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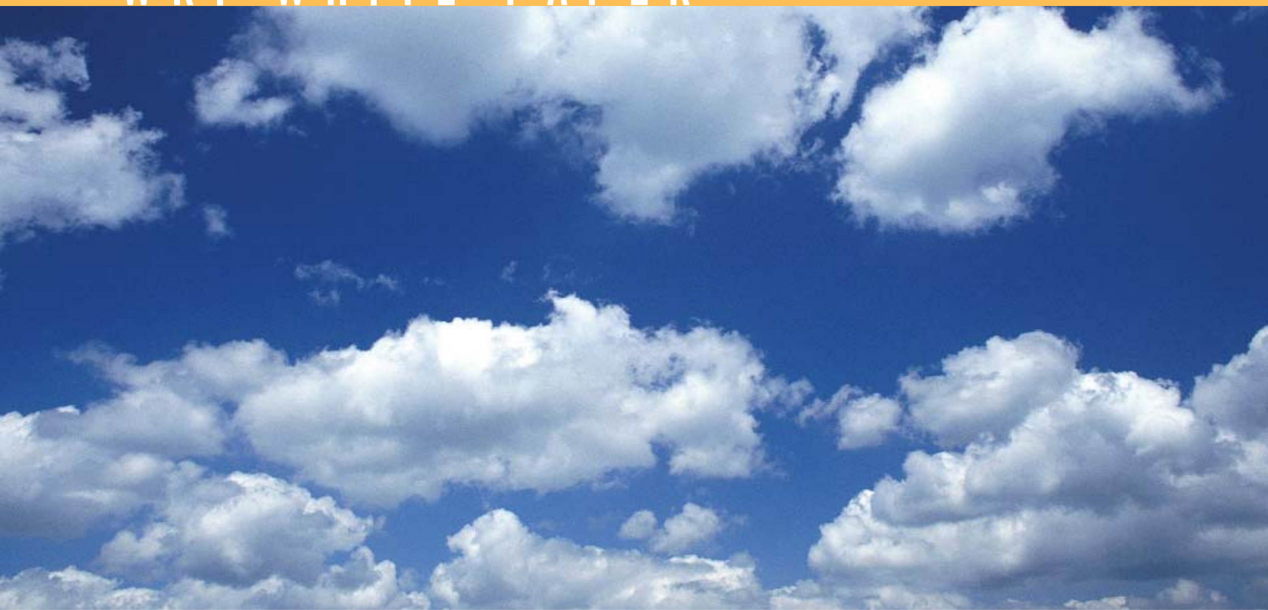

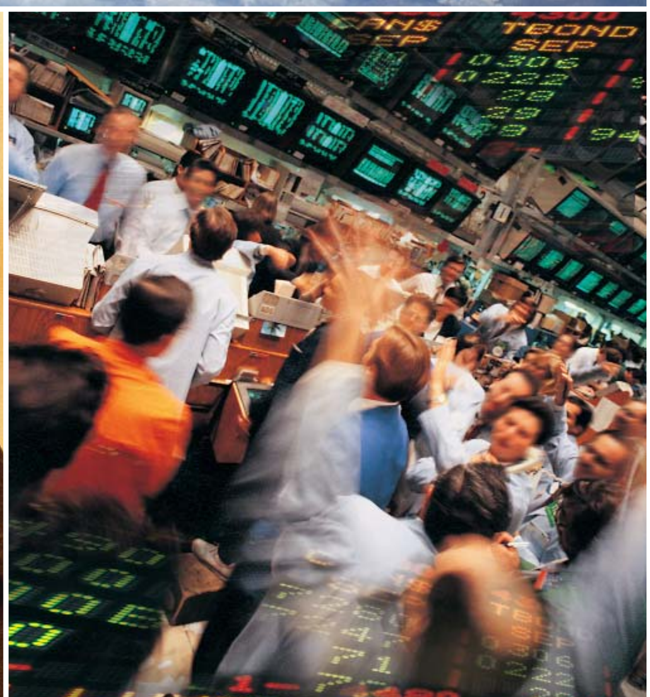

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List of Acronyms

CEM	Continuous emissions monitor
CO_2	Carbon dioxide
EGU	Electricity generating unit
EPA	(United States) Environmental Protection Agency
EU	European Union
GHG	Greenhouse gas
GWh	Gigawatt-hour
MWh	Megawatt-hour
NAAQS	National Ambient Air Quality Standards
NESCAUM	Northeast States for Coordinated Air Use Management
NO_x	Oxides of nitrogen
OTAG	Ozone Transport Assessment Group
OTC	Ozone Transport Commission
RACT	Reasonably available control technology
REC	Renewable energy certificate
RGGI	Regional Greenhouse Gas Initiative
RPS	Renewable portfolio standard
SCR	Selective catalytic reduction
SIP	State implementation plan
SO_2	Sulfur dioxide

Executive Summary

A number of U.S. states are considering market-based policies to reduce emissions of greenhouse gases (GHGs). The experience gained from emissions trading for sulfur dioxide (SO_2) and oxides of nitrogen (NO_x) offers a useful body of information and data to draw on to design a GHG emissions trading system. While many studies have considered the SO_2 experience in detail, this report examines NO_x trading under the Ozone Transport Commission (OTC) NO_x Budget Program. Although this program was motivated by federal law and supported by the federal Environmental Protection Agency, it resulted from the leadership, decisions, and actions by a group of states, ultimately becoming the first multilateral cap-and-trade system for emissions of air pollutants.

The OTC NO_x Budget Program proved to be effective on economic, environmental, and administrative grounds. From 1999 to 2002, annual emissions were significantly reduced and consistently fell below the emissions cap. Compliance with the program was nearly perfect, and it appears that there was little if any leakage, or the displacement of emissions and/or economic activity, from the OTC region to other regions.

The cost of reducing emissions was considerably lower than the initial forecasts, and industrial sources were able to reduce emissions more cheaply than electricity generating units. Despite short periods of price volatility, particularly during the start of the OTC NO_x market, regulators did not intervene with a price cap, nor did participating sources seek regulatory relief in court, and the market routinely stabilized. The program had no discernable effect on the region's economic vitality.

The apportionment of the emissions budget among the OTC states, or the establishment of the state caps, was accomplished in a uniform manner based on heat input. Distribution of allowances to regulated sources was decided by each state, however, with no apparent detriment to the system's performance.

