policy

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Experience, Lessons, and Considerations for Greenhouse Gases

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PEW CENTER ON Global CLIMATE CHANGE

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Prepared for the Pew Center on Global Climate Change

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Foreword *Eileen Claussen, President, Pew Center on Global Climate Change*

In recent years, emissions trading has become an important element of programs to control air pollution. Experience indicates that an emissions trading program, if designed and implemented effectively, can achieve environmental goals faster and at lower costs than traditional command-and-control alternatives. Under such a program, emissions are capped but sources have the flexibility to find and apply the lowest-cost methods for reducing pollution. A cap-and-trade program is especially attractive for controlling global pollutants such as greenhouse gases because their warming effects are the same regardless of where they are emitted, the costs of reducing emissions vary widely by source, and the cap ensures that the environmental goal is attained.

Report authors Denny Ellerman and Paul Joskow of the Massachusetts Institute of Technology and David Harrison of National Economic Research Associates, Inc. review six diverse U.S. emissions trading programs, drawing general lessons for future applications and discussing considerations for controlling greenhouse gas emissions. The authors derive five key lessons from this experience. First, emissions trading has been successful in its major objective of lowering the cost of meeting emission reduction goals. Second, the use of emissions trading has enhanced—not compromised—the achievement of environmental goals. Third, emissions trading has worked best when the allowances or credits being traded are clearly defined and tradable without case-by-case certification. Fourth, banking has played an important role in improving the economic and environmental performance of emissions trading programs. Finally, while the initial allocation of allowances in cap-and-trade programs is important from a distributional perspective, the method of allocation generally does not impair the program's potential cost savings or environmental performance.

With growing Congressional interest in programs to address climate change—including the recent introduction of economy-wide cap-and-trade legislation controlling greenhouse gas emissions—the application of lessons learned from previous emissions trading programs is timely. In addition to this review, the Pew Center is simultaneously releasing a complementary report, *Designing a Mandatory Greenhouse Gas Reduction Program for the U.S.,* which examines additional options for designing a domestic climate change program.

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Executive Summary

Emissions trading has emerged over the last two decades as a popular policy tool for controlling air pollution. Indeed, most major air quality improvement initiatives in the United States now include emissions trading as a component of emissions control programs. The primary attraction of emissions trading is that a properly designed program provides a framework to meet emissions reduction goals at the lowest possible cost. It does so by giving emissions sources the flexibility to find and apply the lowest-cost methods for reducing pollution. Emission sources with low-cost compliance options have an incentive to reduce emissions more than they would under command-and-control regulation. By trading emission credits and allowances to high-cost compliance sources, which can then reduce emissions less, cost-effective emission reductions are achieved by both parties. When inter-temporal trading is allowed, sources can also reduce emissions early, accumulating credits or allowances that can be used for compliance in future periods if this reduces cumulative compliance costs. Accordingly, cap-and-trade programs achieve the greatest cost savings when the costs of controlling emissions vary widely across sources or over time. In practice, well-designed emissions trading programs also have achieved environmental goals more quickly and with greater confidence than more costly command-and-control alternatives.

Emissions trading has achieved prominence beyond the United States largely in the context of discussions regarding implementation of the Kyoto Protocol, a proposed international agreement to control emissions of carbon dioxide (CO_2) and other greenhouse gases. The Kyoto Protocol provides for the use of various emissions trading mechanisms at the international level. Some countries already are developing emissions trading programs while the process of ratifying the Protocol moves forward. Both the United Kingdom and Denmark have instituted greenhouse gas (GHG) emissions trading programs, and, in December 2002, the European environment ministers agreed on the ground rules for a European Union trading program that would begin in 2005 for large sources of CO_2 emissions (and later for other GHG emissions). Indeed, proposals to control GHG emissions in the United States also include the use of emissions trading.

The theoretical virtues of emissions trading have been recognized for many decades—the basic elements were outlined in Coase (1960) and elaborated in Dales (1968)—but actual emissions trading programs have been brought from the textbook to the policy arena mostly in the last decade. It is important to recognize, however, that while properly designed emissions trading programs can reduce the cost of meeting environmental goals, experience does not indicate that significant emissions reductions can be obtained without costs. Emissions trading can be an effective mechanism for controlling emissions by providing sources with the flexibility to select the lowest-cost opportunities for abatement, but it does not make costs disappear. Moreover, emissions trading programs must be designed properly in order to realize their potential cost-reduction and environmental compliance goals. As with any emissions control program, poor design is likely to lead to disappointing results.

Experience with emissions trading, including both the design and operation of trading programs, provides a number of general lessons for future applications. This report reviews the experience with six emissions trading programs with which one or more of the authors have considerable experience:

- The early Environmental Protection Agency (EPA) Emissions Trading programs that began in the late 1970s;
- The Lead Trading program for gasoline that was implemented in the 1980s;
- The Acid Rain program for electric industry sulfur dioxide (SO_2) emissions and the Los Angeles air basin (RECLAIM) programs for both nitrogen oxides (NO_X) and SO_2 emissions, all of which went into operation in the mid-1990s;
- The federal mobile source averaging, banking, and trading (ABT) programs that began in the early 1990s; and
- The Northeast NO_X Budget trading program, which began operations in the late 1990s.

Based on this experience, this report identifies and discusses five general lessons concerning the design and implementation of emissions trading programs, and two considerations of particular relevance for GHG applications.

General Lessons from Experience with Emissions Trading

Emissions trading has been successful in its major objective of lowering the cost of meeting emission reduction goals. Experience shows that properly designed emissions trading programs can reduce compliance costs significantly compared to command-and-control alternatives. While it is impossible to provide precise measures of cost savings compared to hypothetical control approaches that might have been applied, the available evidence suggests that the increased compliance flexibility of emissions trading yields costs savings of as much as 50 percent.

The use of emissions trading has enhanced—not compromised—the achievement of environmental goals. While some skeptics have suggested that emissions trading is a way of evading environmental requirements, experience to date with well-designed trading programs indicates that emissions trading helps achieve environmental goals in several ways.

For one thing, the achievement of required emission reductions has been accelerated when emission reduction requirements are phased-in and firms are able to bank emissions reduction credits. The Lead Trading program for gasoline, the Acid Rain program for the electric industry, the federal mobile source ABT programs, and the Northeast NO_X Budget programs each achieved environmental goals more quickly through these program design features. Moreover, giving firms with high abatement costs the flexibility to meet their compliance obligations by buying emissions allowances eliminates the rationale underlying requests for special exemptions from emissions regulations based on "hardship" and "high cost." The reduction of compliance costs has also led to instances of tighter emissions targets, in keeping with efforts to balance the costs and benefits of emissions reductions. Finally, properly designed emissions trading programs appear to provide other efficiency gains, such as greater incentives for innovation and improved emissions monitoring.

Emissions trading has worked best when allowances or credits being traded are clearly defined and tradable without case-by-case pre-certification. Several different types of emissions trading mechanisms have been implemented. Their performance has varied widely, and these variations illuminate the key features of emissions trading programs that are most likely to lead to significant cost savings while maintaining (or exceeding) environmental goals.

The term "emissions trading" is used, often very loosely, to refer to three different types of trading programs: (1) reduction credit trading, in which credits for emission reductions must be pre-certified relative to an emission standard before they can be traded; (2) emission rate averaging, in which credits and debits are certified automatically according to a set average emission rate; and (3) cap-and-trade programs, in which an overall cap is set, allowances (i.e., rights to emit a unit) equal to the cap are distributed, and sources subject to the cap are required to surrender an allowance for every unit (e.g., ton) they emit.

The turnaround in perception of emissions trading over the last decade—from a reputation as a theoretically attractive but largely impractical approach to its acceptance as a practical framework for meeting air quality goals in a cost-effective manner—largely reflects the increased use of averaging and cap-and-trade type programs. The performance of the early EPA reduction credit programs was very poor and gave "emissions trading" a bad name. These early EPA programs emphasized case-by-case pre-certification of emission reductions and were characterized by burdensome and time-consuming administrative approval processes that made trading difficult. The averaging and cap-and-trade programs have been much more successful. While the use of cap-and-trade or averaging does not guarantee success, and the problems with the reduction credit-based approach can be reduced by good design, avoiding high transaction costs associated with trade-by-trade administrative certification is critical to the success of an emissions trading program. The success of any emissions trading program also requires several additional elements: emissions levels must be readily measured, legal emissions rates or caps must be clearly specified, and compliance must be verified and enforced aggressively.

Banking has played an important role in improving the economic and environmental performance of emissions trading programs. Early advocates of emissions trading tended to emphasize gains from trading among participants (i.e., low-cost compliance sources selling credits and allowances to high-cost compliance sources) in the same time period. The experience with the programs reviewed here indicates that inter-temporal trading also has been important. The form that inter-temporal trading most often takes is credit or allowance banking, i.e., reducing emissions early and accumulating credits or allowances that can be used for compliance in future periods. Banking improves environmental performance and reduces cumulative compliance costs. Moreover, it has been particularly important in providing flexibility to deal with many uncertainties associated with an emissions trading market—production levels, compliance costs, and the many other factors that influence demand for credits or allowances. Indeed, the one major program without a substantial banking provision, the Los Angeles RECLAIM program, appears to have suffered because of its absence.

The initial allocation of allowances in cap-and-trade programs has shown that equity and political concerns can be addressed without impairing the cost savings from trading or the environmental performance of these programs. Because emissions allowances in cap-and-trade programs are valuable, their allocation has been perhaps the single most contentious issue in establishing the existing cap-and-trade programs. However, the ability to allocate this valuable commodity and thereby account for the economic impacts of new regulatory requirements has been an important means of attaining political support for more stringent emissions caps. Moreover, despite all the jockeying for allowance allotments through the political process, the allocations of allowances to firms in the major programs have not compromised environmental goals or cost savings. The three cap-and-trade programs that have been observed so far all have relied upon "grandfathering," i.e., distributing allowances without charge to sources based upon historical emissions information, which generally does not affect firms' choices regarding cost-effective emission reductions and thus the overall cost savings from emissions trading. There are other methods of allocating initial allowances—such as auctioning by the government and distributing on the basis of future information—that can affect cost savings and other overall impacts; but the major effects of the initial allocation are to distribute valuable assets in some manner and to provide effective compensation for the financial impacts of capping emissions on participating sources.

Considerations for Greenhouse Gas Control Programs

Emissions trading seems especially well-suited to be part of a program to control greenhouse gas emissions. The emissions trading programs reviewed for this report generally have spatial or temporal limitations because sources of the pollutants included in these programs—such as lead, SO_2, and NO_X—may have different environmental impacts depending on the sources' locations (e.g., upwind or downwind from population centers) and the time of the emissions (e.g., summer or winter). The concerns of trading programs associated with climate change are different because greenhouse gases are both uniformly mixed in the earth's atmosphere and long-lived. The effects of GHG emissions thus are the same regardless of where the source is located and when the emissions occur (within a broad time band). This means that emissions trading can be global in scope as well as inter-temporal, creating an opportunity for the banking of emission credits, which allows emissions to vary from year to year as long as an aggregate inter-temporal cap is achieved.

Emissions trading is also well suited for GHG emissions control because the costs of reducing emissions vary widely between individual greenhouse gases, sectors, and countries, and thus there are large potential gains from trade. While other market-based approaches, such as emissions taxes, also would provide for these cost savings, the cap-and-trade version of emissions trading has the further advantage of providing greater certainty that an emission target will be met. Moreover, GHG emissions generally can be measured using relatively inexpensive methods (e.g., fuel consumption and emission factors), rather than the expensive continuous emissions monitoring required for some existing trading programs.

Furthermore, emissions trading provides important incentives for low-cost compliance sources initially outside the program to find ways to participate, and thereby further reduce costs. This opt-in feature is useful because an environmentally and cost-effective solution for reducing concentrations of greenhouse gases should be comprehensive and global, whereas initial controls on GHG emissions will—for political reasons—likely be limited, if not to certain sectors and greenhouse gases, then almost certainly to a restricted number of countries. Therefore, an important criterion for initial measures is that they be able to induce participation by sources not yet controlled. The markets created by cap-and-trade programs provide incentives for sources outside the trading program to enter if they can provide reductions more cheaply than the market prices—a common feature of any market. Although, as discussed below, the voluntary nature of these incentives can create some problems, the ability to induce further participation is an important reason to include a market-based approach initially. Indeed, it is hard to imagine how command-and-control regulations or emissions taxes could provide similar incentives to non-participants to adopt new measures to reduce greenhouse gas emissions.

Opt-in or voluntary features have a strategic role that is likely to warrant their inclusion despite the potential problems associated with them. Experience with allowing sources not covered by mandatory emissions trading programs to "opt-in," i.e., to voluntarily assume emissions control obligations and to participate in the emissions market, has revealed a trade-off. Setting clear baselines for opting-in lowers transactions costs and thus encourages participation; but some of this participation consists of credits for calculated "reductions" that are unrelated to the trading program and actually lead to increased emissions. For example, in the Acid Rain Program, evidence indicates that many of the voluntary participants received credits for having emissions below the pre-specified baseline even though they took no abatement actions. The simple emissions baseline had been set higher than these facilities' actual emissions, so at least some of the credits they received did not represent real emissions reductions.

This experience suggests that the decision whether or not to include opt-in provisions should be determined by weighing the cost-saving benefits against the emissions-increasing potential. For greenhouse gases, the potential cost-savings benefits of including a voluntary element in the mandatory program are large because initial efforts are not likely to be comprehensive and global, as they must be eventually to achieve their environmental goals and be cost-effective. Opt-in provisions also have value in improving measurement and monitoring techniques, in familiarizing participants with the requirements of emissions trading, and more generally with inducing participation of sources outside the trading program that can offer cheaper abatement. As a result, allowing participants outside the mandatory GHG emissions control program to opt-in has a strategic value that has not been prominent in other opt-in programs. Indeed, it should be possible to learn from existing experience with opt-in programs how to reduce adverse effects while achieving cost-savings.

Viewed from a broad historical perspective, emissions trading has come a long way since the first theoretical insights forty years ago and the first tentative application almost a quarter of a century ago. Although still not the dominant form of controlling pollution in the United States or elsewhere, emissions trading is being included in an increasing number of programs and proposals throughout the world, and its role seems likely to expand in the future.

I. Introduction

Emissions trading is one of several market-based approaches that theoretically should improve the performance of regulatory regimes designed to improve air quality by giving sources the flexibility to achieve emissions constraints more cheaply than ***command-and-control*** *alternatives.* (Terms in bold are defined in the Glossary at the end of the report.) The other major approach to internalizing pollution externalities efficiently is to apply emissions fees (or "environmental taxes"), in which sources must pay a fee to the government for each unit of emissions they produce to reflect the emissions' social costs. There are obvious differences between these two types—emissions trading typically sets the emission target and leaves the market price of emission rights or **credits** to vary, while emissions taxes set prices and allow realized emissions to vary. Yet both approaches give firms the flexibility needed to achieve environmental goals in the most cost-effective manner.

The first full treatment of the emissions trading approach was in a small volume by John Dales published in 1968, although the basic concept can be traced to an article in 1960 by Ronald Coase. Over the last two decades, regulators have developed specific emissions trading programs that allow us to assess the performance of different program designs and draw lessons for the application of emissions trading to additional environmental problems, including the control of **greenhouse gases.**

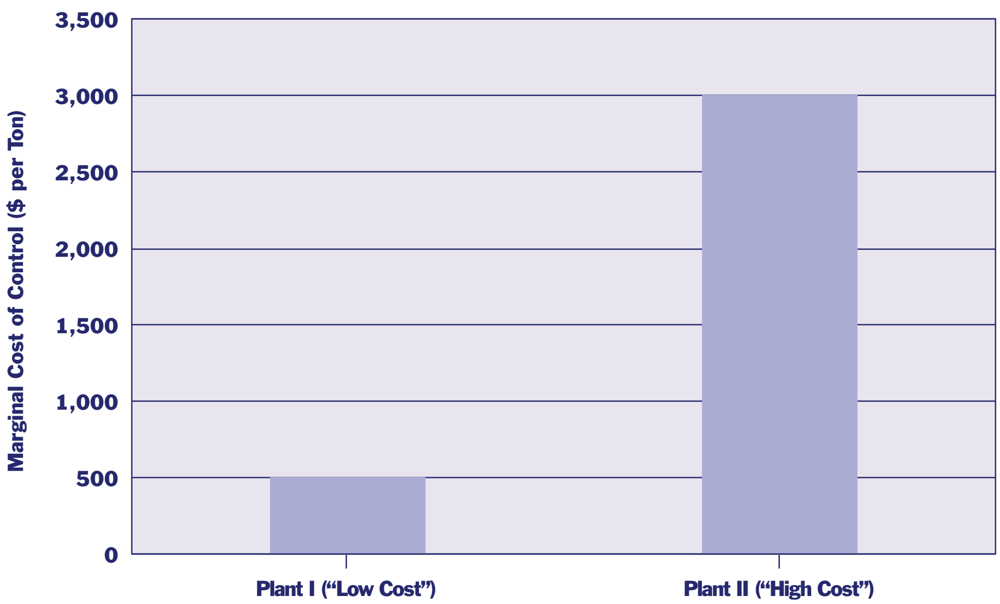
A. Overview of the Concept of Emissions Trading

The basic rationale for emissions trading is straightforward. By giving firms the flexibility to reallocate (trade) emissions credits or **allowances** among themselves, trading can reduce the compliance costs of achieving the emissions target.

