Maureen Cropper, and Karen Palmer, "SO2 Control by Electric Utilities: What Are the Gains from Trade?" Journal of Political Economy 108 (6): 1,292–1,326. See also Alan Carlin, "The United States Experience with Economic Incentives to Control Environmental Pollution," EPA Office of Policy Planning and Evaluation (EE-0216, July 1992), http://www.epa.gov/economics.

9. See, for example, Clifford S. Russell. and William J. Vaughan, "The Choice of Pollution Control Policy Instruments in Developing Countries: Arguments, Evidence and Suggestions," in International Yearbook of Environmental and Resource Economics 2003/2004, Henk Folmer and Tom Tietenberg, eds. (Cheltenham, UK: Edward Elgar, 2003); Ruth Greenspan Bell and C. Russell, "Ill-Considered Experiments: The Environmental Consensus and the Developing World," Harvard International Review (Winter 2003); Bell and Russell, "Environmental Policy for Developing Countries," Issues in Science and Technology (Spring 2002); reprinted in e-journal "Failsafe," June 17, 2002, http://www.felsef.org/summer02.htm#4b; also reprinted in Gloria E. Helfand and Peter Berck, eds., The Theory and Practice of Command and Control in Environmental Policy, International Library of Environmental Economics and Policy Series (Hampshire, UK: Ashgate Publishing,

2003). For an alternate view, see Joe Kruger, Katherine Grover, and Jeremy Schreifels, "Building Institutions to Address Air Pollution in Developing Countries: The Cap-and-trade Approach," OECD paper CCNM/GF/SD/ENV(2003)15/FINAL, 2002, http://www.oecd.org/dataoecd/11/25/2957736.pdf. Also see Jintian Yang and Jeremy Schreifels, "Implementing SO2 Emissions in China." OECD paper CCNM/GF/SD/ENV(2003)16/FINAL, 2002, http://www.oecd.org/dataoecd/11/23/2957744.pdf.

10. Air quality modeling is being conducted by the Norwegian Institute for Air Research, which also participated in this ADB-sponsored project.

11. In the formulation used here, these costs do not take into account the time of year that the emissions occur, the location of the source, stack height, or other parameters that might affect actual human exposures.

12. In the United States, for example, detailed engineering analysis of the control options available to one particular power plant revealed that the marginal abatement costs declined dramatically in the range of 70%–80% reductions. See Deck Leland, "Visibility at the Grand Canyon and the Navajo Generating Station," Economic Analyses at EPA: Assessing Regulatory Impact, Richard D. Morgenstern, ed. (Washington, D.C.: Resources for the Future, 1997), 267–302.

13. Harvard Institute for International Development, "Market-Based Instruments for Environmental Management in the People's Republic of China," paper submitted to the Asian Development Bank (TA No. 2951-PRC), May 1999.

14. Ibid.

15. One RMB (renminbi) or Chinese yuan (CNY) equals approximately US$0.12; 8.28 RMB equals US$1. The details of these calculations are available in Richard Morgenstern, "Inception Report for TA-3325," May 1999 (Contract No. COCS/00-685), submitted to the Asian Development Bank by Resources for the Future, June 2001.

16. The new Air Act was adopted at the 15th Meeting of the Standing Committee of the Ninth National People's Congress on April 29, 2000, promulgated by Order No. 32 of the President of the PRC on April 29, 2000, effective Sept. 1, 2000.

17. See "Key Aspects of the 2000 Amendments to the Air Pollution Prevention and Control Law of the People's Republic of China, Briefing for Corporate Counsel and EHS Managers," Beveridge & Diamond, 2001, http://www.bdlaw.com/publications.asp. The co-author of this briefing paper is the former chief environmental law drafter for the Chinese National People's Congress.

18. For example, the Taiyuan Coal Gasification Company planned to build a 26MW power station to burn low-quality coal (gangue) with 3 new 35-ton/hour fluidized furnaces. Even with dust removal treatment, an additional 660 tons/year of dust would be emitted, and the factory would exceed allowed emissions. Emissions exchange was required by Taiyuan to offset the new pollution. The new power station was required to supply heating to the Coal Separation Factory and the nearby Taiyuan Cement Factory, so that a 41-ton/hour boiler could be decommissioned resulting in a 298-ton/year reduction in dust.

19. A survey of small boilers subject to the closure requirements indicates quite dramatic reductions in SO2 emissions from these sources. See Richard Morgenstern, Alan Krupnick, and Xuehua Zhang, "The Ancillary Carbon Benefits of SO2 Reductions from a Small-Boiler Policy in Taiyuan, PRC," Journal of Environment and Development, forthcoming in 2004.

20. See Jinnan Wang, Jintian Yang, Stephanie Grumet, Jeremy Schreifels and Zhong Ma, eds., SO2 Emissions Trading Program: A Feasibility Study for China (Beijing: China Environment Press, 2002).

21. For a more complete discussion of the policy and administrative issues involved in designing the Taiyuan cap-and-trade system, see "Final Report of Shanxi Air Quality Improvement Project (TA-3325)" submitted to the Asian Development Bank by Resources for the Future, July 2003.

22. Dallas Burtraw, Karen L. Palmer, Ranjit Bharvirkar, and Anthony Paul, "The Effects of Allowance Allocation on the Cost of Carbon Dioxide Emissions Trading," Discussion Paper 01–30 (Washington, DC: Resources for the Future, August 2001).

23. The U.S. EPA and SEPA are working together to propose standards for the certification, installation, operation, maintenance, and calibration of CEMs.

24. See Table 2.

25. Chapter by Elizabeth Economy in this volume details China's environmental enforcement challenges.

26. For more information about the interaction between the pollution levy and emissions trading systems in China, see Denny A. Ellerman, "Designing an Emissions Trading System for the Control of SO2 Emissions in China," in SO2 Emissions Trading Program: A Feasibility Study for China, Wang Jinnan, Yang Jintian, Stephanie Benkovic, Jeremy Schreifels, and Zhong Ma, eds. (Beijing: China Environment Press, 2002).

27. For details on RECLAIM, see http://www.aqmd.gov/reclaim/reclaim.html. Information concerning the New Jersey case can be accessed through the U.S. Justice Department, United States v. PSEG Fossil LLC, D. N.J., No. 02CV340, 1/24/02.

28. In similar economies, such as those of the countries formerly composing the Soviet bloc, environmental regulators' lack of independence while part of the Soviet bloc significantly lessened their ability to enforce environmental requirements, particularly when environmental goals have collided with other important societal goals, such as production targets. The PRC has officially elevated the importance of environmental protection as a key component of its development strategy. The PRC also has demonstrated a willingness to invest state funds in pollution control projects and shut down unprofitable and polluting industries when necessary. Whether these efforts will be successful is yet to be seen.

29. For a debate on the prospects for emissions trading in the PRC in the foreseeable future, see Ruth Greenspan Bell, "Choosing Environmental Policy Instruments in the Real World," OECD paper CCNM/GF/SD/ENV(2003)10/FINAL, Aug. 23, 2003, http://www.oecd.org/dataoecd/11/9/2957706.pdf; and Joseph Kruger, Katherine Grover, and Jeremy Schreifels, "Building Institutions to Address Air Pollution in Developing Countries: The Cap-and-trade Approach." OECD Paper CCNM/GF/SD/ENV(2003)/16/FINAL, 2003, http://www.oecd.org/dataoecd/11/25/2957736.pdf.

30. Copies of the final report on the Shanxi Air Quality Improvement Project (TA-3325) can be obtained directly from the Asian Development Bank, www.adb.org.