Beginning in 2003, the OTC NO_x Budget Program was incorporated into a larger federal system with similar features. That is, the successful state-based program facilitated the adoption of broader emissions control. Critical to this development was the leadership and innovation by the states, which provided valuable information, data, and a set of committed stakeholders.

For GHG emissions, various aspects of the problem make it well suited to a market-based approach that can spur innovation among a wide variety of sources and sectors. Though there is presently little federal prompting for GHG emissions reductions, the experience with NO_x trading should provide confidence for states to take the initiative. States can start with GHG emissions controls, gain experience, and lead the near-term innovation in emissions control technologies and strategies. Over time, this may facilitate broader control at a national scale commensurate with the reductions required in global emissions.

States should give priority to integrating a broad set of sources and sectors into a GHG emissions-trading system, although initial design and requirements for administrative simplicity may dictate starting with a limited set. This will help reduce costs, achieve the environmental goal, and encourage vital technological innovation. A broad set of participating sources will allow a multistate GHG trading system to remain relevant over time and to improve the likelihood that the system will expand geographically. Innovative policies and emissions-trading design elements, such as allocation, opt-in, set-asides, and offsets, can help achieve these aims.

The target-setting process used in the OTC NO_x Budget Program may not be replicable with GHGs, given the global nature of climate change and uncertainty surrounding the environmental impacts and benefits. It is not clear that the stringency of the OTC NO_x cap can be mirrored in a GHG regime, at least at the outset, although the establishment of a GHG cap is a critical first step toward an evolving, global solution. Setting a cap is recognition of the responsibility to reduce emissions and sends economic signals for innovation and investment in low-emission technologies.

Monitoring and reporting of GHG emissions will require a common set of rules, but the allocation could be left to the states individually with no likely diminution in environmental or economic effectiveness. A multistate GHG trading system would need a central coordinating body to track allowances and assess compliance. This body could be a third party, perhaps overseen by a regional council and backed up by individual state enforcement powers.

To minimize price volatility during the start-up of a GHG market, the states should support price discovery, for example, through a preliminary auction of allowances. Banking GHG allowances can also calm volatility over time by providing liquidity in the market, and banking should be encouraged for GHG emissions trading. The use of price caps is not supported by the experience with NO_x trading.

U.S. states have proved to be effective leaders and innovators of emissions trading, and they can contribute much to U.S. efforts to reduce GHG emissions and the threat of climate change. Experience by states thus far represents a clear encouragement to proceed.

1. Introduction

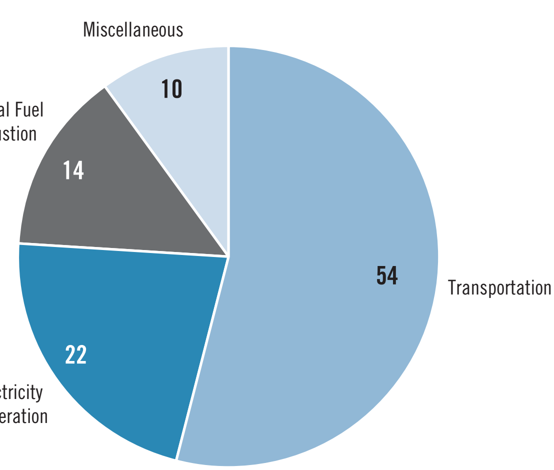
Since the 1970s the United States has sought to reduce air pollution through a succession of far-reaching legislative and regulatory actions, beginning with the federal Clean Air Act and its national ambient air quality standards (NAAQS). The initial approach, known as "command-and-control" regulation, relied on specific technology standards applied by regulators on a source-by-source basis. This method began to recede, particularly for large stationary sources of pollution, when the U.S. Congress enacted the Clean Air Act Amendments of 1990. The amendments include the "Acid Rain Program," which contains a market-based "cap-and-trade" provision for sulfur dioxide (SO_2) (Ellerman et al. 2000). (Cap-and-trade systems are described in box 1.) This market approach succeeded on both environmental and economic grounds (Aulisi et al. 2000). Moreover, it opened the door for additional emissions-trading programs to address other air pollutants, including oxides of nitrogen (NO_x).

NO_x is a pernicious air pollutant that can lead to several forms of environmental degradation and harm to human health and the economy (Burtraw et al. 2001; Metcalfe et al. 1998; National Research Council 1991; Shindell et al. 2003). Most important, NO_x emissions lead to the formation of ground-level ozone, or "smog," which in turn causes both acute and chronic respiratory ailments. Ozone is formed locally during certain periods of time (usually the summer months) under specific conditions of temperature and sunlight. In addition to ozone, NO_x is a leading contributor to the formation of fine particles, tiny airborne solids less than 2.5 microns in length, which can lead to premature mortality. NO_x also contributes to regional haze, eutrophication of water bodies, and acid rain (Grennfelt, Hov, and Derwent 1994). Emissions of NO_x are generally from the combustion of fossil fuels (coal, oil, natural gas) and arise from various economic sectors, as shown in figure 1.

Although ozone originally was thought to be a local problem, in the mid-1970s, evidence of its regional nature began to emerge, and by the 1980s, the phenomenon of "ozone transport" was widely recognized (National Research Council 1991). The movement of ozone from upwind to downwind locations complicated the efforts of downwind states to meet federal air quality standards, including the persistent "nonattain-

Figure 1. NO_x Emissions Sources in the United States, 2002

Percent, 100% = 21.1 million short tons



Source: EPA, National Emission Trends Data (Washington, DC: EPA, 2004)

Box 1. Cap-and-Trade Systems

In a **cap-and-trade system**, the government defines the "cap," or the total amount of pollution that regulated sources can emit over a specified period of time, usually one year. Typically, the cap is set in mass units (usually tons), is lower than the amount of emissions in the past, and shrinks over time. The government creates "allowances" equal in number to the size of the cap and then distributes them to the regulated sources, a process called "allocation." Regulated facilities are periodically required to surrender emission allowances equal to the emissions of the facilities, which is referred to as "true up" or "reconciliation." The government sets the standards for monitoring emissions, establishes rules for how allowances may be used, and determines enforcement. If a regulated source has excess allowances after the reconciliation for a given period, it may be allowed to carry them over to the next period. This is known as "banking" allowances.