A simple numerical example illustrates how emissions trading can reduce control costs relative to a traditional approach that is based upon setting uniform emissions standards (i.e., traditional command-and-control). Figure 1 illustrates a typical situation that could face facilities complying with a single uniform emission standard. In reducing emissions to meet the standard, Facility 1 incurs a cost of $500 for a ton of emissions reduced, while Facility 2 spends $3,000 for a ton reduced. These two facilities might be different plants within the same company, plants owned by different companies in the same sector, or plants in completely different sectors. The particular emissions standards that are compared to the trading approach might be based upon a common regulatory standard or on completely separate regulations.

Figure 1

Marginal Costs of Meeting a Hypothetical Standard at Two Plants



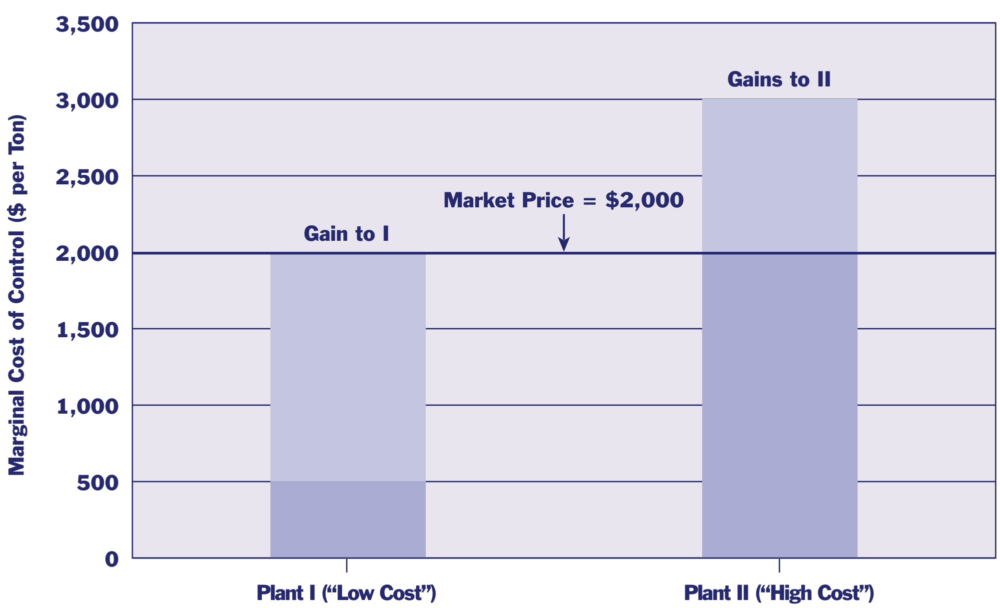
Clearly, the same overall reduction in emissions could be achieved at lower compliance costs by tightening controls at Plant I and relaxing them at Plant II. Initially, loosening controls at Plant II by one ton saves $3,000, whereas tightening controls by one ton at Plant I would raise costs by only $500, for a net savings in compliance costs of $2,500 per ton to achieve the same level of emissions. One way to achieve the cost savings would be to set different standards for the two sources, but such adjustments would be controversial (particularly if the facilities were competitors). Moreover, setting facility-specific standards would require that the government develop enormous amounts of facility-specific information to determine the cost-minimizing emissions reduction levels. These decisions are best left to the firms that operate these facilities, since they presumably have the best information about the costs of control alternatives and can use that information most effectively.

Emissions trading provides a means of achieving these cost savings without the need for regulators to collect such detailed compliance cost information for different sources. The two sources, knowing their own individual compliance costs, could trade emissions credits or allowances among themselves at the market price. Each source would compare its own emissions control costs with the market price and determine whether it is profitable to control more and sell allowances to others or to control less and buy allowances to cover the additional emissions. The trading mechanism allocates emissions reductions among sources in the most cost-effective manner, relying on individual information and self-interest—rather than administrative regulation—to determine compliance decisions by each individual source.

Suppose in the previous numerical example that the market price of an emissions credit or allowance was $2,000 per ton, and that the two facilities were **initially allocated** allowances consistent with the individual emissions levels required under the emissions standard. Figure 2 shows how each of the sources would gain from the market. Plant I (low-cost seller) gains by reducing its emissions further than the standard requires and selling the allowance it no longer needs to Plant II; it receives $2,000 for the allowance but pays only $500 to achieve the reduction, for a net gain of $1,500. On the other side of the transaction, Plant II (high-cost buyer) is able to buy the allowance for $2,000 and reduce its compliance costs by $3,000, for a net savings of $1,000. Thus the total savings in compliance costs of $2,500 per ton is split between the buyer and the seller, with both gaining from trading.

Figure 2

Gains to Plants from the Trade of a Single Emissions Allowance



This simple example illustrates both how emissions trading operates—through exchanges between buyers and sellers of the right to emit a ton—and the major cost-savings achieved. Although many details must be specified, the basic concept is the one illustrated in these two graphs.[1]

B. Three Basic Types of Emissions Trading Programs

*Three broad types of emissions trading programs have emerged: **reduction credit**, **averaging**, and **cap-and-trade** programs. Although all share the feature of tradability, the three differ in important respects.*

Reduction credit programs provide tradable credits to facilities that reduce emissions more than required by some pre-existing regulation (or other **baseline**) and allow those credits to be counted towards compliance by other facilities that would face high costs or other difficulties in meeting the regulatory requirements. (These programs sometimes are referred to simply as "credit-based.") Reduction credits are created through an administrative process in which the credits must be pre-certified before they can be traded.

Averaging programs also involve the offsetting of emissions from higher-emitting sources with lower emissions from other sources, so that the average emission *rate* achieves a predetermined level.[2] Like reduction credit programs, averaging programs provide flexibility to individual sources to meet emissions constraints by allowing differences from source-specific standards to be traded between sources. The primary difference between averaging and reduction credit programs is that reduction credits are created (or "certified") through an administrative process, whereas the certification is automatic in averaging programs.

Cap-and-trade programs operate on somewhat different principles. Under a cap-and-trade program, an aggregate cap on emissions is set that defines the total number of emissions "allowances," each of which provides its holder with the right to emit a unit (typically a ton) of emissions. The **permits** are initially allocated in some way, typically among existing sources. Each source covered by the program must hold permits to cover its emissions, with sources free to buy and sell permits from each other. In contrast to reduction credit programs—but similar to averaging programs—cap-and-trade programs do not require pre-certification of allowances; the allowances are certified when they are distributed initially. Also, cap-and-trade programs limit *total* emissions, a contrast to reduction credit and averaging programs that are not designed to cap emissions.

A trading program might include more than one type of trading mechanism. As discussed below, both the Acid Rain trading program and RECLAIM include reduction credit supplements to the basic cap-and-trade program. In addition, a cap-and-trade program might provide for **early reduction credits,** which allow firms to get credits for voluntarily reducing emissions prior to the introduction of a cap-and-trade program. The credits allocated can be used to meet requirements once the cap-and-trade program goes into force.

All three types of emissions trading rely on certain factors that constitute preconditions for a successful program. First and most importantly, all three forms assume that an emissions control requirement has been put in place that requires emissions to be reduced to levels below what they otherwise would be. For credit and averaging programs, the requirement will typically be a source-specific standard (e.g., a maximum emissions rate). In a cap-and-trade program the requirement will take the form of an aggregate cap on emissions combined with the provision that each source surrender allowances equal to its emissions. Second, the cost savings achieved by all three forms of trading depend upon variability in the costs of reducing emissions among emissions sources. Differences in emission control costs across emissions sources create the opportunity to reduce costs through trading. Finally, in all three types of trading programs, the requirements must be both enforceable and enforced. A corollary to this precondition is that there must be accurate measurement of actual emissions or emissions rates—otherwise it would be impossible to enforce the requirements because it would be impossible to determine whether sources were in compliance.

C. Other Features of Emissions Trading Programs

There are many features that must be specified in an emissions trading program, some of which do not apply to all of the three basic emissions trading types. The following is a list (derived from Harrison 1999a) that categorizes the major features of emissions trading programs into two major categories: design issues and implementation issues.

Design Issues. These include the decisions that arise as the program is designed and turned into a specific regulatory program.

Allocation of initial allowances. This issue is only relevant in cap-and-trade programs. Some method is required to distribute the initial allowances. Basic methods include various formulas to distribute initial allowances to participants on the basis of historical information ("**grandfathering**") or on the basis of updated information ("**updating**") as well as auctioning of the initial allowances.

Geographic or temporal flexibility or restrictions. This includes the possibility of restricting trades among different parts of the geographic range of the program (Tietenberg 1995). It also includes the possibility of **banking** (i.e., reducing emissions more than required in a given year and "banking" the surplus for future internal use or sale) or **borrowing** (i.e., reducing less than required in a given year and thus "borrowing," with the borrowed amount made up by reducing more than required in subsequent years).

Emission sources that are required or allowed to participate. This includes specification of the universe of sources that must participate in the trading program. It also includes the possibility of allowing additional sources to **opt-in** to the program.

Institutions established to facilitate trading. This includes the possibility of encouraging third parties (e.g., brokers) to participate in trading as well as the possibility of setting up an ongoing auction or other institutions to increase liquidity and establish market prices.

Implementation Issues. A number of decisions come into play as the program is implemented.

Certification of permits. This decision applies to reduction credit programs, which require that emission reductions be certified before they can be traded.

Monitoring and reporting of emissions. Methods must be designed to monitor and report emissions from each participating source (Tietenberg 2002).

Determining compliance and enforcing the trading program. These decisions relate to the means of determining whether sources are in compliance and enforcing the program if sources are out of compliance.

Maintaining and encouraging participation. This relates to decisions made to keep sources in the program and encourage participation of sources whose participation is optional (e.g., those given the opportunity to opt-in).

D. Objective and Organization of this Report

The principal objective of this paper is to draw upon the more than two decades of experience with emissions trading in the United States to provide lessons for future applications, including for climate change. The paper focuses on major U.S. domestic emissions trading programs—as they have actually been developed and implemented—and thus does not consider either the issues of setting up international trading programs or the lessons from nascent GHG emissions trading programs.[3] Because climate change is clearly a global issue, however, it is important to consider international dimensions in the design of domestic programs.

Table 1 summarizes the six major programs considered in this paper.[4] The six programs—which represent the bulk of existing experience with emissions trading—include examples of all three basic types. The U.S. EPA has administered most of the programs, although the programs include those administered by states and local air quality agencies as well. The range of experiences represented in these programs, which span about a quarter of a century, provide important insights into the factors that affect the economic and environmental performance of emissions trading in practice.

Table 1

Summary of Emissions Trading Programs

Program	Agency	Type	Emissions	Source	Scope	Year
EPA Emissions Trading Program	U.S. EPA	Reduction Credit, Averaging	Various	Stationary	U.S.	1979–Present
Lead-in-Gasoline	U.S. EPA	Averaging	Lead	Gasoline	U.S.	1982–87
Acid Rain Trading	U.S. EPA	Cap-and-Trade, Reduction Credit	SO_2	Electricity Generation	U.S.	1995–Present
RECLAIM	South Coast Air Quality Management District	Cap-and-Trade	NO_X, SO_2	Stationary	Los Angeles Basin	1994–Present
Averaging, Banking, and Trading (ABT)	U.S. EPA	Averaging	Various	Mobile	U.S.	1991–Present
Northeast NO_X Budget Trading	U.S. EPA, 12 states, and D.C.	Cap-and-Trade	NO_X	Stationary	Northeastern U.S.	1999–Present

The paper is organized as follows. Section II discusses experience with the principal emissions trading programs over the last quarter century, focusing on the experiences of the programs that provide significant lessons for future applications. Section III analyzes in detail the general lessons to be learned from these domestic emissions trading programs.[5] Section IV discusses special considerations that are relevant to the use of emissions trading to control GHG emissions. Section V provides concluding remarks.

II. Experience with Emissions Trading

This chapter introduces the major U.S. emissions trading programs implemented over the last two decades and the primary lessons to be learned from them.[6]

A. EPA Emissions Trading Programs (EPA ET)

*Starting in the mid-1970s, the U.S. EPA and the states developed four limited emissions trading programs to increase flexibility and reduce the costs of compliance with air emissions standards for **stationary sources** under the Clean Air Act.*

1. Netting. Netting allows large new sources and major modifications of existing sources to be exempted from otherwise applicable review procedures if existing emissions elsewhere in the same facility are reduced by a sufficient amount.

2. Offsets. The offset policy allows a major new source to locate in an area that does not attain a given **National Ambient Air Quality Standard**—a non-attainment area—if emissions from an existing source are reduced by at least as much as the new source would contribute (after installation of stringent controls).

3. Bubble. The bubble policy allows a firm to combine the limits for several different sources into one combined limit and to determine compliance based on that aggregate limit instead of from each source individually. The name alludes to an imaginary "bubble" placed over the several sources.

4. Banking. Under banking, firms that take actions to reduce emissions below the relevant standard can accumulate credits for future internal use or sale.

These four programs—collectively referred to as EPA Emissions Trading or EPA ET[7]—are related by the common objective of providing sources with flexibility to comply with traditional source-specific command-and-control standards while maintaining environmental objectives focused primarily on local air quality.

Reliance on these early EPA ET programs has been limited mostly as a result of implementing burdensome regulations that take up 47 pages of multi-column fine print in the *Federal Register*

(51 Federal Register 43814, September 1986). In general, the regulations have restricted substantially the applicability of the programs in response to regulatory concerns that the programs would compromise environmental objectives by encouraging "paper credits" or "anyway tons"—credits for emissions reductions that would have been made without the incentives provided by the emissions trading program. Credits must meet detailed criteria to be certified as eligible for trading. Offsets can only be used in certain geographic areas and any "trades" using them are not one-for-one, since the regulations require emissions reductions at the source providing the credit to be greater than the expected increase in emissions by the source using the credit. Potential applications of the bubble policy initially faced even greater hurdles because proposed bubbles had to be approved as revisions to an applicable State Implementation Plan (SIP), a lengthy administrative process that discouraged their use (U.S. Environmental Protection Agency 2001). These and other EPA regulations made efforts to identify and create trading opportunities expensive and uncertain.

The result of this process for creating and approving tradable credits, often called certification, is that the EPA ET programs have yielded relatively few trades and low cost savings relative to their potential (Hahn and Hester 1989). The combination of pre-approval requirements and the need to construct customized arrangements for each trade has created substantial transactions costs—often exceeding the market value of the credits.[8] These transaction costs—in effect the result of the lack of a well-defined and standardized commodity to be traded—have been the primary obstacle to more widespread participation in these programs.

The EPA ET programs constitute the first official recognition of the potential value of emissions trading, but the disappointing experience with these programs is the primary reason for the early reputation of emissions trading as a theoretically desirable but largely impractical concept.