The method of allocation is important and varies, depending on several factors. First, the regulator can either give the allowances away for free, known as "grandfathering," or auction them. A combination of grandfathering and auctioning is possible as well. If the regulator grandfathers its allowances, then a performance parameter, such as historic emissions, generation output, and heat input, is needed to prorate the allowances among regulated sources. Allowances are generally distributed at the start of the program—before the compliance period—but the regulator must decide whether to fix the allocation for the duration of the program or allow for periodic updating, for example, based on changes in production.

Because the allocation to each firm is usually less than its previous emissions, regulated firms have four basic options: (1) controlling their emissions to match their allocation exactly; (2) "undercontrolling" and buying allowances to cover excess emissions; (3) "overcontrolling" and selling their unused allowances; or (4) "overcontrolling" and banking unused allowances for use in future years. The reason that companies may buy or sell allowances is that their facilities may have different emissions control costs or they may change their operations so that they would need more (or fewer) allowances. Companies with higher costs will be able to save money by undercontrolling and buying allowances from those with lower costs, which make money by overcontrolling and selling.

The government usually acts as the accountant for the trading systems, by establishing a registry in which the participants are required to report the size of their transactions and the names of the buyers and sellers. This procedure can be made easier by creating a serial number for each allowance. Brokerage and consulting firms complete the picture by providing services to the market participants, including markets in derivative commodities, and by

ment" of the ozone NAAQS in the Northeast. It was clear that regional policies were needed, so in 1990 the U.S. Congress established the Ozone Transport Commission (OTC) under the Clean Air Act Amendments. The OTC[1] was designed to help the Northeast and the mid-Atlantic region reduce harmful ground-level ozone, specifically by cutting precursor NO_x emissions. In 1994, the states participating in the OTC signed a memorandum of understanding to develop a regional strategy for controlling NO_x. The majority of those states eventually chose to use emission trading to reduce emissions from large stationary sources.

The OTC states implemented their strategy in three phases. Phase 1 began in 1995 and relied on the traditional technology standards specified in the Clean Air Act, known as "reasonably available control technology" (RACT). Phase 2 began in 1999 and marked the beginning of emissions trading. Nine of the OTC states and the District of Columbia launched a cap-and-trade system called the "OTC NO_x Budget Program," one of the main subjects of this report. This phase lasted for four years, from 1999 to 2002. Phase 3 was scheduled to begin in 2003 and was designed to continue with emissions trading, but with more stringent emissions caps, specifically a 10 percent decrease in allowable emissions. A broader federal program was instituted, however, known alterna-

1. The OTC consists of representatives from Connecticut, Delaware, District of Columbia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, and Virginia.

Box 1: *continued*

increasing transparency by providing information (including price information) about the markets.

A cap-and-trade system may include provisions known as "opt-ins," "set-asides," and/or "offsets":

Opt-ins: Sometimes called "voluntary compliance," opt-in provisions allow unregulated sources to voluntarily join a cap-and-trade program. The purpose is to attract sources with low control costs, which can lower their emissions below the number of allowances allocated to them and then sell the excess. This desired effect can be counteracted by "adverse selection," in which opt-in sources expect to see their emissions drop below their allocation, for example, owing to a planned equipment upgrade. In this way they can reap a financial benefit (excess tradable allowances) without making reductions in emissions beyond "business as usual."

Set-asides: Set-aside provisions place a fixed number of allowances into a pool that is designated for particular technologies or sources, such as renewable energy, energy efficiency, and combined heat and power technology. Investors in qualified technologies may be granted allowances based on an emissions rate, for example, pounds per MWh in the case of electricity generation. The allowances can then be sold to gain a financial reward for avoiding emissions. The rationale for this type of set-aside is to provide incentives that drive market penetration for new, clean technologies, which in turn can reduce pressure on the emissions cap and thus lower overall costs. Because these allowances are part of the cap, environmental performance remains intact. Set-asides also may be provided for new facilities, or "new entrants." This helps new factories and electricity generators to obtain allowances at reasonable prices, since they need allowances to operate yet compete with the established holders of most allowances.

Offsets: Offset provisions allow investors to develop emission reduction credits from projects involving unregulated sources (emissions sources that are not regulated under the cap). A project investor must demonstrate that the emissions fall below some baseline, usually defined by a regulatory standard. Emissions reduction credits can then be certified and awarded to the investor, who can sell them to sources regulated by the cap-and-trade program. In other words, the credits are "fungible," meaning they can be exchanged with allowances and used for compliance. The purpose of offset provisions is to allow entrepreneurs and technology developers to find innovative, low-cost emission reductions. Like opt-in provisions (but unlike set-asides), offset provisions increase the number of tradable allowances and the size of the cap while regulating additional emissions sources.

tively as the "NO_x State Implementation Plan (SIP) Call" trading program or the "NO_x Budget Trading Program."[2] This system, which established emissions caps similar to those of the OTC's phase 3, essentially incorporated the OTC NO_x program into a larger trading pool that allowed other states to participate (see box 2).

The market-based approach is now being considered for another type of pollution: greenhouse gas (GHG) emissions, which cause climate change. As policymakers work to design and implement GHG trading systems, the experience with emissions trading thus far provides useful information. All cap-and-trade systems contend with similar design issues and implementation hurdles, including the emissions sources to be covered, the level and timing of emission reductions, market development, and the political economy. A number of studies have reviewed the SO_2 trading experience to gain insights into GHG trading (Ellerman et al. 2003; Tietenberg 2003). This report looks at the OTC NO_x Budget Program, which has not been as widely reviewed, but perhaps is more relevant to the current political context. In particular, the OTC NO_x Budget Program set an important precedent: the successful negotiation by multiple jurisdictions to establish a shared emissions-trading program that would eventually be expanded to other jurisdictions. More generally, lessons from the OTC NO_x experience are applicable to GHG trading, given that (1) the challenge to reduce

2. In 1998, the EPA finalized the "NO_x SIP Call" to mitigate the transport of NO_x and to support attainment of the NAAQS for ozone. For states opting to meet the obligations of the NO_x SIP Call through a cap-and-trade program, the EPA included a model rule called the "NO_x Budget Trading Program" specifically for large stationary sources of emissions. For clarity, this report uses the term "NO_x Budget Program" to refer to the state-led OTC effort.

Box 2. The OTC NO_x Budget Program and the Federal NO_x SIP Call

Concerns about regional air pollution led to the creation of two cap-and-trade systems in the eastern United States: the OTC NO_x Budget Program and the federal NO_x SIP Call. The states participating in these programs are shown in figure 2. Both systems were designed to help these states meet the federal NAAQS for ozone.

The OTC NO_x Budget Program was a state-led effort created within the framework of federal/state air quality management (Portney and Stavins 2000). Based on a memorandum of understanding among the states (signed in 1994) and a subsequent "model rule" for emissions trading (issued in 1996), nine states and the District of Columbia coordinated a set of laws and regulations to form a regional cap-and-trade system, which began operating in 1999. Three states in the OTC chose not to participate in the program: Maine and Vermont had so few sources that they felt it was not worth the effort to develop the necessary regulations and instead enacted more traditional controls. Virginia had already achieved the ozone air quality standards by the late 1990s and so did not enact any NO_x control program. Maryland delayed its participation until 2000 because of a legal challenge.

Although the OTC NO_x Budget was designed to help the states meet federal requirements for air quality, it was not federally mandated or scripted by a federal regulatory process. Rather, the role of the federal government in the program was largely about technical assistance. The EPA helped draft the model rule, developed data systems for the program, and accounted for emissions and allowances once the program was running. In addition, the OTC NO_x Budget relied in part on requirements in Title IV of the 1990 Clean Air Act Amendments (the Acid Rain Program) for continuous emission monitors (CEMs), with which most sources were already equipped.

At roughly the same time that the OTC states were designing their NO_x trading program, a broader effort was under way to expand emissions controls throughout much of the eastern United States. The OTC states, together with a number of midwestern states that also were facing air-quality problems, led a multistate study of ozone transport known as the Ozone Transport Assessment Group (OTAG). This was partly an attempt to create a larger state-led cap-and-trade emissions control program for NO_x (Arrandale 2000; Farrell and Keating 2002). The OTAG worked for two years (1995–97) but was unable to develop broader emissions controls because many states contributing to the regional ozone problem, for example, Ohio and Kentucky, would not participate voluntarily. These states did not have local ozone problems at the time and were not willing to impose emissions reductions on local sources solely for the benefit of downwind states.

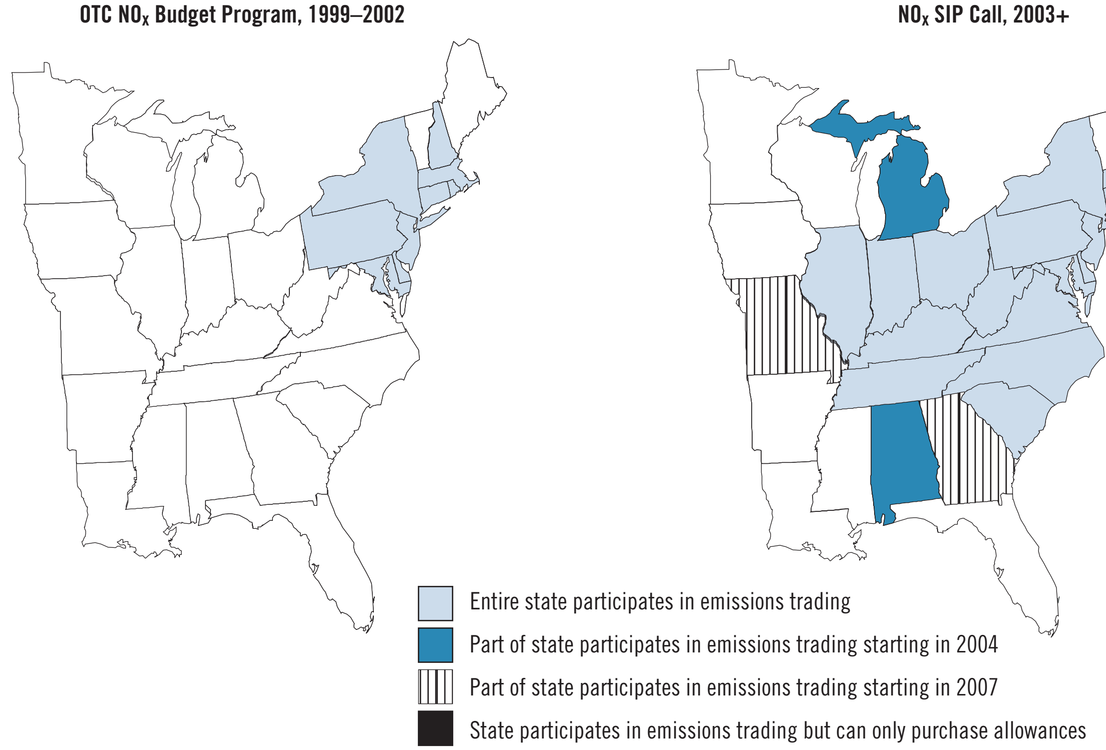
After OTAG failed to arrive at a consensus on new controls, eight northeastern states filed petitions with the EPA to reduce the transport of ground-level ozone pollution. The petitions, which were based on section 126 of the Clean Air Act, asked the EPA to make a finding that upwind sources of NO_x emissions, particularly in the Midwest, were exacerbating ozone problems in the petitioning states. At the same time, the EPA was revising the NAAQS for ozone and making the standard more stringent, thus necessitating greater emissions controls for many eastern states. Shortly after the "126 petitions" were filed, the EPA issued its "NO_x SIP Call," requiring significant emissions reductions by 22 eastern states and the District of Columbia and encouraging them to set up trading programs to achieve the reductions and satisfy the stricter NAAQS. Lawsuits ensued, most notably American Trucking Association v. Whitman, suggesting the futility of the earlier voluntary approach. Eventually, however, the EPA's actions were upheld. The NO_x SIP Call emissions-trading program essentially began in 2003, but only the OTC states were ready to participate, given their existing system. Full implementation of the NO_x SIP Call trading program did not take effect until May 31, 2004.

GHG emissions is both significant and urgent, (2) GHG emissions are particularly well suited to the market approach, and (3) regulators in the United States and abroad are proposing trading as a way to reduce emissions.

GHG emissions come from a wide variety of sources and sectors. They are predominantly in the form of carbon dioxide (CO_2) emissions from the combustion of fossil fuels but also include significant and important sources of methane (CH_4), nitrous oxide (N_2O), and other gases. In aggregate, these emissions can be categorized by economic sectors, as figure 3 illustrates. Note that more than half of U.S. GHG emissions come from large stationary sources.