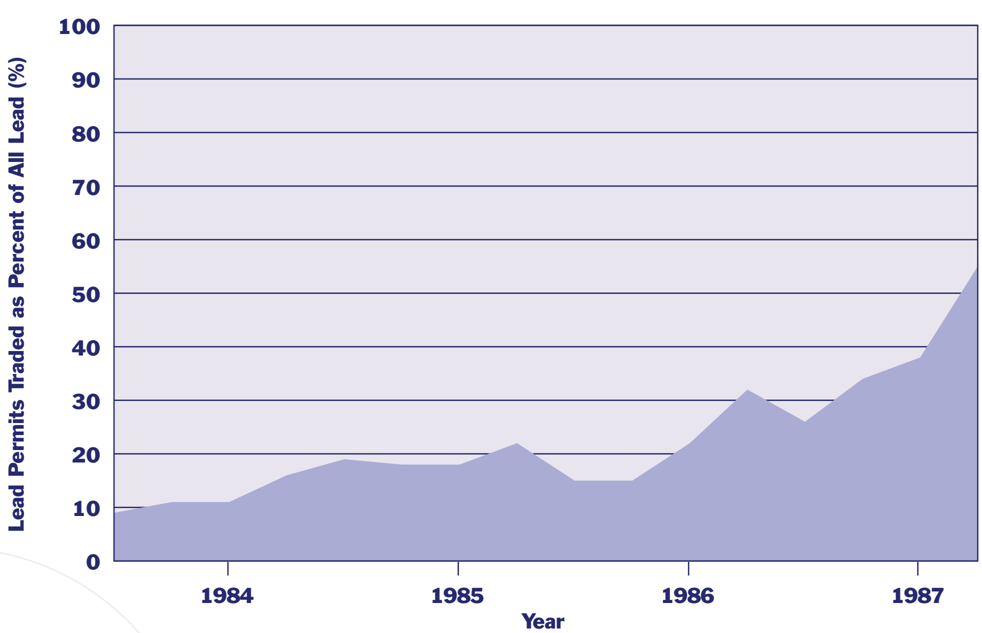
B. Lead-in-Gasoline Program

The averaging program used to regulate lead in gasoline during the mid-1980s provides an example of a much more successful trading program than the early EPA ET programs. The averaging program for lead grew out of EPA's efforts to reduce the lead content of gasoline starting in the early 1970s. Through 1982, lead limits were enforced on a refinery-by-refinery basis, with each refinery allowed to average lead concentration across its total gasoline production. In 1982, the rules were changed to allow trading across refineries and refining firms (47 Federal Register 49322). Under the new rules, a refinery could use lead in its gasoline above its usual limit if it purchased an equivalent number of rights from other refineries that had reduced their own lead content below their usual limits. It was possible to implement nationwide trading because the wide geographic distribution of gasoline from any given refinery removed the local concerns that had limited the scope of trading in the early EPA ET programs. In 1985, EPA promulgated a new rule to reduce the lead limit more than ten-fold in two phases: in mid-1985, from 1.1 grams per leaded gallon (gplg) to 0.5 gplg, and then, in January 1986, to 0.1 gplg (50 Federal Register 9400).[9] As part of this new phase-down rule, EPA allowed refiners to "bank" lead reductions: if they reduced ahead of schedule during 1985, they could save the excess rights for use or sale in 1986 and 1987.

The 1980s lead program is widely regarded as a success with respect to the initial trading opportunities permitted in the 1983–85 period and the addition of banking in the 1985–87 period. Figure 3 shows the development of the trading market for lead in gasoline. From mid-1983 (when the new rules took effect) until early 1985 (when the further phase-down began), an increasingly vigorous market in lead rights developed. In a typical quarter, over half of all refineries participated in the market, and up to one-fifth of the lead rights were traded. In 1985, when provisions for banking were added and the restrictions were tightened, an even larger fraction of lead was bought and sold on the market.

Figure 3

Lead Permits Traded as Percent of All Lead Emissions, 1983-1987



Source: Adapted from Hahn & Hester (1989, p. 387).

The banking components of the Lead Trading Program appear to have been particularly successful. The EPA had predicted that refiners would bank seven to nine thousand tons of lead, resulting in savings of up to $226 million (in 1985 dollars, discounted at a 10 percent real rate) over two and one-half years, or about 20 percent of the estimated cost of the rule over that period. Although no new estimates of the cost savings were made after banking occurred, the level of banking was even higher than predicted: refineries banked a total of 10.6 thousand tons, almost 17 percent higher than the upper end of the predicted range. Thus, it seems likely that the actual savings were higher than the EPA estimate. In addition, the use of banking led to a faster reduction in lead emissions than might otherwise have occurred.

The Lead Trading Program also marked an innovation in regulation by using the refinery-specific limit as the baseline for establishing credits without worrying about whether the lead content of gasoline from a specific refinery might have been lower anyway. This innovation avoided the need for case-by-case review to certify tradable credits. Differences between the refinery-specific average limits and the refinery's average lead content—and thus credits and debits—could be calculated easily. Monitoring for purposes of calculating credits and debits involved no additional costs beyond those required to enforce command-and-control requirements. This streamlining of the process for measuring compliance and certifying tradable credits has characterized all of the successful trading programs. In effect, the owners of refineries that reduced lead content below the average were automatically issued credits that could be used at other facilities.

Two additional conclusions may be drawn from the Lead Trading Program. First, the Lead Trading Program led to more efficient adoption of lead-reducing technologies by refiners (Kerr and Newell forthcoming). Second, banking introduced useful flexibility into the rapid phase-down in lead content scheduled for the last half of 1985. Refiners that reduced lead content ahead of schedule at one facility were able to receive automatic credit for use at other facilities, which could thereby undertake a slightly later phase-down. This flexibility reduced the costs and increased the speed with which the phase-out of lead in gasoline was achieved (U.S. Environmental Protection Agency 2001).

C. Acid Rain Trading Program

The largest, best-known, and most successful experience with emissions trading is the sulfur dioxide (SO_2) cap-and-trade program created by Title IV of the 1990 Clean Air Act Amendments. We will refer to this program as the Acid Rain Program. Two components of this program will be discussed in this report: the mandatory two-phase SO_2 cap with trading and banking that constitutes the core of the program, and the SO_2 opt-in provisions.[10]

Because of its large scale and high profile, the success of the Acid Rain Program has contributed more than anything else to the change in attitude towards emissions trading in the 1990s, and it is often cited as an example for other applications, including GHG emission reductions.

1. SO_2 Cap-and-Trade Provisions

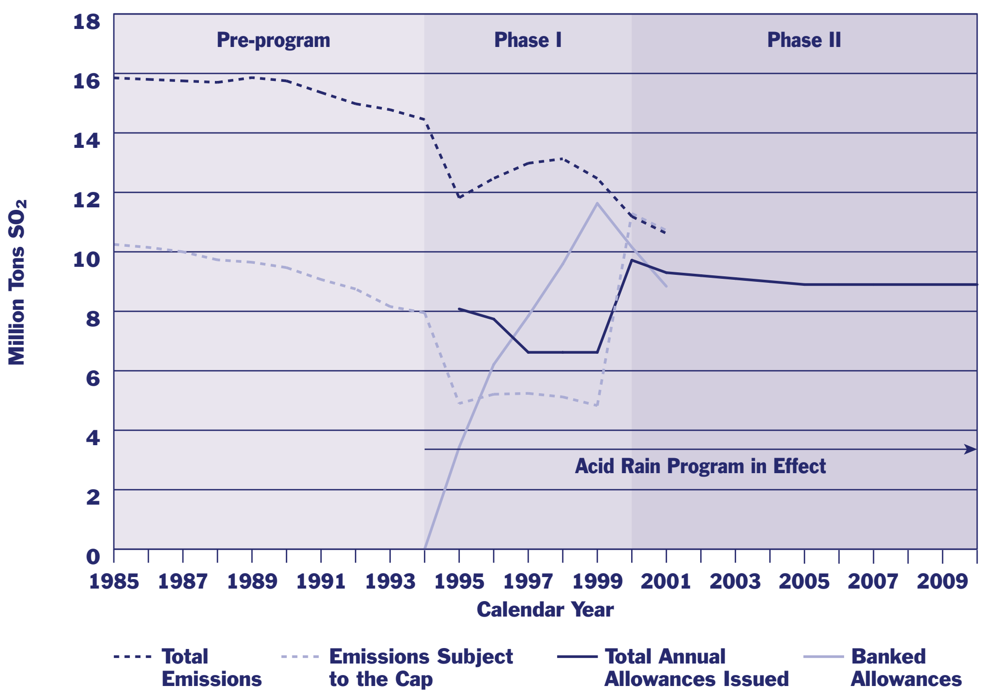
The Acid Rain Program created a national cap of roughly nine million tons of SO_2 emissions per year from electricity generating plants. The national target was to be achieved in two phases. During Phase I, lasting from 1995 through 1999, the 263 electricity generating units emitting the largest volume of SO_2 were subject to an interim cap that required projected average emissions from these units to be no greater than approximately 2.5 pounds of SO_2 per million Btu of **heat input.** In Phase II, beginning in 2000 and continuing indefinitely, the program was expanded to include virtually all fossil-fueled electricity generating facilities and to limit emissions from these facilities to a cap of approximately nine million tons—which implies an average emission rate of less than 1.2 pounds of SO_2 per million Btu. The final Phase II cap will eventually reduce total SO_2 emission from electricity generating units to about half of what they had been in the early 1980s.

This cap on national SO_2 emissions was implemented by issuing tradable allowances—representing the right to emit one ton of SO_2 emissions—equal to the total annual allowed emissions, and by requiring that the owners of all fossil fuel-fired electricity generating units surrender an allowance for every ton of SO_2 emissions. Allowances not used in the year for which they are allocated can be banked for future use or sale. These allowances are allocated to owners of affected units free of charge, generally in proportion to each unit's average annual heat input during the three-year baseline period, 1985–87. A small percentage (2.8 percent) of the allowances allocated to affected units are withheld for distribution through an annual auction conducted by the EPA to encourage trading and to ensure the availability of allowances for new generating units. The revenues from this auction are returned on a *pro rata* basis to the owners of the existing units from whose allocations the allowances are withheld.

Figure 4 illustrates the basic structure of the SO_2 cap-and-trade program and its performance. The figure portrays the two-phase structure of the SO_2 cap and its effects on emissions—both the subset of emissions from units affected in Phase I and total emissions from all units subsequently included in the program. It also shows the accumulation of the allowance bank in Phase I and the first two years of its draw down in Phase II.

Figure 4

Emissions, Allowances, and Banking Under the Acid Rain Program



Sources: U.S. EPA, 1995-2001; Pechan and Associates 1995; separation of Phase I unit emissions done by authors.

The solid dark blue line beginning in 1995 indicates the total number of allowances issued to generating units subject to the Acid Rain Program. The total is less during 1995–99 because only a subset of units, accounting for slightly more than half of national emissions, were affected during the transitional Phase I. The purple broken line plots emissions from the units subject to Title IV during Phase I from 1995 through 1999 and from all units for 2000 and 2001. The dark blue dotted line at the top indicates total emissions from *all* units, whether subject to Title IV in Phase I or not, from 1985 through 2000. The purple solid line represents the accumulated bank of unused allowances.

Since all units are subject to Title IV after 2000, the dark blue broken line and the purple broken line merge in this year. Eventually, this merged line representing total emissions will become equal with the solid dark blue line representing the cap, as the allowance bank—represented by the purple solid line—is drawn down. As the figure shows, this process began in 2000; until 2000, the number of banked allowances grew each year, but then began to be drawn down after the start of Phase II.

The most remarkable feature of Figure 4 is the striking reduction of SO_2 emissions in the first year of the program. Emissions had been falling steadily throughout the 1980s, even before Title IV was enacted, and they continued to fall at about the same rate during the first half of the 1990s.[11] But the reduction from 1994 to 1995 was far greater than anything that had been seen before, and there can be no doubt that it was caused by Title IV. The only precedent for such a rapid reduction in emissions of this magnitude in the history of the Clean Air Act is the lead phase-down program, which was also implemented by the use of emissions trading and banking.

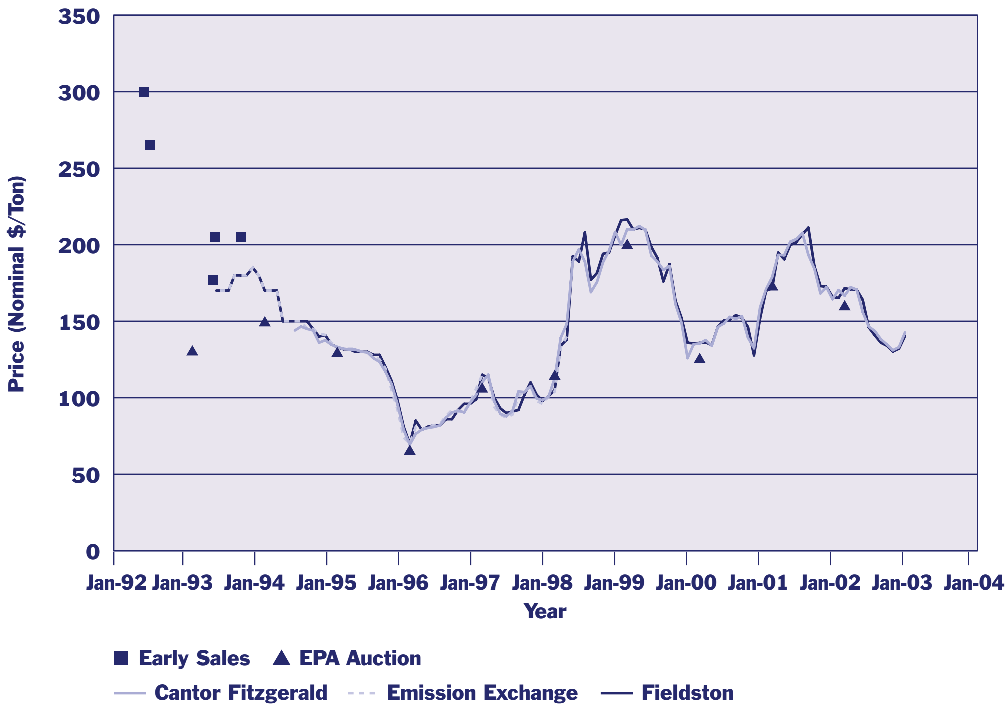
The reason for the remarkable reduction in emissions in 1995, when the allowable emissions for that year required only a small reduction in emissions, is the availability of "inter-temporal trading" in the form of banking. The prospect of higher marginal abatement costs after 2000 made abating more than required in Phase I an appealing option for smoothing the transition to the more demanding Phase II cap. As a result, the reduction in emissions experienced in Phase I was about twice what would have been required to bring emissions below the level allowed in these years.[12]

Inter-source or "spatial" trading also has been an important feature of the Acid Rain Program. Compliance data for each year shows that about one-third of the affected units in Phase I obtained allowances from other units, either by intra-firm transfers or through purchase in the allowance market, to cover emissions in excess of the allowances allocated to those units.[13] Spatial trading has allowed sources with high abatement costs to reduce emissions less—and those with low abatement costs to reduce emissions more—than under a command-and-control mechanism requiring uniform emissions rates, and thus has reduced the overall cost of the mandated emissions reduction.

The purchase and sale of allowances by the owners of affected units has created an active and efficient market for SO_2 allowances. This is evidenced by the single price for allowances at any one point in time regardless of the source of the price quote, by the high volume of inter-firm trades that can be deduced from the allowance registry maintained by EPA, by the low transactions costs associated with trading,[14] and by the development of an active and diverse contract and futures market. The EPA auction has also provided a transparent mechanism to reveal prices, which was very important in the early years when few private transactions were being reported. Figure 5 shows SO_2 allowance prices under the Acid Rain Program, beginning with early sales in 1992.

Figure 5

SO2 Allowance Prices 1993-2003



Source: Data compiled by authors from EPA auction results, periodic broker reports, and news items.

The cost savings due to emissions trading in the Acid Rain Program clearly are substantial. Table 2 summarizes estimates of cost savings developed by Ellerman et al. (2000) attributable to different types of trading, i.e., the savings due to spatial trading in Phase I, banking between Phases I and II, and spatial trading in the more stringent and comprehensive Phase II.[15]

Table 2

Abatement Cost and Cost Savings from Title IV Emissions Trading

			Cost Savings from Emissions Trading				
	Abatement Cost With Trading	Abatement Cost Without Trading	Phase I Spatial Trading	Banking	Phase II Spatial Trading	Total Cost Savings	Savings as a Percentage of Cost Without Trading
Average Phase I Year (1995–99)	735	1,093	358			358	33%
Average Phase II Year (2000–07)	1,400	3,682		167	2,115	2,282	62%
13-Year Sum	14,875	34,925	1,792	1,339	16,919	20,050	57%

Source: Adapted from Ellerman et al. (2000).

Note: All costs are in millions of present-value U.S. 1995 dollars. Estimates are based on economic reasoning assuming reasonably efficient markets based on observed allowance prices and abatement (as explained in chapter 10 of the source). A cost estimate is provided for only the first eight years of Phase II since this is the time period when most of the cost savings from banking were thought likely to be realized.

On average, spatial trading during Phase I reduced annual compliance costs by $358 million per year, a reduction of about 33 percent from the estimated cost of $1,093 million per year under a non-trading regime in which each affected unit limits emissions to the number of allowances received without any trading. During the first eight years of Phase II, the combination of spatial trading and banking is estimated to reduce annual compliance costs by about $2.3 billion per year, a reduction of over 60 percent from a total of about $3.7 billion per year. Over the first 13 years of the program, the ability to trade allowances nationwide across affected units and through time is estimated to reduce compliance costs by a total of $20 billion, a cost reduction of about 57 percent from the assumed command-and-control alternative. This percentage cost saving is similar to that developed by other researchers,[16] although it is less than the percentage cost savings sometimes claimed for emissions trading programs, including the Title IV SO_2 cap-and-trade program.[17]

There are several reasons why the Acid Rain Program has been successful. Of critical importance is the absence of any requirement for regulatory pre-approval of individual trades. Like the Lead Trading Program, the SO_2 program dispensed with the restrictions and cumbersome bureaucracy that characterized the EPA ET program. The lead program took the first step in avoiding the costly process of verifying credits for every transaction by allowing for an automatic crediting of differences from an agreed-upon baseline. Title IV took the further steps of explicitly recognizing the right to emit[18] (albeit at a reduced quantity) and then determining compliance based on an account of *all* emissions, not just the differences from the agreed-upon baseline. These further steps changed the nature of the item traded from an emission reduction, which depends on an agreed upon and non-observable baseline, to emissions that are actually measured—in this case using a **continuous emissions monitoring system** (CEMS). As was also the case in the Lead Trading Program, the reduced importance of location and timing of emissions facilitated the simpler procedures that made emissions trading successful. In both cases, the reduction in aggregate, cumulative emissions was more important than the precise pattern of reductions at individual sources. Both programs also built in flexibility in the timing of emissions reductions by allowing for banking.

The requirement to verify actual SO_2 emissions using CEMS played an important role in gaining support for the trading program and in its ultimate success. Any trading program must have an accurate method for measuring emissions so that the requirement that all emissions be matched by surrendering an equal number of allowances can be enforced. The only significant issue concerning CEMS was whether less costly alternatives would have provided equivalent measurement accuracy. CEMS added about seven percent to total Phase I compliance costs, and a less costly "materials balance" method could provide equally accurate estimates of total emissions.[19] However, environmental groups doubted the accuracy of the latter method, and negotiations and disputes with regulators over its application might well have increased transactions costs or undermined the credibility of the program (Ellerman et al. 2000).

The explicit "free" grant of allowances to the owners of affected units in the SO_2 program was another innovation in emissions trading. Since allowances have value that can be readily realized by trading, the grant of these allowances endowed the recipients with a lump-sum transfer payment. Because the allowances were granted rather than sold, and were based upon historical data rather than contemporaneous or future data, the allowances are said to be grandfathered.[20] When Title IV was enacted, this initial allocation of allowances through grants based on historical activity was not especially controversial. Since then, the method for allocating allowances for new cap-and-trade programs, especially whether the initial allocation should be through grants or auctions, has become more controversial. The issue of how to distribute the allowances created by a cap-and-trade program has inspired a rich literature exploring the welfare, efficiency, and equity implications of various methods of granting or auctioning the allowances, and, in the case of auctions, of how revenues are recycled.[21]

From the perspective of the performance of the program, i.e., the cost of reducing emissions and the speed with which they were reduced, there is no credible evidence that the initial allocations had any significant effects. This is the case because the allocation process was structured so that the number of allowances a source received was independent of its future output and its future emissions.[22] Any lump sum allocation process will not distort future output and emissions decisions and will not inhibit the performance of the program. Of course, since allowances were potentially valuable assets there was substantial political maneuvering regarding how the lump sum distributions would be made (Joskow and Schmalensee 1998). It is difficult to tell how the distribution of the valuable allowances among units compares to the distribution of the costs among units subject to the cap.

Notwithstanding its success, the SO_2 cap-and-trade program was not perfect, and it is unlikely that the full potential cost savings of an ideal "textbook" program design have been realized in practice (Carlson et al. 2000). It took time for the allowance markets to develop and mature. The fact that initially the emissions sources were primarily regulated utilities may have reduced incentives to trade and slowed the development of efficient markets. Phasing in sources subject to the program complicated the program's administration and also lessened the achievement of the emissions reduction goals (McLean 1997).[23] In particular, some misuse occurred as a result of the opt-in features of the program, which is discussed in the next section. Despite these caveats, it seems safe to conclude that the major economic and environmental promises of the SO_2 cap-and-trade program have been realized.

2. Opt-in Features of the SO_2 Trading Program

The opt-in features of the SO_2 cap-and-trade program demonstrate two major points: (1) participation in opt-in programs can be considerable; and (2) these opt-in programs can detract from the achievement of the program's environmental goals. The Acid Rain Program had two principal **voluntary** features.[24] One opt-in component allowed generating units not subject to Title IV until Phase II to receive allowances and to be subject to emission coverage requirements in Phase I. A second opt-in component allowed industrial sources of SO_2 emissions not otherwise subject to Title IV to receive allowances and to be subject to emission coverage requirements in Phase I or II. The provisions applying to electricity generating units were extensively used, with approximately 30 percent of eligible sources participating;[25] but the industrial opt-in provisions were little utilized. The experience with these two opt-in programs says much about the motivations behind voluntary participation and the problems that it may create.

The high participation rate in the opt-in program by electric utilities was encouraged by several factors. First, virtually all of the Phase II units eligible for opting-in were owned by utilities that were already incurring the overhead costs of dealing with the Acid Rain Program's requirements because they owned units required to be a part of Phase I. Second, the transaction costs of monitoring and reporting emissions were already being incurred because electric utilities were required to install CEMS on all units subject to the Acid Rain Program and to report emissions from those units beginning in 1995 regardless of whether the unit was required to be in Phase I or not. Finally, the owners of eligible units knew beforehand how many allowances they would receive since this had been clearly defined in earlier regulations. Unlike the EPA ET programs, the transaction costs were low for any electricity generating units eligible for opt-in participation in the Acid Rain Program. This made the theoretical flexibility provided by the opt-in provisions a realistic option to allow affected sources to reduce the costs of complying with the emissions caps.

In contrast, industrial facilities that might opt-in would need to establish an inventory and baseline and incur the costs of monitoring emissions and participating in the program. As Atkeson (1997) points out, these transaction costs explain the absence of industrial opt-ins. The circumstances of the few that did opt-in emphasize the importance of transactions costs: all industrial opt-in facilities involved an electric utility that was already participating in the program and all facilities had either already installed CEMS equipment or would not be required to do so because the industrial source was being replaced by an electric utility unit.

The ease with which Phase II units could choose to opt-in to Phase I was not without some potential environmental costs. In principle, units opting-in were to be given allowances equal to their emissions had they not opted-in. In practice, projecting hypothetical emissions was difficult because of the time that had elapsed between the determination of the baseline and the receipt of the allowances. One major problem was that trends in coal markets were causing many units to switch to lower sulfur coal anyway. Instead of only those facilities with low abatement costs choosing to opt-in, opting-in became attractive for facilities whose emissions would have fallen below the baseline levels anyway without the additional reductions required by Title IV. In such cases, the difference between the defined baselines and actual emissions created "anyway emissions reductions" and an associated incentive to opt-in to Phase I to obtain valuable allowances that would not be required to cover actual emissions.[26]

Determining baseline allowances for opt-in units was by far the most contentious issue in the implementation of Title IV. As a result of litigation, allocations to opt-in units were reduced, but this did not eliminate the baseline problem. As shown in the careful and detailed analysis conducted by Montero (1999),[27] the units most likely to volunteer were those whose expected emissions were lower than the baseline. Indeed, Montero finds that "baseline errors" were the most significant factor affecting utility decisions to opt-in under the voluntary provisions. As he points out, the problem is a classic one of asymmetric information in which the owners of the units opting-in know more about emissions trends than the regulator.

Although the increase in emissions due to the voluntary component of the program needs to be acknowledged, its magnitude in this case also should be put in perspective. Montero estimates that the effect on emissions was tiny. "Anyway emissions reductions" accounted for less than two percent of total emissions over the first ten years of Phase II, the period in which these extra allowances would be used.

A comparison of the experience with the voluntary components of the Acid Rain Program and the EPA ET programs suggests opt-in programs have both potential benefits and potential costs. Effective program design must face an unavoidable tradeoff. Simple rules and clearly specified baselines reduce certification costs greatly and thereby encourage voluntary participation and real reductions that reduce costs. But these simple rules may also result in paper credits that can detract from the achievement of the environmental goal. Paper credits can be avoided by requiring elaborate case-by-case determinations of what emissions would be; but the costs of case-by-case certification can discourage participation to such an extent that no cost savings are achieved. Accordingly, the design of opt-in programs should be sensitive to both the potential cost savings and the potential for adverse selection and should carefully consider the likely costs and benefits in specific cases.

D. Los Angeles Air Basin RECLAIM Program

Regulators in the Los Angeles air basin were developing another prominent cap-and-trade program in the early 1990s at the same time that the Acid Rain Program was being developed. This program, called the Regional Clean Air Incentives Market (RECLAIM), was significant both in some of its provisions and as the first major example of a tradable permit program developed by a local jurisdiction rather than a federal authority.

The South Coast Air Quality Management District (SCAQMD) approved the RECLAIM program in October 1993 after a three-year development process, and the program began operation in January 1994 (South Coast Air Quality Management District 1993). RECLAIM was developed as an alternative means of achieving the emission reductions of NO_X and SO_2 mandated by a set of command-and-control measures in the 1991 Air Quality Management Plan to bring the Los Angeles Basin into compliance with National Ambient Air Quality Standards. Under RECLAIM, the caps for both NO_X and SO_2 were set higher than expected emissions in the initial years, but the overall caps were reduced steadily over time so that, by 2003, emissions from sources emitting more than four tons of either pollutant would be reduced to about 50 percent below early-1990s emission levels. From 2003 on, the caps would remain constant.

Several features of the design of the RECLAIM program distinguish it from the Acid Rain and Lead Trading Programs. First, a heterogeneous group of participants is covered by the program, including power plants, refineries, cement factories, and other industrial sources. Second, the RECLAIM program distinguishes between emissions in two geographic zones.[28] Since emissions in the Los Angeles Basin generally drift inland from the coast, sources located in the inland zone were allowed to use RECLAIM Trading Credits (RTCs) issued for facilities in either the inland or coastal zones, but sources located in the coastal zone could use only RTCs issued for facilities in the coastal zone. A third distinctive feature of the RECLAIM program is that it does not allow banking because of concerns that the ability to use banked emissions might lead to substantial increases in actual emissions in some future year, and thus delay compliance with ambient air quality standards. RECLAIM does provide limited temporal flexibility, however, by grouping sources into two 12-month reporting periods, one from January through December and the other from July through June, and by allowing trading between sources in overlapping periods.

The initial allocation of RTCs was the most contentious part of the planning process, although eventually an allocation plan acceptable to the wide range of affected facilities was developed (Harrison 1999a). As was the case with the Acid Rain Program, RTCs were allocated free to incumbents and distributed many years prior to when they could be used for compliance.[29] The final set of formulas for allocating RTCs departed considerably from the simple formula initially proposed by the SCAQMD, and it was the result of literally dozens of proposals, many of which were exhaustively studied by the SCAQMD (and no doubt by the affected firms as well). Despite threats by several firms and sectors to oppose the program if their formulas were not chosen, the final result was an administratively feasible and politically viable cap-and-trade program.

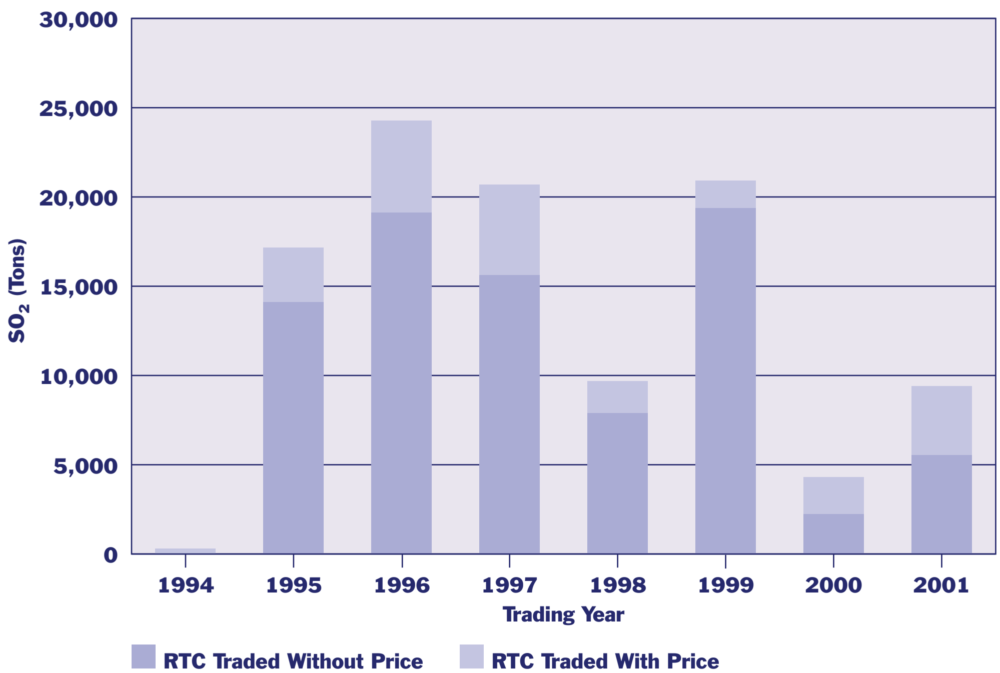
Experience in the first eight years of RECLAIM has been more mixed than in the Acid Rain and Lead Trading Programs. As with those programs, markets for the trading of credits and allowances appeared quickly and the volumes traded have been significant. However, unlike those programs, the NO_X component of the RECLAIM program has run into substantial difficulties. In late 2000 and early 2001, NO_X RTC credit prices rose to extraordinarily high levels primarily as a result of increased demand. The increase in RECLAIM NO_X prices was a significant contributing factor to the dramatic increase in California wholesale electricity spot market prices during 2000 (Joskow 2001; Joskow and Kahn 2002). As a result of these circumstances, NO_X emissions exceeded the cap for 2000 by about six percent. These events provoked major changes to RECLAIM that have in effect suspended participation by electricity generators and returned the control of emissions at least temporarily to a command-and-control program. Since difficulties and not only successes generate lessons, as seen with the opt-in aspects of the Acid Rain Program, we make a considerable effort to explain these developments in the RECLAIM NO_X program. First, however, we turn to the trading experience with both NO_X and SO_2 RTCs prior to and during California's electricity crisis in 2000–01.

Figure 6 and Figure 7 show the volume of trading in SO_2 and NO_X RTCs over the first eight years of RECLAIM. The figures show the number of RTCs of all **vintages** "traded" internally among different sources owned by the same firm (i.e., without a price), as well as the number of RTCs traded between firms at various prices. As of the end of 2001, RTC permits for over 300,000 tons of NO_X and over

100,000 tons of SO_2 had been traded. Since the aggregate NO_X and SO_2 caps were non-binding in the first few years of the program, and because the volumes traded in virtually every year exceed that year's cap (often by several multiples), the presumption is that most of these trades are in future vintages.[30] Moreover, the trend of decreased trading over time, especially for NO_X, suggests that future vintages were bought, sold, and transferred ahead of time, in keeping with plans to install the required abatement equipment to meet the final cap in 2003 and thereafter.

Figure 6

SO_2 Trading Volume Under RECLAIM (Including Future Vintages), 1994-2001

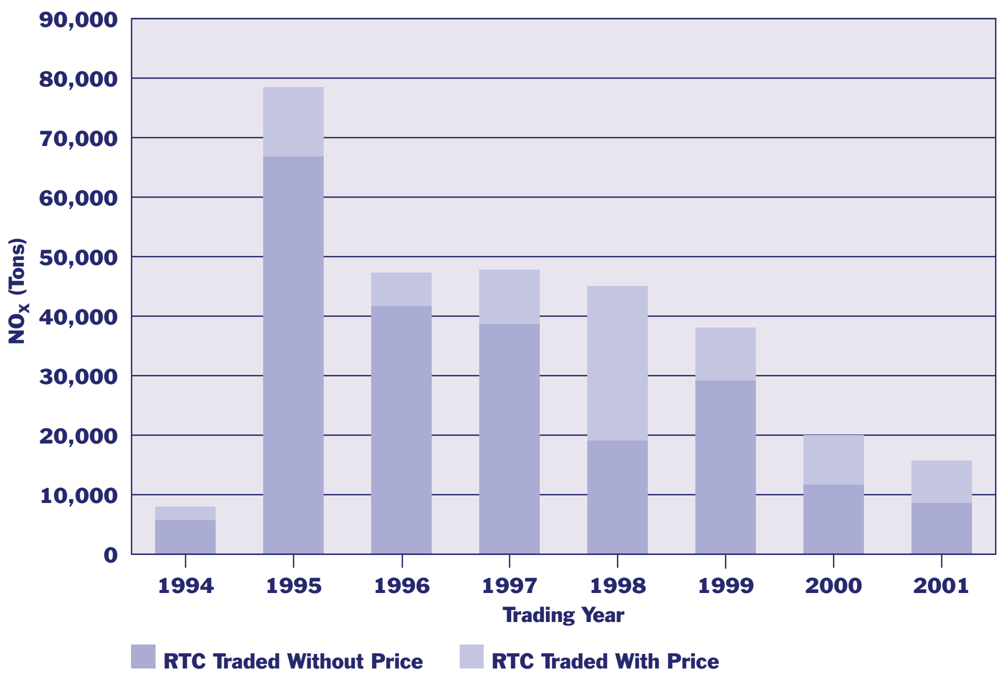


Source: South Coast Air Quality Management District (2002).