As GHG emissions accumulate in the atmosphere, they trap additional heat from the sun. This warming

Figure 2. States Participating in the OTC and NO_x SIP Call Programs

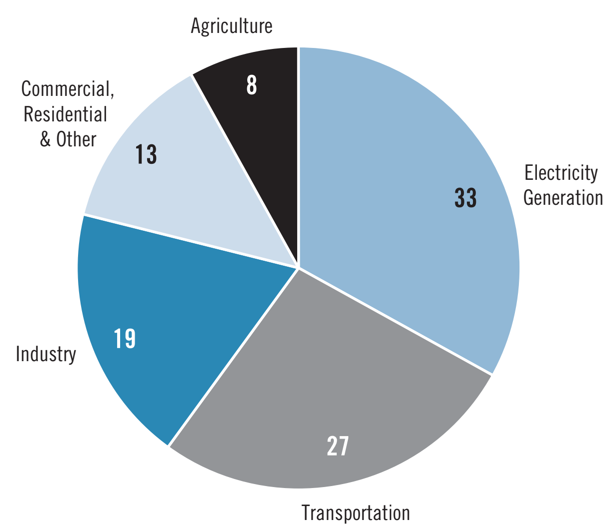


effect changes the global climate system, which in turn poses significant threats to the environment, the economy, and people. It is estimated that deep, near-term, and sustained cuts in global GHG emissions will be required to stabilize atmospheric concentrations at a level that averts dangerous climate impacts (O'Neill and Oppenheimer 2002). Global emissions may need to be cut by 50 percent or more from current levels, which will require enormous changes, especially in the way that energy is consumed throughout the global economy.

This challenge has led to a variety of proposals for GHG emissions trading. GHGs are particularly well suited to the market-based approach because they do not directly cause acute, short-term, or localized impacts. Rather, the concern is for long-term accumulation of GHGs in the global atmosphere and the long-term damages that may arise. Accordingly, the location and timing of emissions reductions can be flexible, which a market system allows.

Figure 3. GHG Emissions Sources in the United States, 2002

Percent, 100% = 6,935 million metric tonnes



Source: EPA, Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990–2002 (Washington, DC: EPA, 2004)

Proposals for GHG emissions trading are being considered at the international, federal, and state levels. The Kyoto Protocol on climate change has been ratified by more than 130 countries and relies on a market structure that allows international emissions trading. Although the Bush administration pulled the United States out of the Kyoto negotiating process in 2001, the majority of the world's countries have approved the treaty and will comply with its rules as international law when the agreement enters into force in February 2005. The Kyoto Protocol also is a driving force behind the European Union (EU) Emissions Trading System for GHGs, which took effect on January 1, 2005. This system will cover all 25 EU member countries, including large economies such as France, Germany, Italy, and the United Kingdom. Emissions-trading systems are also being weighed in Canada and Australia.

In the United States, though, even as the scientific understanding of climate change strengthens, the political will at the federal level to regulate emissions remains weak. In 2003, the McCain-Lieberman Climate Stewardship Act proposed a national emissions-trading system, but it was defeated in the U.S. Senate by a vote of 43 to 55. Even though supporters of the bill have promised to reintroduce it in both the Senate and the House, it may take years and possibly a change in administration before the measure could become law. Opponents of the bill often cite concern about economic costs, and while the literature on this subject offers widely ranging estimates, recent research suggests that the costs of the McCain-Lieberman bill could be modest (Paltsev et al. 2003).

In the absence of federal action, many U.S. states have taken the lead on GHG regulation (Rabe 2004). California has proposed regulating CO_2 emissions in the transportation sector and is coordinating a regional approach to GHG control with Oregon and Washington. The most advanced trading initiative is that of the northeastern and mid-Atlantic states, known as the Regional Greenhouse Gas Initiative (RGGI).[3] Through negotiation and agreement, these states are proposing to regulate CO_2 emissions from power plants through a regional cap-and-trade system. The framework for this system is to be designed by 2005, followed by individual state rule-making procedures. When the system is launched, it will likely be the United States' first mandatory GHG-trading program. As a result, RGGI may well influence future federal policies, which is a critical issue. Given the global nature of climate change and GHGs, the long-term relevance of multistate GHG trading systems is tied to their ability to expand to broader control of emissions. This expansion may be to different types of emissions sources, gases, and geographic scope, including linkages to other GHG-trading systems. In contrast, a narrowly focused multistate program among a limited group of participants is likely to become obsolete over time.

3. See **http://www.rggi.org**. Participating states are Connecticut, Delaware, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont. Maryland, the District of Columbia, Pennsylvania, the eastern Canadian provinces, and New Brunswick are observers in the process.

2. Review of the OTC NO_x Budget Program

The world's first multilateral cap-and-trade system was the OTC NO_x Budget Program (Farrell 2000; OTC/EPA 2003). It operated successfully between 1999 and 2002, after which it was incorporated in the federal NO_x SIP Call program administered by the EPA (box 2).

Although the OTC NO_x Budget used a cap-and-trade approach similar to that of the Acid Rain Program for SO_2, it was not a federally organized system but a set of coordinated state laws and rules. These rules were based on a template, known as a "model rule," which was written by state representatives from the north-eastern and mid-Atlantic regions in cooperation with the EPA. Once the model rule was completed, it then was modified to fit each state's specific circumstances before it was adopted. The details of the model rule were crucial, since they needed to be defined narrowly enough to yield a consistent regulatory program yet be flexible enough to suit the interests and local politics of each jurisdiction.

The OTC states already had a history of working cooperatively on air-quality management, dating from the debates on acid rain in the 1980s. This cooperation led to a network of organizations, personal relationships, technical competencies, and trust. The development of the model rule began in late 1994 when the level and timing of emission reductions were set. The technical/political negotiation process that followed was designed to determine whether emission trading would be used as part of a multiphase approach. In early 1996 the model rule was published (Carlson 1996), and the OTC states began to write their own rules, finishing by the end of 1998 and thus allowing the NO_x Budget to start in May 1999.[4]

The OTC NO_x Budget applied to electrical generating units (EGUs) of 15 or more megawatts[5] (MW) and similar-size industrial facilities, for example, process boilers and refineries, with a heat input rate of 250 or more mmBtu per hour. In total, more than 900 EGUs and more than 120 industrial units were affected, involving more than 100 different facility owners. Despite the large number of facilities, these large stationary sources represented less than half the region's total NO_x emissions.

The emissions control period was defined as the five months from May through September, which is known as the "ozone season." From 1999 to 2002, the NO_x emissions cap for the ozone season was set at 219,000 tons. This amount represented a decrease of 25 percent compared with emissions levels in the mid-1990s, when the OTC states were using the technology standards required under the Clean Air Act, specifically "reasonably available control technology" (RACT) to reduce NO_x emissions.

4. Some regulated sources felt this was premature because the rules were not in place in several states until a short time before the first ozone season began and because the engineering, procurement, and construction of NO_x control technologies could take several years. The regulators, however, disagreed with this objection, noting that if the emission trading program had not come together, similar command-and-control regulations that had been in place for several years would have taken effect at about the same time.

5. In the subsequent NO_x SIP Call trading program, the threshold for EGUs was set at 25 MW capacity, although some states in the OTC opted to maintain the inclusion of sources at 15 MW and greater.

To monitor and track both emissions and the tradable allowances, the NO_x budget program benefited from existing systems and the EPA's past experience. Under the Acid Rain Program, requirements were already in place for continuous emissions monitors (CEMs) for NO_x emissions from EGUs with a capacity of more than 25 MW, which meant that the only new monitoring rules needed were for smaller EGUs and industrial sources. In addition, the OTC asked the EPA to help develop and manage the data systems for the NO_x budget program. The EPA agreed to determine the data systems' requirements, to select a contractor to create the data systems, to oversee the contractor's work, and, eventually, to maintain the data systems and the accounts used by the regulated sources. The EPA's motivation for helping the OTC, and specifically for creating the NO_x data systems, was the potential expansion of the OTC program to additional states, and thus the development of a larger trading system to address the nonattainment of the ozone NAAQS in the eastern United States (Donovan et al. 1996; Schary and Culligan 1996).

After some debate about accounting rules for NO_x allowances, the states adopted a serialized approach. That is, each allowance that a state created would receive a unique serial number assigned by the EPA. They rejected the other options—individual state serial numbers and unserialized approaches—concluding that state-by-state serial numbers would be too complicated and unserialized approaches would require more oversight. Having selected the EPA rather than a private firm as the accountant, the states left a key part of an environmental regulatory program in the hands of the government, as they could not see any advantage in having competing private accounting systems. Other than the accounting by the EPA, the OTC NO_x Budget Program has no market oversight comparable to, for example, that of the Securities and Exchange Commission for the New York Stock Exchange or the Commodities and Futures Trading Commission for the Chicago Mercantile Exchange. Private emissions traders and brokers have been able to operate successfully in this environment.

As originally spelled out in the model rule and as implemented in the various state rules, the OTC NO_x Budget was to continue after 2002 with a lower cap that required further reductions. However, the geographic scale of NO_x transport and ozone pollution turned out to be larger than that of the OTC states. The EPA issued its NO_x SIP Call in 1997 and went on to win a number of legal challenges, the effect of which extended to a total of 22 states the level of emission reductions that would have taken effect under the OTC NO_x Budget starting in 2003. Thus, a state-based cap-and-trade program evolved into a federal program with similar features.

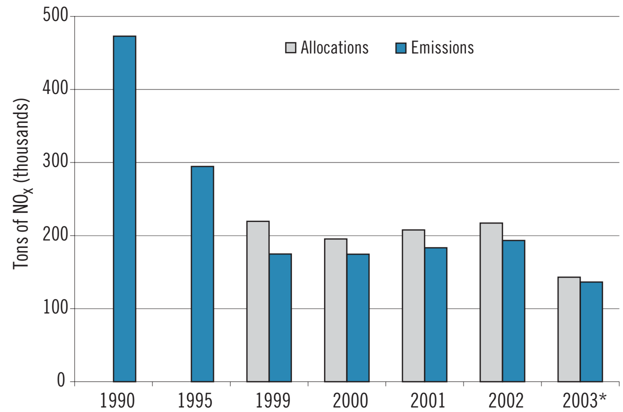
ENVIRONMENTAL OUTCOMES

Figure 4 and table 1 illustrate the OTC NO_x Budget Program's most important accomplishment: the reduction of seasonal emissions. Figure 4 shows the total annual allocations, or the total number of allowances provided to regulated sources each year, compared with the total emissions during the May-to-September ozone period. For historical reference, figure 4 also shows emissions in 1990 and 1995. The implementation of RACT technology standards in the mid-1990s greatly reduced NO_x emissions, usually by installation a control technology called a "low NO_x burner," sometimes in combination with overfire air. Once RACT had been instituted, though, the OTC states turned to emissions trading to deliver additional reductions.

Figure 4 shows that emissions were always below the number of allowances that had been distributed. In fact, regulated sources "overcontrolled" by an average of 13.5 percent. More than 110,000 tons of NO_x that could have been emitted into the atmosphere were either delayed or avoided as banked tons were either used or expired, respectively. By 2002, emissions were 34 percent lower than in 1995. For the four years that the OTC NO_x Budget was in place, emissions were more than 60 percent lower than the 1990 base year emissions.

In regard to the year-to-year changes in figure 4, two factors deserve mention. First, the drop in allocations between 1999 and 2000 is largely explained by the discontinuation of early reduction credits. Second, the rise in allocations in 2001 and 2002 is largely the result of regulating, for the first time, additional sources in Maryland under the NO_x Budget. Nonetheless, the overall environmental outcome is clear: substantially reduced emissions of NO_x. In 2003, a more stringent allocation took effect with the transition to the NO_x SIP Call, and the OTC states adapted smoothly. Emissions continued to fall, dropping by about 30 percent from 2002 values.

Figure 4. Total Allocations and Emissions, OTC NO_x Budget Program



* In 2003, the OTC NO_x Budget Program was incorporated into the federal NO_x SIP Call.

Source: OTC/EPA, OTC NO_x Budget Program: 1999–2002 Progress Report (Washington, DC: OTC, 2003); EPA, OTC NO_x Budget Program Compliance Reports (Washington, DC: EPA, 2000–2003).

Figure 5 presents a more detailed analysis of environmental performance from 1998 to 2001 for participating EGUs in the Pennsylvania-New Jersey-Maryland (PJM), New York, and New England power pools. This includes all power plants in New England, New Jersey, New York, Delaware, and some of those in Pennsylvania. While this is not the entire universe of sources in the OTC NO_x Budget, it is the largest set for which straightforward comparisons can be made. Various measures of performance were compared using plant-level data for this period. The data in figure 5 were normalized to allow all relevant values to be shown. Five measures of environmental performance are illustrated, along with the amount of electricity generated during the relevant ozone periods. The basis of comparison was 1998, which took into account all the reductions of emissions between 1990 and 1998 achieved using RACT.