Although most of the trading has occurred within firms, the volume of external trades among firms has been significant measured against the annual volume of current or post-2003 vintages. Numerous brokers and other intermediaries have emerged to facilitate these trades and to provide other services to participants, such as pricing information and derivatives to manage price risk. Transaction costs have been relatively low and there can be no doubt that RECLAIM markets have been active. The adequacy of these markets was affirmed by the rejection of a proposal in 2002 to require the use of a centralized market for all RTC transactions. The SCAQMD ruled that there was no evidence that the existing system of bilateral transactions was not working sufficiently well to provide efficient markets for RTCs of both current and future vintages (South Coast Air Quality Management District 2002).

Figure 7

NO_X Trading Volume Under RECLAIM (Including Future Vintages), 1994-2001



Source: South Coast Air Quality Management District (2002).

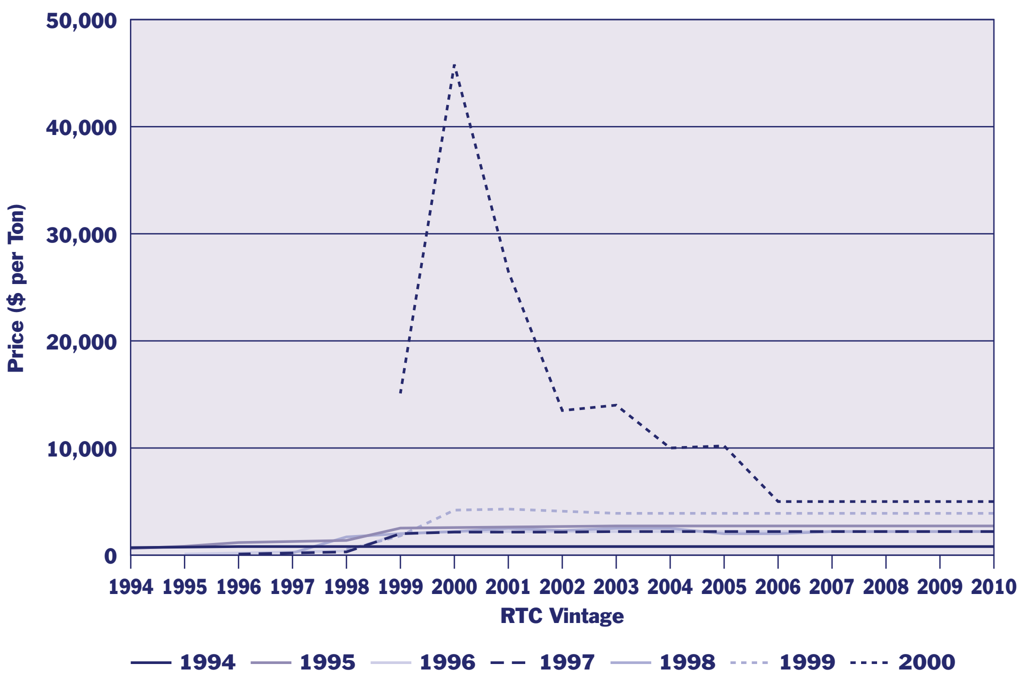
RECLAIM required that the largest sources use CEMS—like the SO_2 cap-and-trade program—to verify their emissions as a means of providing assurance that the data were valid. When the program first was implemented, there were technical difficulties with some of the CEMS and some facilities could not rely upon CEMS data for all of their submissions (South Coast Air Quality Management District 1998).[31] These difficulties prompted requests that the large sources be allowed to use the less expensive monitoring options allowed for smaller sources, a request that was denied by program administrators. Eventually the technical difficulties with these CEMS were overcome and virtually all of the emissions data from large sources now are based upon the CEMS information. As with the SO_2 program, although CEMS are expensive, their use in RECLAIM ultimately may reduce transaction costs by reducing the perceived need for the more costly review of emissions data.

The high volume of trading in the RECLAIM program implies significant cost savings relative to the command-and-control alternative that it replaced, but no *ex post* estimates of these cost savings have been made. When the program was being developed, cost savings were estimated to be about 40 percent compared to the cost of achieving the same emission levels using the traditional command-and-control approach (see Harrison and Nichols 1992 and Johnson and Pekelney 1996).

The difficulties experienced by the RECLAIM program in 2000 centered around the NO_X market, and the problem manifested itself most visibly in the dramatic spike in the price of NO_X RTCs in the year 2000 for vintages of this year and those surrounding it, as shown in Figure 8.

Figure 8

Average NO_X RTC Prices



Source: South Coast Air Quality Management District (2001b).

The horizontal axis in Figure 8 represents the vintage, i.e., the year in which the RTC can be used, and the lines in the graph show the average prices for current and future vintages in successive calendar years. Thus, the lines show the forward prices for the current and future vintages in each calendar year. The purple broken line representing 1999 in Figure 8, for example, indicates that the price in 1999 of the current 1999 vintage is substantially lower than the 1999 prices of future vintages (2000, 2001, 2002, etc.), which are about equal. In addition, between 1994 and 1998, the prices of all NO_X RTC vintages remained relatively stable, ranging from $1,500 to $3,000 per ton. In year 2000, the prices for all "near-term" vintages of allowances jumped significantly (the peak of the top dark blue broken line in the figure), with the largest price increase exhibited for the 2000 vintage allowances, tapering off quickly for later vintages.[32] The price for year 2000 NO_X RTCs increased from an average of $4,284 per ton for trades in 1999 to almost $45,000 per ton for trades in 2000 (comparing the "1999" line with the "2000" line). The average price of 2000 vintage NO_X RTCs reached in the peak month in 2000 was more than $70,000 per ton, with the highest single price reported equal to more than $90,000 per ton. The price increases—in 2000, relative to 1999—for 2001 and later vintage allowances (the points on the top line) were smaller and taper off for farther-out vintages.

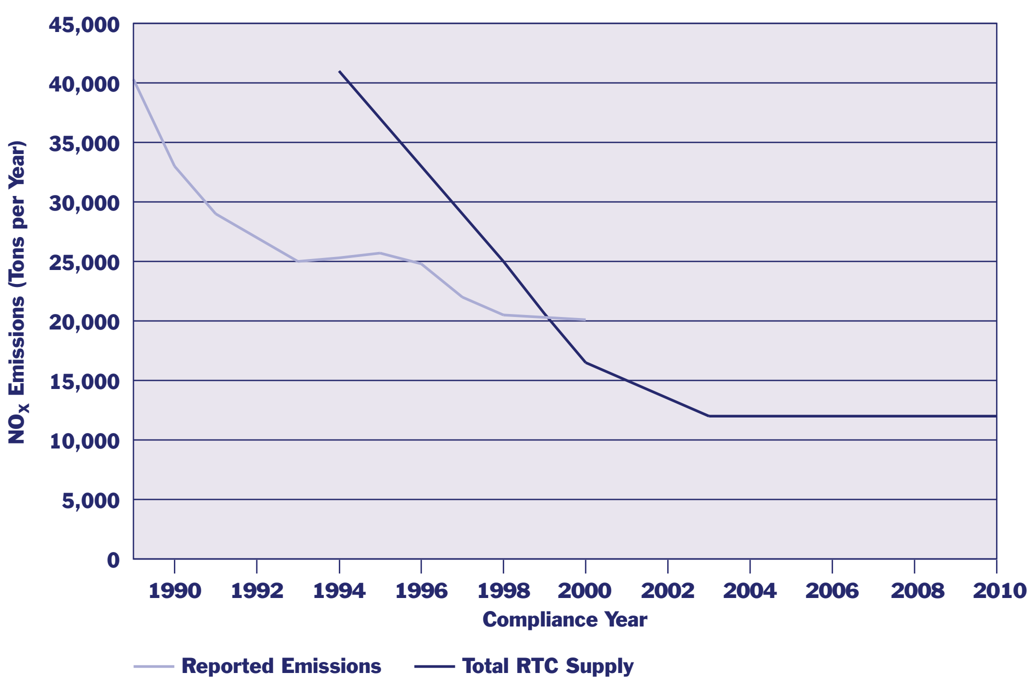
This dramatic increase in the cost of NO_X RTCs in the summer of 2000 was caused by a substantial increase in the demand for RTCs on the part of electricity generators. The demand for electricity soared in California during the summer of 2000 while the availability of imported power from other states declined (Joskow 2001). The increased demand had to be met by running the large fleet of old in-state gas-fired generating facilities more intensively than in the recent past. Few of these old plants had yet installed NO_X emissions controls and no new plants were completed until the summer of 2001. As a result, the demand for NO_X RTCs and their prices increased significantly during summer 2000 as generation from the in-state gas fired power plants increased to balance supply and demand. Indeed, as Joskow and Kahn (2002) show, the high price for NO_X RTCs was one of several factors leading to the high wholesale electricity prices in California during that period.[33]

In response to the price spikes for NO_X RTCs—along with the breach of the cap and the price spikes for electricity linked in part to high NO_X prices—electricity generating plants were removed from the RECLAIM program, at least temporarily, in May 2001 (South Coast Air Quality Management District 2001a). The electricity generators were allowed to pay a mitigation fee of $15,000 per ton when they exceeded their caps—with fee revenues used to pay for emission reductions elsewhere—and were placed temporarily under an alternative command-and-control regulatory regime. Thus, an unfortunate outgrowth of the California electricity crisis was the abandonment—at least temporarily—of the use of a successful cap-and-trade program to control electric power emissions.

What lessons can be learned from the problems that emerged in 2000 and the responses to them? With regard to lessons for the environmental performance of RECLAIM, Figure 9 shows the evolution of the annual NO_X cap from 1994 and reported NO_X emissions since 1989. The increase in demand on electric generating units in 2000 caused emissions to exceed the 2000 cap by about 3,000 tons, or 20 percent; however, the use of allowances from the overlapping 1999 and 2001 cycles reduced the shortfall between NO_X emissions and RTCs to 1,110 tons, or about six percent of the 2000 cap, a modest increase given the extraordinary circumstances in 2000. In addition, as noted, the mitigation fees paid by electricity generators are to be used to reduce emissions from other sources and, in any event, the shortfall in emissions will be reflected in decreased future NO_X RTC allocations. Thus, the net effect on NO_X emissions of the increase in demand in 2000 for NO_X allowances is largely to shift a small number of NO_X emissions reductions to future years. Moreover, there is no reason to believe that a command-and-control alternative would have performed better under the circumstances. Indeed, since command-and-control mandates typically regulate emission *rates*—rather than overall emissions—this alternative would likely have resulted in the same emissions increases but without the compensating measures taken as a result of exceeding the RECLAIM NO_X cap.

Figure 9

NO_X Emissions and Available RTCs



Source: South Coast Air Quality Management District (2002).

Perhaps the most important lesson from the 2000 experience with RECLAIM is that the “problems” were due primarily to flaws in California’s newly deregulated electricity markets rather than to serious flaws in the RECLAIM program itself. The RECLAIM trading regime operated largely as it should have. Demand for NO_X RTCs increased, their supply decreased and their prices increased as expected, and the prices of an important product (electricity) that required NO_X credits also increased.[34] This should have provided signals to affected sources to invest in emissions controls, as well as signals to consumers to reduce consumption of electricity. Had the structure of California's electricity industry remained composed of regulated monopolies, or if the transition to new competitive market structures had been done more competently and with greater sensitivity to the interactions between NO_X RTC prices and spot electricity prices, the impact of higher NO_X RTC prices on the average price of electricity would have been much more modest.[35] And if the electricity crisis had not occurred, electricity generators likely would not have been removed—at least temporarily—from the NO_X RECLAIM program.

Nevertheless, the California electricity crisis should make us sensitive to the fact that in the absence of inter-temporal flexibility, short-term fluctuations in emissions levels can lead to significant volatility in allowance prices. Allowance price volatility in turn can lead to significant short-term volatility in prices of goods whose production involves significant "use" of emissions allowances. Accordingly, the recent experience with RECLAIM suggests that it is important to give emissions market participants the necessary tools to manage extreme price volatility effectively. The ability to bank allowances, a tool that was largely unavailable under RECLAIM, is one potentially important tool for managing price volatility.

E. Mobile Source Averaging, Banking, and Trading (ABT) Programs

*The federal **mobile source** averaging, banking, and trading (ABT) programs are similar to the Lead Trading Program in providing the manufacturers of certain mobile sources of emissions the flexibility to trade, without expensive pre-approval, differences around a pre-specified emission rate standard, usually expressed as emissions per horsepower-hour.* The acronym ABT refers to the specific uses for the credits, namely, (1) "averaging" emissions over engine families produced by the manufacturer in the same model year, (2) "banking" credits to offset emissions from the same or other engine families produced by the manufacturer in future years, or (3) "trading" credits by sale to another firm to offset emissions from that firm's engine families. Instead of requiring manufacturers to meet the same emission standard for all of their engine families within a particular category, such as heavy-duty trucks or lawn mowers, the ABT programs grant manufacturers credit for engine families with emissions rates *below* the emission rate standard. Credits can then be used to offset emissions from other engine families that are above the standard.

The calculation of emissions credits (and "debits") is based upon clearly established factors that differ somewhat by mobile source category. The factors typically include the difference between the applicable emissions standard and the engine family emissions limit (FEL), estimated sales of each engine in the relevant model year, estimated average annual use in hours, the power output of the engine family, and the expected useful life of each engine. The regulations frequently also allow banking of "early action" credits for emissions reduced before the program is put in place. Like the Lead Trading Program, the monitoring of emission rates required to implement ABT programs is the same as that required to implement a traditional command-and-control program. Thus, no major additional monitoring costs are imposed by ABT.

The ABT approach was first provided for heavy-duty trucks in 1991 and has been extended to several other categories of mobile sources regulated under Title II of the 1990 Clean Air Act Amendments. The mobile source categories with ABT programs now include the following:[36]

- Automobiles and light-duty trucks;[37]
- Heavy-duty truck engines;
- Large non-road diesel engines used in construction, agriculture, and other uses;
- Locomotive engines;
- Marine outboard engines and personal watercraft; and
- Small engines used in various lawn, garden, and other applications.

In addition, ABT programs have recently been initiated to cover the sulfur content in gasoline and diesel fuel, and these appear likely to become important new applications of emissions trading.

Experience with the existing ABT programs indicates that averaging and banking are much more heavily used than trading. In the case of heavy-duty trucks and buses—which have been subject to the program for the longest period—there has been considerable averaging and banking, but only one trade between firms (U.S. Environmental Protection Agency 2001).[38] Several factors may explain this pattern: (1) the small number of manufacturers and thus of potential trading partners, (2) the likelihood that the differences in abatement cost exist more among different engine families than among different manufacturers of the same engine families, (3) lower transaction costs for keeping transactions within the firm, and (4) the possibility that trading could reveal sensitive information about emissions costs to direct competitors. In any case, manufacturers have responded to the flexibility provided by ABT programs, mostly by intra-firm trading, and it is reasonable to assume that the costs of compliance with the emission rate standards have been reduced without adverse environmental impact.[39]

The ABT programs further exemplify that the flexibility provided by emissions trading reduces costs and allows more ambitious environmental targets to be adopted. In the case of marine outboard and personal watercraft engines, for example, the EPA set the average emissions standard in part on the basis of a marginal cost curve that assumed emissions trading.[40] If the ABT provisions had not been included, the average emissions standard would likely have been less stringent to accommodate the higher costs of compliance for some manufacturers and engine families, or different standards would have been established for each engine family. The cost-saving flexibility of ABT allowed the EPA to set an average for all engine families without having to deal with the problems of imposing high costs on some engine families. Since the engines in each family are distributed nationwide, there is no evidence that the deviations from the single standard have adversely affected the attainment of local environmental standards. If anything, the lower average has helped localities in non-attainment achieve ambient air quality standards.

F. Northeast NO_X Budget Trading

The Northeast NO_X Budget Trading program grew out of provisions in the Clean Air Act Amendments of 1990 that facilitated common actions among the District of Columbia and twelve states in the Northeastern United States[41] to deal with concerns about regional tropospheric ozone or "smog." These participants adopted a cap-and-trade program to reduce NO_X emissions from electricity-generating facilities having 15 MW of capacity or greater and equivalently sized industrial boilers by about 60 percent from uncontrolled levels in a first phase starting in 1999 and by up to 75 percent in a second phase starting in 2003.[42]

A unique feature of the program is that it operates only during the summer months, from May through September, when NO_X effects on ozone concentrations are greatest in this part of the country. Although the environmental objective is to reduce the incidence of ozone non-attainment, the program does not contain provisions that would distinguish days during the summer when the ozone standard is exceeded from days when it is not. Several ideas to address this problem were considered, but none were considered feasible (Farrell 2000). Instead, reliance is placed on the decrease in the overall level of NO_X emissions during the critical summer season.

The program includes a novel banking provision that attempts to address the concerns about excess concentrations that also were present in the design of the RECLAIM programs. Instead of banning banking altogether, a mechanism called Progressive Flow Control was devised that permits unused allowances to be banked but limits the use of these allowances in future periods.[43] If the total number of banked permits exercised in one year exceeds ten percent of the cap for that year, some of the banked allowances would be "discounted" by 50 percent (i.e., for each ton of NO_X emitted, *two* banked allowances would have to be redeemed). The proportion of discounted allowances grows with the size of the bank relative to the cap for that year. While this provision diminishes the incentive for sources to bank emissions, it does not seem to have discouraged banking. NO_X emissions during the summer season from affected sources in the eight participating states were approximately 175,000 tons, about 20 percent below the total number of allowances distributed (see Farrell 2000).

The Northeast NO_X Trading Program is the first major example of a multi-jurisdictional program, developed by several states, instead of being imposed by the federal government (as was the case with the Title IV SO_2 Program) or by a local regulator (as was the case with the RECLAIM program in the Los Angeles Basin). The 1990 Clean Air Act Amendments created an Ozone Transport Region containing the twelve Northeastern states, and these states and the EPA then worked together to develop a "Model Rule" as a guide to programs to be adopted by the individual states. Nine states have adopted trading programs that have generally followed the Model Rule.[44] Allowances are allocated to each state based upon 1990 emission rates, and each state then determines the allocations to individual boiler units.

The principal variations from the Model Rule have concerned allocations to individual units. Some states have adopted an "updating" approach whereby allocations are not fixed for all time based on some historic period, as in the Acid Rain and RECLAIM programs, but changed periodically as old units are shut down and new ones brought into service (Harrison and Radov 2002). For example, Massachusetts bases allocations to electricity generators on the average of the two highest electricity output years for the six, five, and four years prior to the allocation year. Updating can provide a counterproductive incentive to increase production in order to gain more allowances in the future and thereby can reduce the cost savings from trading. But this effect (and thus the inefficiency) is considerably attenuated by the effect of discounting when the lag—i.e., the time between production and receipt of more allowances—is substantial, and when emissions costs are small relative to total operating costs.

The NO_X Budget Program in the Northeast Ozone Transport Region has not been in operation long enough to evaluate its effectiveness or cost savings thoroughly, although an early review suggests the program is operating effectively (Farrell 2000). During 1999, the first year of the program's implementation, NO_X emissions from affected units decreased by 64 percent from the "uncontrolled" 1990 level of emissions and by another 25 percent from the 1998 level, which was already about half the 1990 level due to the application of NO_X RACT (Reasonably Available Control Technology) requirements. No study has been conducted on the effects of the reduction in total NO_X emissions on ozone levels (or exposure levels) in areas within the region. However, concerns about the direction of trading (purchases of allowances by upstream sources from downstream sources) in the Northeast appear not to be justified.[45]

The speed with which the NO_X market developed is also notable. Despite a slow and awkward start (Farrell 2000), about 16 percent of 1999 vintage NO_X allowances were traded among economically distinct entities and a slightly larger percentage of the 1999 allowances were reallocated among units owned by the same firm. The quick development of the NO_X market has been attributed to the participation of marketing and brokerage firms that participate in power, emissions, fuel, and other markets simultaneously, and to whom generating companies are turning for risk management services (Farrell 2000). Also, the NO_X market involved greater use of derivative products (e.g., options) than the SO_2 market, because of its greater price volatility and its later start—at the time when similar derivatives were being developed for the SO_2 market.

III. Lessons from Experience with Emissions Trading

A. Economic Effectiveness

Emissions trading has been successful in its major objective of lowering the cost of meeting emission reduction goals. The high volume of trading observed in nearly all programs provides circumstantial evidence that this objective has been achieved since there would be little reason to trade other than to reduce costs. In addition, the Acid Rain Program has been the subject of specific studies that have carefully quantified the cost savings.

The early examples of emissions trading—the EPA ET programs—produced relatively small reductions in control costs simply because few trades actually took place. The cumulative savings from the EPA ET programs totaled at most several billion dollars, a few percentage points of the hundreds of billions of dollars spent to control the stationary emission sources that could benefit, in theory, from trading. The cost savings from the Lead Trading Program were greater. As much as 50 percent of overall lead rights were traded in a given year and significant banking activity indicates additional gains.

The Acid Rain Trading program has the most solid evidence of cost savings from trading as the result of several careful studies that have attempted to assess gains from both spatial and temporal trading under the cap-and-trade component of the program (Ellerman et al. 2000; Carlson et al. 2000). These gains are measured in comparison to estimates of the costs that would have been incurred to obtain the same emission reductions without emissions trading. They confirm that cost savings can be achieved and that compliance costs have been reduced by as much as 50 percent relative to the costs of a command-and-control alternative.

None of the other emissions trading programs have been subject to careful *ex post* studies, but all have experienced significant trading activity, which suggests cost savings. In RECLAIM, trading activity has been substantial, with the overall volume in any given year exceeding the annual cap as a result of trading in future vintages. This high level of trading suggests that the estimates of cost savings of 40 percent made when RECLAIM was being designed may have been achieved, although future cost savings from RECLAIM will depend on whether electricity generators re-enter the program. Similarly, no estimates have been developed for the many mobile source ABT programs or the relatively new Northeast NO_X Budget Trading Program. Experience with the ABT programs applied to sources ranging from heavy-duty trucks to lawn mowers indicates substantial use of the averaging and banking flexibility, but virtually no use of inter-manufacturer trading. This pattern suggests both that the major cost-saving gains are realized by internal trading and that trading may be limited when participants include only a small handful of competing firms who may be reluctant to trade for fear of revealing confidential information to competitors. The Northeast NO_X Budget Program seems to be functioning well—partly due to relatively sophisticated broker activity—with about one-third of allowances being exchanged either internally or externally.

With the exception of the early EPA ET program, the emissions trading programs reviewed in this paper appear to have been successful at realizing in practice the gains from trade that have long been predicted in theory. As such, these programs provide a solid basis for expecting that future well-designed emissions trading programs will realize significant cost savings in comparison to conventional command-and-control alternatives.

B. Environmental Effectiveness

The use of emissions trading has enhanced—not compromised—the achievement of environmental goals. Emissions trading is sometimes portrayed as a way of evading environmental requirements, but the experience to date has demonstrated the opposite. Environmental goals have not been compromised by trading; rather, emissions trading has helped achieve environmental targets.

Enhanced environmental performance can be attributed to the increased flexibility associated with emissions trading for three reasons. First, where emission reduction requirements are phased in and firms can bank emission reductions—as was the case in the Lead Trading, Acid Rain, ABT, and Northeast NO_X Budget Programs—the achievement of the required emission reduction has been accelerated. The early reductions may defer the achievement of future annual emissions control targets as the banked credits are used. However, as long as a positive discount rate is assigned to the benefits associated with emission reductions—as is surely the case, since benefits today are preferred to the same benefits tomorrow—accelerating the timing of the cumulative, required emission reductions is an environmental gain.

Second, allowing firms that face high marginal costs of abatement, or even technical infeasibility, to comply with environmental requirements by buying allowances—effectively paying others to reduce more on their behalf—has eliminated one of the features of command-and-control programs that diminishes environmental effectiveness. In a command-and-control program, economic hardship or technical barriers can be dealt with only by relaxing the emissions standard in some way. While often justified, these exceptions reduce the regulation's environmental effectiveness because they are one-sided: standards are relaxed to avoid "hardships" for some facilities, but increased emissions cannot be offset by increasing standards at facilities for which abatement is less expensive or easier technologically. The net result is more emissions than would be produced by an "ideal" regulation—one taking into account differing compliance costs. Emissions trading programs avoid this problem by providing an alternative means of compliance to facilities that face high costs of abatement and by providing an incentive to abate more to facilities with low costs of abatement. The result is a decentralized mechanism for offsetting emissions that does not detract from achievement of the environmental goal.

A third reason for enhanced environmental results is the greater ability to gain consensus on the environmental goal, and even adopt a more demanding goal, when flexibility is present. An important reason for the acceptance of more demanding environmental targets in conjunction with trading appears to be that the allocation mechanism can be used to win over those who might otherwise stand to lose the most from tighter regulations. The inclusion of emissions trading in Title IV of the Clean Air Act Amendments of 1990 broke what had been a decade-long stalemate on acid rain legislation. In the Northeastern NO_X trading program, state officials and regulators turned to emissions trading as a better means to come into attainment with the National Ambient Air Quality Standards for ozone, a goal which had long eluded these states (and a number of others) despite ample regulatory authority in the existing Clean Air Act. Similarly, regulators in Southern California adopted emissions trading in both SO_2 and NO_X as a more likely means of achieving emission reduction requirements that were already required. There also is evidence that more stringent emission standards were set for various categories of mobile sources because of the flexibility provided by the ABT programs.

Finally, some ancillary benefits of trading programs that would lead to improved environmental quality may be anticipated. Although evidence is limited so far, trading programs should create greater incentives for innovation in emission-reduction technologies than command-and-control regulations have created. While the latter may "force" some technological development, there is no incentive to go beyond the standard, and indeed a disincentive because investments in developing more efficient abatement technology might be "rewarded" only by a tighter standard. In contrast, the incentive to abate in cap-and-trade programs, where there is no specific standard for any single plant, is continuous and any improvements in abatement technology will result in allowance savings (Swift 2001). There is also empirical evidence that the Lead Trading Program led to more efficient adoption of lead-reducing technologies by refiners (Kerr and Newell forthcoming). As confidence is gained in the effect of these incentives on innovation, it should be feasible to reduce emissions more than would otherwise be the case. Another ancillary benefit is the significant improvement in the quality of environmental data that results from the monitoring requirements of emissions trading programs.[46] This information should contribute to better understanding of and solutions to remaining environmental problems.

Experience with the opt-in features of the Acid Rain Program and with the NO_X RECLAIM Program could be cited as counter-examples to the proposition that emissions trading has improved environmental performance when compared with a command-and-control alternative, but these instances must be placed in perspective, as we have attempted to do in the sections dealing with each. In the Acid Rain Program, the issuance of allowances reflecting "baseline errors" constituted only a small percentage of the total number of allowances and these extra allowances do not seem to have had any material effect on the achievement of the program's goals. Similarly, the additional RECLAIM NO_X emissions in 2000 represented a small percentage of the 2000 cap and, moreover, procedures were put in place to compensate for the shortfall in future years. It seems unlikely that a command-and-control program would have been any more effective in reducing emissions before and during the unique circumstances associated with the California electricity problems of 2000-01. California's electricity crisis was an extraordinary event and its principal lessons relate to the proper design of competitive electricity market institutions and the transition to them. It would be a mistake to draw many conclusions about environmental policy from the problems with California's experiment in electricity market deregulation.

C. Ability to Trade

Emissions trading has worked best when the allowances or credits being traded are clearly defined and tradable without case-by-case certification. The earlier view of emissions trading as a theoretically advantageous but mostly impractical concept, which reflected the disappointing early experience with the reduction credit approach to emissions trading, has been largely supplanted by a view that trading is a practical means for reducing emissions and lowering the cost of meeting environmental targets. This turnaround in perception reflects the increased and successful use of cap-and-trade and averaging approaches, which share the important features that the allowance or credit to be traded can be clearly defined and that each trade does not require an expensive pre-approval and certification process.

Allowances allocated under the Acid Rain, RECLAIM, and Northeastern NO_X Budget cap-and-trade programs provide pre-certified transferable rights to emit. Similarly, the credits in the Lead Trading and ABT programs can be readily determined using a simple formula that can be calculated by firms and easily verified by regulators. The creation of clearly defined and freely tradable "commodities"—principally in cap-and-trade programs but also in averaging programs—has removed the greatest impediment to better performance from emissions trading: the costly and time-consuming pre-approval of trades by the regulatory agency that was typical of the early EPA ET programs.

The clear definition and ready transferability of allowances and credits also encourages the emergence of intermediaries that provide liquidity and lower transaction costs. Intermediaries linking buyers and sellers exist in all emissions trading approaches, but their roles are different. In cap-and-trade and averaging systems—where the allowances or credits are typically homogeneous products that can be used by any source—intermediaries can aggregate sources of supply and demand, provide risk management services (e.g., options, swaps, and forward contracts),[47] and otherwise function as they do with other financial instruments.

In contrast, in reduction credit programs—in which the commodity for sale typically must be defined, measured, and verified in each case—the intermediaries facilitate trading not so much by buying and selling in the market, as by helping to interpret complex rules and to navigate the pre-approval process. Trades tend to be idiosyncratic events arranged between specific buyers and sellers with a price negotiated for each trade. Although markets exist for the credits created under these programs, their scope is limited, transaction costs are high, trades are infrequent, and financial instruments to manage risk develop much more slowly, if at all. Developing more effective programs based on emissions reduction credits will require more effort put into standardizing the baseline and verification processes in advance, so that the costs of participating are reduced.

Of course, a program's use of cap-and-trade or averaging does not guarantee clear definition, ready transferability, low transaction costs, or a successful program. The early bubble program was an averaging program, but case-by-case approval kept it from being successful. Similarly, a cap-and-trade program would get bogged down if pre-approval of trades were required in order to guarantee that trades did not negatively impact air quality in some way. Examples of such restrictions do not exist because regulators who have adopted cap-and-trade and averaging programs have wisely chosen to dispense with costly pre-approval and to resist temptations to complicate the transferability of allowances and credits.

D. Banking

Banking has played an important role in improving the economic and environmental performance of emissions trading programs. One of the surprising results emerging from this review of experience with emissions trading is the role of inter-temporal trading, or, the form that it most often takes, banking. Most of the attention given to emissions trading has focused on spatial trading, and indeed most of the cost savings seem to occur from this form of trading, as indicated by Table 1 (on page 7), which provides estimates of the cost savings attributable to spatial and temporal trading in the Acid Rain Program. Nevertheless, banking has been included in most of the emission trading programs reviewed in this report, and its inclusion appears to have improved program performance. The one major program without substantial temporal flexibility, RECLAIM, appears to have suffered because of it.

The role of banking in the improved environmental performance of both the Lead Trading Program in the mid-1980s and the later Acid Rain Program has been noted in a preceding section. In both programs, emissions reductions were accelerated as firms banked emissions allowances to smooth out the transition to the ultimately much lower level of allowable lead content and SO_2 emissions. The same pattern of banking and accelerated emissions reduction has emerged in the Northeastern NO_X Budget Program, even though the incentive to bank is diminished by the potential discount applied to the use of the banked allowances.

Although banking provides environmental and cost-saving gains, its greatest advantage may lie in the flexibility it provides for dealing with uncertainties. An inherent feature of cap-and-trade programs is that uncertainty in demand translates into variations in the price of allowances instead of variations in the quantity of emissions, as is the case with conventional emission rate limits and as would be the case with emission taxes. When abatement responses are not instantaneous, banking provides some flexibility for an otherwise fixed cap and uncertain demand for allowances. Banking does not eliminate vulnerability to unexpected shifts in demand, and it is not the only means of avoiding price spikes, but it does dampen potential allowance price volatility.[48]

E. Initial Allocation

The initial allocation of allowances in cap-and-trade programs has shown that equitable and political concerns can be addressed without impairing the cost savings from trading or the environmental performance of these programs. The initial allocation of allowances in cap-and-trade programs is a contentious process, as is the distribution of anything of value, but the political difficulty of allocation should not obscure the evidence from the three existing cap-and-trade programs that initial allocation has not compromised the achievement of environmental goals or the potential cost savings.

Imposing an emissions constraint creates a valuable property right for those who receive initial allocations. In cap-and-trade programs, allowances can be distributed either by auction, in which case the government is the immediate recipient of the gains from the valuable property rights, or by direct allocation, in which case the entities receiving the allowances, typically corporate incumbents, capture the gains. A rich literature has developed concerning the efficiency and equity implications of the distribution of auction revenues.[49] Governments could use the revenues to reduce existing taxes, to provide transitional assistance to workers displaced as a result of the environmental constraint (Barrett 2001; Greenwald et al. 2001), for any number of other worthy purposes, or could simply distribute the proceeds directly to households as an "environmental dividend."[50] Corporate profits may increase if allowances are grandfathered to incumbents, although the increased profits will be taxed and only the after-tax portion will be passed on to shareholders.[51]

The cap-and-trade programs described in this paper all have distributed allowances to participating units rather than auctioning them. The only program with an auction feature is the acid rain program; however, the auction accounts for a very small share (2.8 percent) of allowances, and, as if to prove the point, the proceeds of the auction are returned to the initial recipients from whose grandfathered allocations the auctioned allowances are initially withheld.[52] The reasons for the apparent preference for grandfathering are beyond the scope of this paper, but some comments can be made concerning the considerable differences in the manner of initial allocation and the lack of effect on program performance (as distinct from issues of equity and macro-economic efficiency).