Table 1. Total Allocations and Emissions, OTC NO_x Budget Program

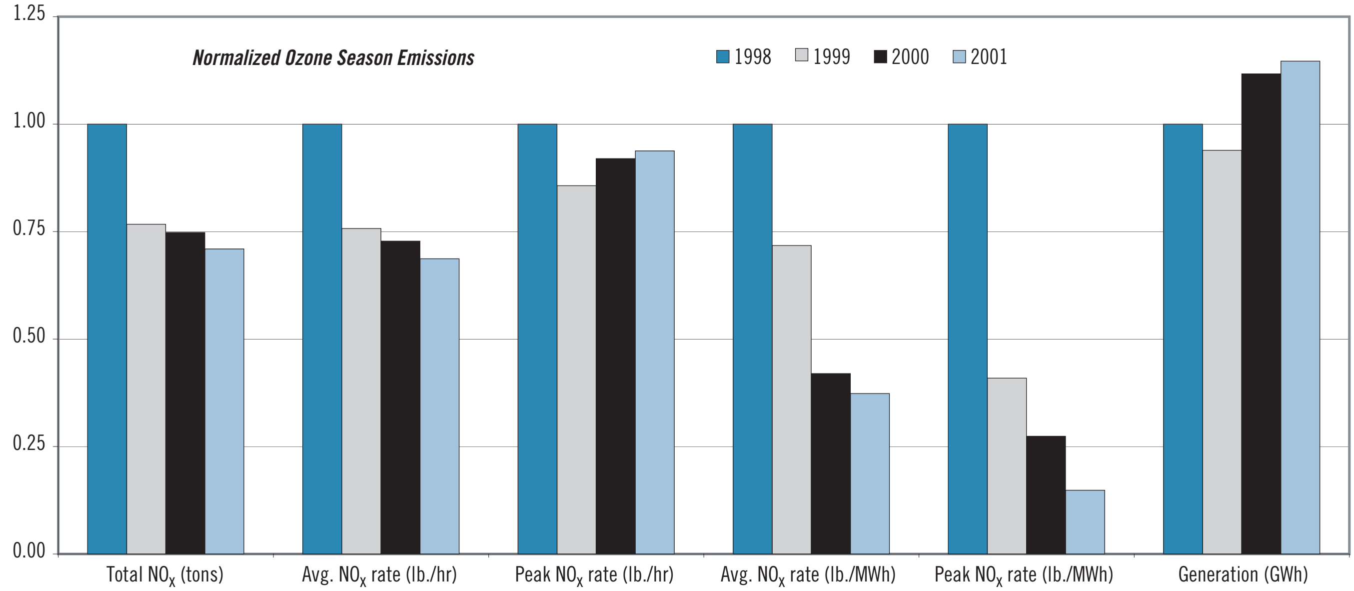
	1999	2000	2001	2002
Total allocation (tons)	219,438	195,398	207,756	217,175
Total emissions (tons)	174,843	174,492	183,283	193,393
Unused allowances (tons)	44,595	20,906	24,473	23,782
Percent unused allowances	20	11	12	11

Source: EPA, OTC NO_x Budget Program Compliance Reports (Washington, DC: EPA, 2000–2003).

The emissions from EGUs declined (from left to right in figure 5) in each of the first three years of the OTC NO_x Budget, with the average drop from the 1998 emission levels of the NO_x RACT program being more than 25 percent. The next four sets of measures are emissions rates, either emissions per hour or emissions per megawatt-hour (MWh) of net electricity generated and provided to the grid. These provide different perspectives on how the OTC NO_x Budget performed. Generally, the data indicate good performance. The average emission rates fell each year, and both average and peak emission rates per MWh of generation fell substantially, by an average of more than 50 percent from 1998 levels from 1999 to 2001. Note that the large declines in emissions per generation were driven by the combined effects of decreasing emissions and increasing generation. This is a good example of one of the chief benefits of cap-and-trade regulation: the cap helps maintain environmental protection goals while still allowing for greater economic activity. If command-and-control approaches had been used, the emissions would likely have first fallen in 1999 when the new regulation took effect and then gone up as the generation increased.

This, in fact, is the pattern seen in the peak emission rate, NO_x lbs/hour, recorded over any single hour during the ozone season. This performance measure

Figure 5. Measures of the OTC NO_x Budget Program's Environmental Performance (normalized)



Note: Includes representative EGUs only.

Source: EPA, CEMs data.

first drops by about 15 percent from 1998 to 1999 and then rises again, although never back to 1998 levels. This pattern is of concern because smog is an episodic problem in the eastern United States where the highest concentrations and the greatest health risks occur during a few short periods over two to five days. These "ozone episodes" tend to happen on hotter days, which is also when electrical generation usually peaks. The higher peak emission rates shown in figure 5 may not, however, be a health concern, for two reasons. First, these peak rates do not always occur during ozone episodes, depending on the emissions profile of the peak generating units in a given state. Second, the peak rates are short-term phenomena lasting only an hour or two. Thus, the total number of EGU NO_x emissions during ozone episodes between 1999 and 2001 was smaller than that during ozone episodes in 1998, and the average emission rates were generally lower as well.

Another measure of the OTC NO_x Budget's environmental effectiveness is compliance. One virtue of this program is that it requires rigorous monitoring of emissions, which can be difficult with the command-and-control style of regulation. Because of the monitoring, cap-and-trade regulation makes the probability of detecting noncompliance relatively high. In addition, because the penalties for noncompliance are strict and sure—an automatic three-to-one penalty deduction for each ton of emissions over a unit's allowance holding—there is little room for legal or other arguments about why penalties for any specific instance of noncompliance should be reduced or waived. These features create strong incentives for compliance, which, not surprisingly, was high with the NO_x budget program, more than 99.99 percent (table 2). In comparison, many air-quality programs are assumed to have compliance rates, or "rule effectiveness" rates, of 80 percent or so (EPA 1992).

These analyses suggest that the OTC NO_x Budget functioned as it was designed to do, lowering regional emissions during the ozone season between May and September, including episodes of especially high ozone concentrations. There also is evidence that peak ozone concentrations in the OTC region diminished between 1999 and 2002 and that no significant differences were measured at the state level.