The rules adopted to allocate allowances initially to participating units have differed significantly (Harrison and Radov 2002). Usually, historical data are used as the basis for a "once-and-for-all-time" grandfathered allocation, although some states in the Northeast NO_X Budget Program are updating the initial allocation on a lagged basis. The metric used in the grandfathering formulas has also varied considerably, from inputs, to output, to emissions. Furthermore, all levels of government—federal, state, and local—have been involved in making allocations, and allocations have been made both by legislative bodies and administrative agencies.

The many differences in how allowances have been allocated appear to have had no discernible effect on trading activity, the cost savings from trading, or the environmental effectiveness of the trading system. The likely reason for this outcome is that the dominant mechanism used to allocate allowances, grandfathering based on historical data, provides no incentive to alter production or abatement behavior in order to obtain more allowances in present or future periods and thus does not create distortions.[53]

IV. Considerations for Greenhouse Gas Control Programs

Every environmental problem possesses unique characteristics that strongly influence the regulatory programs that are adopted to address it. Some programs are local, such as RECLAIM; others, like the Northeastern NO_X Budget program, are regional; and still others are nationwide in scope, such as the Lead Trading, Acid Rain, and Mobile Source ABT Programs. The essential difference in all of these examples concerns the fate of the controlled emissions and the nature of the damages attributable to them. An important question with regard to the use of emissions trading to control greenhouse gas (GHG) emissions is then: What special considerations might apply to the design of a program to address climate change?[54]

For climate change, the fundamental issue is the contribution that various emissions make to the greenhouse effect, which depends upon the atmospheric concentrations of the various greenhouse gases (Reilly et al. 2003). Once emitted, greenhouse gases have long residence times in the atmosphere, usually measured in decades, centuries, and even millennia. Moreover, atmospheric currents ensure that emissions are dispersed quickly in the atmosphere, so that atmospheric concentrations of greenhouse gases are relatively uniform over the globe. In sum, emissions are uniformly mixed and long-lived, and the effects are cumulative and global.

A. Suitability of Trading

Emissions trading seems especially well suited as part of a program to control greenhouse gas emissions. The uniform mixing of GHG emissions in the atmosphere removes the chief concern limiting the scope of emissions trading in other applications and creates the opportunity to design trading programs without geographic limits defined by localized environmental impacts. Uniform mixing means that a ton of a given GHG will have the same effect on atmospheric concentration—and thus on climate change—regardless of whether the ton is emitted in California, New York, or elsewhere on the globe. Thus, trading can be national and international in scope, and the cost savings commensurately larger as the scope broadens. Moreover, the opportunities for cost savings through trading are greatest when the costs of control differ widely among sources. There is every reason to believe that the cost of reducing GHG emissions varies widely among sources and across countries. Accordingly, trading can provide the flexibility needed to allow GHG reductions to be achieved using the lowest-cost abatement options. Moreover, GHG emissions generally can be measured using relatively inexpensive methods (e.g., fuel consumption and emission factors), rather than the expensive continuous emissions monitoring required for some existing trading programs (Pew Center on Global Climate Change 2002).

In addition, the cumulative effect of greenhouse gases and their long duration in the atmosphere means that the *timing* of emissions reductions within a control program will not have a significant effect on atmospheric concentrations and on climate.[55] Thus, trading across time periods by banking offers still more potential for cost savings. And, as we have seen in other programs with phased-in emissions reduction requirements, which will almost certainly be the case for any GHG control program, banking can be a means of accelerating the required emission reductions.

A final feature that makes emissions trading particularly well-suited for a GHG control program, especially when it takes the form of a cap-and-trade program, is the incentive to take advantage of opportunities for less costly abatement that may lie outside the trading program. For a variety of reasons, ranging from concerns about measurement to varying political commitment, the least expensive abatement opportunities may lie outside the trading program. Examples would be domestic non-CO_2 GHG abatement possibilities (if the trading program initially focused on CO_2), the enhancement of forest and terrestrial sinks for CO_2, and reductions in developing countries that are not expected to accept GHG restrictions as soon or as demanding as those adopted by the relatively rich countries. Many issues must be dealt with in order to take advantage of these opportunities, but these difficulties can be addressed, and as we will emphasize below, should be addressed. The prerequisite, however, is an incentive to seek out opportunities for cheap abatement outside the cap. Although mechanisms could be devised to encourage cost-reducing abatement outside of the program under the emission tax or command-and-control approaches, these other approaches do not provide as exact and efficient an incentive for such abatement as does the emissions trading approach.[56]

In sum, although the specific nature of domestic and global measures to address climate change will evolve over time, few environmental problems appear so well suited to emissions trading as GHG emissions control.

B. Opt-in Features

Opt-in or voluntary features have a strategic role that is likely to warrant their inclusion despite the problems associated with them. Emissions trading has worked well in reducing costs and enhancing the achievement of an environmental goal when it is linked to a specific requirement, such as the cap in a cap-and-trade program or the mandatory standard in an averaging program. However, when participation has been voluntary, as in the opt-in features of the Acid Rain Program and also in the EPA ET programs, the results have been less encouraging. An unavoidable element of "moral hazard" is present and the regulator seems to be faced with the unenviable choice of eliminating it, and foregoing the cost savings from expanded emissions trading, or countenancing it, and accepting some degradation of the environmental goal.

One could in theory avoid the issues related to voluntary participation by requiring all sources to be covered by the trading program. However, considerations of transactions costs and politics frequently lead to a situation in which the trading program initially covers only some sources of the targeted emissions. For example, the Acid Rain Program covered only SO_2 produced by electricity-generating plants exceeding a certain size and it excluded industrial sources. Similarly, the RECLAIM program did not cover mobile sources, which are a major contributor of NO_X emissions in the Los Angeles basin. By the same token, GHG emission control programs are unlikely to cover all sources and sinks because of measurement problems, and are unlikely to cover all countries because of differences in political will and considerations relating to an equitable distribution of the global burden of pollution control between rich and poor countries. Given this reality, questions arise as to whether sources that are not included in the program by mandate can enter the program voluntarily—and if so, under what conditions.

The answers to these questions require a balancing of the expected costs and benefits of allowing opt-in participation. The environmental integrity of the Acid Rain Program was not significantly impaired by the opt-in provisions, and in retrospect measures could have been taken to lessen the impact still more. At the same time, the cost-reducing benefits were small, since the units that opted-in and reduced emissions did so for only a few years before they were subject to the mandatory cap. While the opt-in provisions of the Acid Rain Program may well be judged (in retrospect) not to have been worth the effort, the same cannot be assumed to be the case for GHG emission control.

Two arguments strongly favor including opt-in provisions in any GHG cap-and-trade program. The first is that much has been learned in two decades of experience with analogous requirements to set baselines in various environmental and non-environmental credit reduction programs. As discussed in Harrison et al. (2000), the worst abuses of opt-in features have been avoided in other programs.[57] For example, the U.S. EPA has developed models to estimate the likely future baseline status of natural resources damaged by oil spills or other environmental insults. Similarly, private firms have developed methods of estimating baseline energy use for purposes of determining compensation for efficiency-enhancing programs. Although admittedly not perfect, these and other mechanisms can be used as guidelines for the development of similar procedures for setting reasonable baselines for GHG emission reduction programs.

The second argument for incorporating opt-in features is strategic—to extend the caps in domestic programs to include non-capped sources and sinks domestically and abroad. The global nature of climate change requires that the control program eventually be global, but for a variety of technical, institutional, and political reasons, a comprehensive control program will not be achieved in the near term. But, if rich countries provide an example—as well as an incentive through the value created in their own allowance markets—opt-in projects will provide the mechanism by which the market and the caps can be broadened geographically and extended to include both CO_2 sinks and greenhouse gases in addition to CO_2. Trading in reduction credits—with all of its well-known difficulties—will play an important role in developing inventories and measurement protocols for non-capped sources and sinks at home and abroad. In effect, each emissions reduction project will be an experiment that tests the feasibility of including various types of sources and sinks in the program.

Opt-in projects in developing countries may provide similar experience and incentives that expedite the inclusion of activities contributing to climate change under the various caps. Some developing country emission sources, notably large stationary ones, are readily identifiable; measurement techniques are available; and there is no reason to foreswear cheap abatement opportunities while waiting for a more comprehensive global regime to emerge. Each project constitutes an incremental extension of the emission caps and the incentives will be strong to extend the caps to include related facilities, a whole sector, or even a country. The greater the scope of the caps, the less **leakage** (i.e., shifting emissions from capped to uncapped sources), and the less costly it will be to establish credible baselines. This will lower transaction costs and provide trading opportunities to the advantage of both buyers and sellers. Of course, opt-ins alone will not create an *equitable* scheme for sharing the burden of global emissions reductions. That will require international negotiation and diplomacy beyond the efforts of a single country establishing a domestic program. But opt-in projects can prepare the way for these international developments.

V. Conclusions

Emissions trading has emerged as a practical framework for introducing cost-reducing flexibility into environmental control programs and reducing the costs associated with conventional command-and-control regulation of air pollution emissions. Over the last two decades considerable experience with various forms of emissions trading has been gained, and today nearly all proposals for new initiatives to control air emissions include some form of emissions trading. This report has attempted to summarize that experience and to draw appropriate lessons that may apply to proposals to limit GHG emissions. In doing so, we hope that the reader has gained a better understanding of emissions trading and the reasons for its increasing importance as an instrument for addressing environmental problems.

Six diverse programs constitute the primary U.S. experience with air emissions trading. The EPA's early attempts starting in the late 1970s to introduce flexibility into the Clean Air Act through netting, offsets, bubbles, and banking were not particularly encouraging. Most of the potential trades, and economic gains from trading, in these early systems were frustrated by the high transaction costs of certifying emission reductions. The first really successful use of emissions trading occurred in the mid-1980s when the lead content in gasoline was reduced by 90 percent in a program that allowed refiners to automatically earn credits for exceeding the mandated reductions in lead content and to sell those credits to others or bank them for later use.

The Acid Rain or SO_2 allowance trading program for electricity generators, which has become by far the most prominent experiment in emissions trading, was adopted in 1990 and implemented beginning in 1995. This innovative program introduced a significantly different form of emissions trading, known as cap-and-trade, in which participants traded a fixed number of allowances—or rights to emit—equal in aggregate number to the cap, instead of trading on the differences from some pre-existing or external standard as had been the case in the early EPA trading programs and the lead phase-down program.

Another cap-and-trade program, the RECLAIM program for both SO_2 and NO_X emissions, was developed and implemented at the same time as the Acid Rain program by the regulatory authority in the

Los Angeles Basin as part of its efforts to bring that area into attainment with National Ambient Air Quality Standards. The RECLAIM program is the first instance of emissions trading both supplementing and supplanting a pre-existing command-and-control structure that theoretically was capable of achieving the same environmental objective. The standards of the pre-existing command-and-control system largely determined the level of the cap, and the program's ten-year phase-in design and trading provided the flexibility that led to the achievement of environmental goals that had been previously elusive. RECLAIM also introduced trading among different sectors.

The 1990 Amendments to the Clean Air Act also provided enabling legislation for two other emissions trading programs. Emissions from mobile sources were more effectively and efficiently controlled by the introduction of mobile source averaging, banking, and trading programs. The mobile source programs followed the example of the lead phase-down program by allowing firms to create credits automatically for any reductions beyond a required uniform emission standard and to use these credits in lieu of more costly reductions elsewhere or later within the company and to sell them. The 1990 Amendments also provided the mechanism that encouraged states in the Northeastern United States to adopt cap-and-trade programs to control NO_X emissions that contributed to ozone non-attainment in that region of the country. As was the case in the RECLAIM program, emissions trading was adopted as a means to attain environmental objectives more quickly and cost-effectively than had proved possible through conventional command-and-control regulation.

There are many lessons to be gained from the experience with these six programs, but the five most important lessons can be summarized as follows. First, the major objective of emissions trading, lowering the cost of meeting emission reduction goals, has been achieved in most of these programs. Second, emissions trading has not compromised the achievement of the environmental goals embodied in these programs. If anything, and this is perhaps surprising, the achievement of those goals has been enhanced by emissions trading. Third, emissions trading has worked best in reducing costs and achieving environmental goals when the credits being traded are clearly defined and readily tradable without case-by-case certification. Fourth, temporal flexibility, i.e., the ability to bank allowances, has been more important than generally expected, and the ability to bank has contributed significantly to accelerating emission reductions and dampening price fluctuations. Fifth, the initial allocation of allowances in cap-and-trade programs has shown that equitable and political concerns can be met without impairing either the cost savings from trading or the environmental performance of these programs. In addition, the success of any emissions trading program requires that emissions levels can be readily measured and compliance verified and enforced.

All of these five lessons are relevant when considering the use of emissions trading in a program aimed at reducing GHG emissions. In fact, emissions trading seems especially appropriate for this environmental problem. Greenhouse gas emissions mix uniformly and remain in the atmosphere for a long time. Thus, it matters little where or when the emissions are reduced, as long as the required cumulative reductions are made. These specific characteristics of GHG emissions eliminate two of the concerns that have limited the scope of emissions trading in many other programs.

Although an effective GHG mitigation program must eventually be global in scope and comprehensive in its coverage of pollutants and economic sectors, the likelihood that control efforts will be limited initially to the richer countries, the more easily measurable gases, and perhaps to certain sectors of the economy introduces another consideration. The ability to induce initially uncapped sources to participate voluntarily in the early efforts will reduce costs and prepare the way for extending the caps. Thus, providing opportunities to opt-in for uncapped sources that can reduce emissions at lower cost than those within the cap has a strategic value beyond the potential cost savings. Although some existing programs with voluntary provisions have revealed opportunities for misuse, these problems can be managed more successfully now with the benefit of experience. The strategic value of opt-in provisions in any GHG emission control program makes their inclusion highly desirable.

Emissions trading has come a long way since the first theoretical insights forty years ago and the first tentative application almost a quarter of a century ago. Since then, the use of emissions trading has expanded steadily and significant experience has been gained. Although not the dominant form of controlling pollution in the United States or elsewhere, emissions trading now seems firmly established as a valuable instrument and its future use seems sure to increase. Our review of experience over the past quarter century suggests that this trend toward greater use of emissions trading will improve the performance of environmental regulation, including efforts to control GHG emissions.

Glossary

Allowance: The right to emit one unit (e.g., one ton) of a pollutant or greenhouse gas such as carbon dioxide (CO_2), generally distributed by the governing authority for a cap-and-trade program.

Averaging program: An emissions trading program in which an overall average emissions rate is set (e.g., emissions per unit of input or output), and firms may have different emission rates for individual facilities as long as the required average is achieved. In some cases, there is a maximum emission rate (or cap) set. Averaging programs do not constrain the total number of tons that can be emitted.

Banking: Banking is a form of inter-temporal substitution that allows sources to reduce emissions below their requirement in one year and bank "surplus" allowances for use or trade in future years.

Baseline: The level of emissions that would have taken place without the given emissions regulations. Baselines must be calculated when implementing credit-based programs.

Borrowing: A form of inter-temporal substitution related to banking. Under a borrowing program, a source of pollution is allowed to emit above its requirement in a given year (i.e., "borrow" allowances) in exchange for the obligation to emit below its requirement in future years, when the "borrowed" amount would be "repaid."

Cap-and-trade program: An emissions trading program in which policy-makers set an overall limit or cap on emissions of one or more pollutants. Rights to emit the pollutant(s), also known as allowances, are distributed in some way to participants, who are then allowed to trade them among themselves.

Command-and-control program: A program that sets individual and specific emission standards for various facilities without any flexibility to average or trade allowances.

Continuous Emissions Monitoring System (CEMS): A system for continuously monitoring emissions from a source, for instance by the installation of probes or other sensing instruments in the exhaust stack of a power plant.

Credit or emissions-reduction credit: The right to emit one unit (e.g., one ton) of a pollutant in excess of what would normally be permitted. Credits are typically awarded for reducing emissions below a baseline or existing emissions cap. Under some trading programs, credits and allowances can be used interchangeably.

Early reduction credit: A mechanism to compensate companies that voluntarily reduce emissions prior to the introduction of a cap-and-trade program. The credits allocated can be used to meet requirements once the cap-and-trade program goes into force.

Grandfathering: A method of initially distributing emissions allowances using only historical data. The data used as the basis for the grandfathered allowances can be on a variety of types of facility activity, including emissions, input, or production.

Greenhouse gases: Atmospheric gases that change the Earth's radiative balance by absorbing heat. Six gases and gas families are specifically covered in the Kyoto Protocol: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and three industrial gas families, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). See Reilly et al. (2003) for a more complete discussion.

Heat input: The energy content of fuel used to fire power plants (usually measured in joules or Btu). Historical heat input has been used for grandfathering allocations under various cap-and-trade programs.

Initial allocation: A term used to refer to the method by which emissions allowances are distributed by a government or regulator in a cap-and-trade program. Allowances are either auctioned or distributed freely based on a variety of criteria.

Leakage: The "migration" of emissions-intensive activities from an area required to participate in a cap-and-trade program to an area not covered by the emissions cap. The result is that emissions are reduced within the capped region, but are increased outside it, resulting in lower overall emission reductions.

Mobile sources: Sources of emissions that are not geographically fixed, including motor vehicles (including motorcycles), large non-road engines such as those used in construction and agriculture, locomotive engines, marine engines, engines used in recreational equipment, and small utility engines (e.g., lawn mowers).

National Ambient Air Quality Standards: Standards established by the U.S. EPA under Section 109 of the Clean Air Act. The Clean Air Act calls for the Administrator of EPA to set national primary and secondary ambient air quality standards for each air pollutant for which air quality criteria have been issued. The primary standards are to be set "to protect the public health" including "allowing an adequate margin of safety." The secondary standards are set "to protect the public welfare from any known or anticipated adverse effects." Section 110 of the Clean Air Act calls for states to develop State Implementation Plans that provide for implementation, maintenance, and enforcement of the primary and secondary ambient air quality standards. These standards are periodically reviewed and possibly revised.

Opt-in program: A type of voluntary program that allows certain eligible facilities to participate in an emissions trading program even though they are not required to do so. Sources will typically opt-in if they believe they will have lower emissions reduction costs than other participants, and therefore will be able to profit from the sale of surplus allowances.

Permit: A formal document which gives to its holder the right to emit certain kinds of pollutants, subject to various constraints and restrictions—one of which may be that the holder comply with the rules of an emissions trading program. Note: some authors use *permit* interchangeably with *allowance.*

Reduction credit program: An emissions trading program in which participants can earn tradable credits if they reduce their emissions below some approved baseline. Credits can then be sold in the emissions market to firms that expect to have emissions higher than an existing cap or baseline.

Stationary sources: Sources of pollution that are fixed in place, such as electricity generation units and industrial facilities.

Updating: A method of initially distributing allowances in which participants' future allocations change based on their current or future activity. This method contrasts to the grandfathering approach, in which firms receive their allocations regardless of their current or future activities.

Vintage: The year(s) in which the allowance in a cap-and-trade program can legally be used to cover emissions. For programs that allow banking and borrowing, allowance vintages may not be relevant.

Voluntary programs: Programs that allow pollution sources to undertake voluntary emissions reductions and receive credit for those emissions reductions if they so choose. Typically, only volunteers would be required to monitor emissions and to achieve emissions targets. Mandatory programs may be combined with voluntary features, for example, if certain firms must comply with the emissions targets but others are allowed to participate if they choose to. Voluntary features of otherwise mandatory programs are typically referred to as opt-in components.

Endnotes

1. See Harrison 1999a for additional details on how emissions trading markets operate and how allowance prices are determined.

2. In the context of GHG emissions, averaging programs sometimes are referred to using other terms, including "rate-based programs" and "relative targets."

3. Some of the special issues involved in establishing international trading programs are considered elsewhere; see Ellerman (1999) and Harrison (1997). The issues involved in currently observable GHG trading are discussed in Rosenzweig et al. (2002).

4. Other studies provide more comprehensive lists of previous and current emissions trading programs (see, e.g., Harrison 2002). The six programs included in this paper represent the bulk of the actual experience with emissions trading.

5. The lessons in this paper are applicable for countries with the necessary legal and institutional infrastructure to implement emissions trading programs effectively. In particular, we assume that the accurate monitoring of emissions, the effective enforcement of applicable regulations, and basic commercial contract law are all well established. Without these basic institutions, emissions trading would not be feasible.

6. These descriptions draw on Harrison (1999a) and Harrison (2002). Several of the emissions trading programs discussed in these references are not included in this paper because their experience was judged not to provide major additional insights. The programs are described in rough chronological order.

7. These programs are referred to as the EPA ET to distinguish the specific programs from the general concept of emissions trading.

8. Brokers and other intermediaries have evolved in some jurisdictions to put buyers and sellers of these credits together, but substantial fees are charged because of the complexities associated with putting together a "trade" that complies with EPA's administrative and regulatory requirements. In the Los Angeles region, for example, broker fees vary between 4 percent and 25 percent of the value of the trade, depending on the complexity of the transaction; administrative fees to government agencies in Los Angeles can total about $25,000 per trade, with the approval process taking from five to 12 months (Foster and Hahn 1995). Moreover, only about 20 percent of proposed trades are fully approved as proposed.

9. Note that the program did not cap the total lead emissions from gasoline, because refiners had to meet an average rate per leaded gallon and the number of leaded gallons was not controlled. This is a characteristic of all averaging programs. In this particular case, however, lead eventually was eliminated from gasoline.

10. Title IV also includes a requirement for reducing nitrogen oxide (NO_X) emissions with a provision for averaging plans that allows a firm to establish a bubble across all of its affected generating units. This component of Title IV will not be discussed further because the Northeastern NO_X Budget Program and the prospective NO_X SIP call, both of which address ozone non-attainment, have superseded most of its requirements. We use the term "opt-in" to refer generically to all the voluntary programs associated with the SO_2 reduction requirements of Title IV.

11. See Ellerman et al. (2000) for a detailed discussion of the trends in SO_2 emissions and the effects of Title IV.

12. This pattern of emission reductions corresponds to that predicted by economic theory in a phased-in emission reduction program where banking is allowed (Schennach 2000; Ellerman and Montero 2002).

13. Analyses conducted for EPA during development of the Acid Rain trading program indicated the likely importance of intra-firm trading (ICF, Inc. 1989).

14. Commissions declined from about 1.5 percent to 0.5 percent in the first years of trading (Ellerman et al. 2000).

15. Much of the cost savings from spatial trading and from banking are due to intra-utility trading, i.e., trading of allowances among units under common ownership. Ellerman et al. (2000) note (pp. 154–161) that in the first three years of Phase I, from 25 to 30 percent of the allowances needed to cover emissions at affected units with emissions greater than the allowance allocation came from sources external to the utility, or by inter-utility trading.

16. Carlson et al. (2000) develop estimates of cost savings for Phase I and Phase II years. For 1995 (Phase I), they estimate gains from trade equal to 13 percent of the "No Trading" costs. In 2005 (Phase II), they estimate that overall compliance costs will be reduced by about 37 percent relative to "No Trading" costs. See also Stavins (1998) for a review of the SO_2 program.

17. Potential cost savings of as much as 95 percent have been estimated for some theoretically possible emissions trading programs (Tietenberg 2000). Note that a confusion of allowance prices with average incurred costs led official Administration spokesmen to claim cost savings of 90 percent for Title IV (Smith et al. 1998).

18. Note that under Title IV, an allowance is defined as a "limited authorization to emit" SO_2 and not a property right.

19. Materials balance methods rely on the law of conservation of matter to account for all the pollutants contained in the fuel combusted. The chemical content of all fuel is determined by frequent sampling and diagnostic tests of the samples at independent laboratories. These reports are reliable since they form the basis for the transfer of billions of dollars annually between the sellers and buyers of fuel. Estimates of SO_2 (and other) emissions prior to the requirement in Title IV to install CEMS on all power plants were made using materials balance calculations.

20. This term has a meaning in emissions trading that differs from its use in other contexts, where it implies exemption from tax or regulatory provisions.

21. The implications of alternative initial allocation methods have been discussed in several recent papers and reports. See Goulder et al. (1999), Burtraw et al. (2001), and Dinan (2002) for discussions in the context of a potential U.S. cap-and-trade program for CO_2 emissions. See Harrison and Radov (2002) for a discussion of issues in the context of the proposed European Union trading program for GHG emissions.

22. The one major exception was the provision that provided bonus allowances for installing scrubbers in Phase I. Bonus allowances for energy efficiency programs were of little consequence.

23. McLean (1997) points out that with interconnected electric grids, participating Phase I units could shift electrical load to non-participating Phase II units, whose emissions could increase and undermine the Phase I emissions reduction goal.

24. The voluntary provisions for electric generating units are formally known as the substitution and compensation provisions, while the voluntary provisions for industrial units are known as the industrial opt-in program. A conservation and renewable energy reserve was established to provide additional allowances for utilities adopting energy conservation programs or introducing additional renewable energy sources, but this provision has seen little use and will not be discussed further.

25. Eligible sources were largely those with common ownership or associated in some manner with the 263 electricity-generating units required to participate in Phase I. The number of utility sources opting-in varied from year to year, but 111 generating units constituting approximately 20 percent of the affected capacity and 12 percent of the allowances distributed during Phase I remained in the voluntary program for all five years of Phase I. The peak year was 1995 in which voluntary units numbered 182 and constituted 32 percent of the electric generating capacity subject to Title IV and 16 percent of the allowances issued for that year.

26. Certain features of Title IV's voluntary programs made the creation of paper credits more likely. Chief among these was the ability of units to decide each year whether they would participate and to make that choice as late as November 30 of each compliance year. Units that considered volunteering knew how many allowances they would receive for the year and they could wait until nearly eleven of the twelve months of the year had passed before deciding to participate.

27. Montero (1999) examines the importance of different incentives on an eligible unit's decision to become a substitution unit. These incentives include the potential to receive allowances through baseline errors ("paper credits"), the potential to achieve cost-savings (i.e., reduce emissions at a cost lower than the cost of an allowance), and NO_X grandfathering benefits. Montero is one of the co-authors of Ellerman et al. (2000) and an entire chapter of this latter work is dedicated to this problem and provides some updating to Montero's earlier work. See also McLean (1997) and Environmental Law Institute (1997).

28. The original RECLAIM proposal included 38 separate trading regions, corresponding to the regions used for the offset program. This detailed geographic division was abandoned as a result of the plausible fear that the trading markets would be too thin. See Harrison (1999b).

29. SO_2 allowances in the Acid Rain Program are distributed for 30 years forward on a rolling basis, while RTCs are distributed indefinitely into the future.

30. Because the published data do not differentiate the vintage of the RTCs traded, it is not possible to provide information on the percentage of RTCs of a particular vintage that are traded.

31. The early problems with CEMS occurred because of technical malfunctions of the CEMS equipment.

32. The price for the 1999 vintage allowance also increased because RTCs from the 1999 July cycle could be traded and used to cover emissions through June 2000 (South Coast Air Quality Management District 2001a, p. 5).

33. In brief, the generating units subject to NO_X RECLAIM requirements became the marginal units for a significant number of hours, thus setting prices for wholesale electricity throughout California. Moreover, a large fraction of electricity demand under California's new wholesale market institutions was supplied through the spot market, where demand was effectively insensitive to prices, rather than through long-term contracts. As a result, the huge spikes in spot market prices for electricity, caused in part by the spike in NO_X RTC prices, became an enormous financial burden on distribution utilities, consumers, and the state of California.

34. Questions have been raised about whether unregulated electricity suppliers manipulated the NO_X RTC credit market as well as electricity and (possibly) natural gas markets. We offer no opinion on this issue.

35. This is the case because regulated prices would have been based on the average costs of generating electricity, including the average costs of NO_X RTC credits rather than the marginal cost of the generating units with the highest marginal spot fuel and RTC costs that cleared the spot electricity market. In addition, further price increases resulting from unregulated generators exercising market power (Joskow and Kahn 2002; Borenstein, Bushnell, and Wolak 2002) would not have occurred under regulation. Finally, the disruptions caused by divestiture, the hasty movement to a set of complex new wholesale market institutions, inelastic short-term electricity demand, and the excessive amount of electricity demand supplied out of the spot market probably undermined rational forward contracting and investments in NO_X controls by the new owners of most of the fossil-fired power plants in California (Joskow 2001) and shifted the burden of short-term price volatility to economic agents (distribution utilities and retail consumers) who did not have the ability to manage it.

36. The EPA Office of Air and Radiation website has information on various ABT programs. See http://www.epa.gov/oar/oarhome.html.

37. The ABT program for automobiles and light-duty trucks is distinct from the Corporate Average Fuel Efficiency (CAFE) Program, which is an averaging program for fuel efficiency without inter-firm trading and is administered by the Department of Transportation. See Committee on the Effectiveness and Impact of CAFE Standards (2001).

38. In 1996, Navistar sold credits for 5 tons of particulate matter to Detroit Diesel.

39. Several ex ante studies have simulated cost savings, but no ex post evaluations have been conducted. See Harrison (1999a) and Rubin and Kling (1993) for examples of the former.

40. The average emission standard was set to reduce emissions by 75 percent, based in part on information that showed that the marginal cost per ton increased dramatically beyond a 75 percent reduction. The marginal cost curve was based upon detailed information on emission control technologies and on the assumption of "perfect" trading, i.e., that all cost-reducing trades took place (U.S. Environmental Protection Agency 1996).

41. The twelve include the six New England states (Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut) plus six Mid-Atlantic States (New York, New Jersey, Pennsylvania, Maryland, Delaware, and Virginia).

42. Technically, these phases are the second and third of a three-phase program, the first phase of which consisted of re-labeling existing technology-based requirements and did not involve emissions trading.

43. See Nichols (1997) for an analysis of issues related to banking and the development of the concept of flow control in the context of the NO_X Budget program.

44. Vermont and Maine decided to operate traditional permit-based programs because the small number of sources in their states (less than three in each state) did not justify the administrative expenses of developing an emissions trading program. Maryland's program was delayed for a year by a lawsuit from a power company. Virginia did not join the NO_X Budget Program and has not taken any action to regulate sources. See Farrell (2000).

45. Farrell (1999) reports that "wrong way" trades (net allowance sales from upstate New York and New Hampshire, which could only have been upwind, account for only about 3 percent of the total allocation. Moreover, at the time of his report, brokers and speculators owned many of these allowances and thus the geographic location of the corresponding emissions was not determined.

46. Although emissions monitoring could be, and sometimes is, required of command-and-control regulation, more typically emissions are not monitored since compliance is determined by inspection to ensure that the mandated equipment is installed and working or that the mandated practices are being followed.

47. These financial derivatives provide the means for reducing specified risks, such as the price of allowances that might be needed two years in the future.

48. A "safety valve" has been proposed as a mechanism for avoiding price spikes (see, e.g., Pizer 1999). This mechanism allows sources subject to a cap-and-trade program to purchase additional allowances at the "safety valve" price and thereby to avoid an "excessive" allowance price if demand for allowances is greater than expected. If the safety valve is used, however, overall emissions will exceed the cap that has been set unless there is some other mechanism to provide offsets for the increased emissions. Jacoby and Ellerman (2002) provide a discussion of the origin and role of the safety valve concept.

49. See Goulder et al. (1999) for discussions of the major efficiency effects of auctions. For a general discussion of the distributional impacts of emissions trading, see Harrison (1996).

50. A lobbying organization, Americans for Equitable Climate Solutions, has recently been established in Washington, D.C. for the purpose of advocating this last use of auctioned revenues. The idea has been included in both the Clean Power Act of 2003, S. 366, 108th Congress, sponsored by Senator James Jeffords (I-VT), and the Climate Stewardship Act of 2003, S. 139, 108th Congress, sponsored by Senators John McCain (R-AZ) and Joseph Lieberman (D-CT).

51. Research by Terry Dinan and colleagues at the Congressional Budget Office indicates that about 85 percent of the after-tax rent distributed through direct stock holdings and mutual funds would go to the top quintile of the income distribution. Work is currently underway to estimate the distribution of the part passing through pension funds and 401(k) plans (Private communication from Dinan to Ellerman 2002).

52. One other program, the UK's Emissions Trading Scheme for greenhouse gases, has made use of an auction mechanism. However, the UK program is an unusual hybrid between the credit-based and cap-and-trade options, and its voluntary nature required the use of a reverse auction of government incentives. The program also relied on a form of grandfathering to set baselines.

53. See Harrison and Radov (2002) for analyses of the circumstances in which the method used to distribute initial allocations could reduce the cost savings from emissions trading or otherwise distort allowance or product markets. See also Burtraw et al. (2002).

54. Our focus in this section on a domestic program should not be taken as suggesting less importance for the design of international mechanisms for emissions trading, such as those included in the Kyoto Protocol. We focus on domestic programs both because the existing experience is most relevant to these programs and because domestic programs are likely to be the building blocks of international regimes. See Ellerman (1999).

55. This point about the indifference to the timing of emissions reductions within some control program does not imply that the initiation of some program to control GHG emissions is also a matter of indifference.

56. Many studies have estimated gains from international trading of GHG emissions. See, e.g., Edmonds et al. (1999), and Weyant and Hill (1999) (which provides a review of international modeling results). Most of these assume completely efficient markets with no transaction costs, but the point is that these cost savings will be realized, albeit slowly, only if the incentive is provided by a mandatory cap in some country.

57. Harrison et al. (2000) provide analyses of the experience with setting baselines in 15 environmental and non-environmental programs and the implications for setting GHG baselines.

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notes

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