Table 2. OTC NO_x Budget Program Compliance Data

	1999	2000	2001	2002	Cumulative Total
Number of units in non-compliance	1	2	5	6	14
Emissions in excess of allowance holdings (tons)	1	6	19	56	82
Penalty allowance deductions for non-compliance (tons)	3	18	57	168	246
Percent non-compliance (excess emissions relative to total annual allocation)	0.0005	0.0031	0.0091	0.0259	0.0010

Source: EPA, OTC NO_x Budget Program Compliance Reports (Washington, DC: EPA, 2000–2003).

Moreover, counties in the OTC region with the highest historic NO_x emissions tended to achieve the greatest level of reductions (EPA 2004c), which alleviates concern that emissions trading could result in concentrated areas of high emissions, or "hot spots."

LEAKAGE

The issue of "leakage" applies to both environmental and economic concerns. The term generally refers to the migration of emissions from a regulated to an unregulated geographic area (emissions leakage), but it also may refer to the related migration of economic activity (economic leakage). Leakage thus poses two problems: a less effective environmental program and a drop in economic activity, including employment.

In the case of the OTC NO_x Budget, leakage could have been a significant problem if it had increased NO_x emissions from upwind electric power generators, thus aggravating the situation that the program was designed to remedy. In addition, the restructuring of the electric power industry in the 1990s made leakage more likely. That is, restructuring allowed low-cost, high-emitting electric power plants in upwind midwestern states, like Ohio, to become sources of power for the OTC states. As a result, the regulated activity (electricity generation) was potentially able to avoid environmental regulation by moving from the OTC region to upwind states, but because of prevailing winds, the emissions could be transported back to the OTC region anyway.[6]

There is some evidence that a small amount of emissions may have leaked from the OTC region into Maryland during 1999 (J. Bluestein, personal communication, 2004). Beyond that, however, there is little to suggest that leakage was a problem, because the economic incentive to avoid environmental regulation is small compared with other financial incentives. The average cost of NO_x control under the OTC NO_x Budget is only \$0.1 to \$0.2 per MWh, or less than 1 percent of the average wholesale price of electricity, although on a marginal basis it could have been somewhat higher.[7] In contrast, the differences in retail prices for electricity could be more than \$20 per MWh (EIA 2000, 2002; Farrell 2001). This difference alone appears to have raised imports of electricity from the Midwest to the OTC region between 1995 and 1996 as restructuring proceeded (EIA 1997a & b; NESCAUM 1998). Thus, although the costs of the OTC NO_x Budget varied from generator to generator, in aggregate they changed the economic incentives of generators relatively little.

When evaluating the potential for leakage, it also is useful to consider the Pennsylvania-New Jersey-Maryland (PJM) power pool. The PJM is a voluntary coordination organization that operates the electric power transmission system in these three states plus Delaware and Washington, DC. About half the NO_x

6. Leakage is not necessarily a problem with emission trading per se because any regulatory program can be affected by leakage. In fact, because emissions trading can be more flexible and less expensive than command-and-control regulation, it may be less susceptible to leakage.

7. Based on electricity prices in the Northeast in 2000.

emissions in the OTC region come from power plants scheduled through the PJM, and the PJM pool is electrically connected to both upwind states (to the west and south) and downwind OTC states (to the north and east) where leakage is a concern.[8] Changes in the PJM during the OTC NO_x Budget period, therefore, are one indicator of possible emissions leakage. For example, net electricity imports into the PJM between 1999 and 2003 fluctuated between 7 and 10 percent, which was not very different from that of previous periods, suggesting little leakage. This is a rough indicator, though, especially because the area covered by the PJM actually grew over this time.

Another way to assess leakage is to examine electricity supply and demand inside the OTC region. Electricity generated by major fossil-fired units inside the OTC region fell from 1997/98 to 2000/01 by less than 0.5 percent. During the same time, nuclear generation inside the OTC region rose by more than 5 percent, while electricity demand rose during this period by slightly less (EIA 2002). Overall, therefore, the electricity supply and demand inside the OTC states during the OTC NO_x Budget remained balanced at about the same point it had been before, with no significant decline in fossil-fueled generation. Since there appears to be no substantial increase in imports into the PJM to match the increases in electricity demand since the start of the OTC NO_x Budget, it does not appear that the leakage was significant.

ECONOMIC OUTCOMES

This report evaluates three economic outcomes of the OTC NO_x Budget: (1) the allowance market, which reflects the marginal costs of emissions control; (2) electricity markets in the OTC region; and (3) the overall performance of the OTC states' economies.

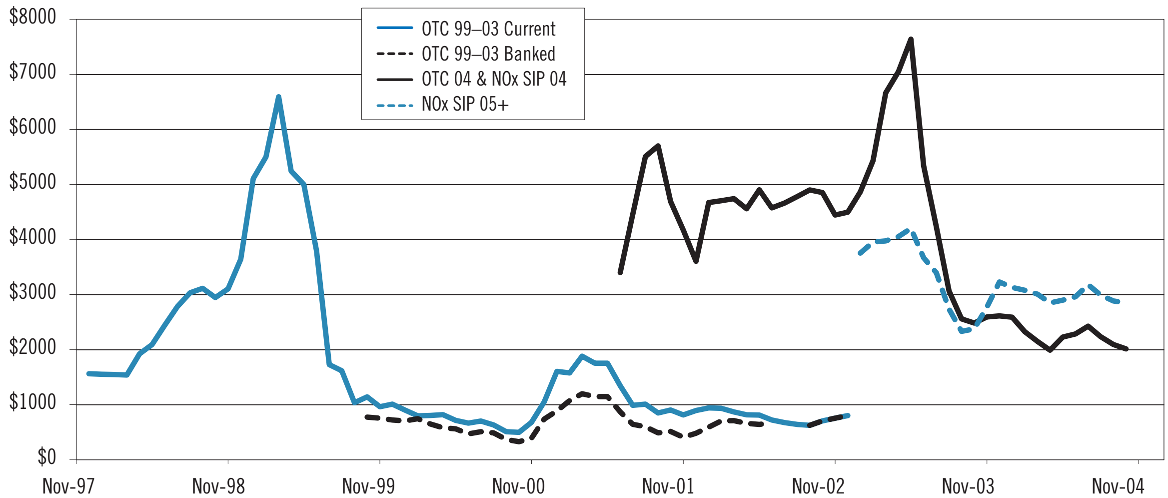
The allowance market

The OTC NO_x Budget had several distinctive features in relation to the development of its allowance market. First, the program had three phases. Phase 1 adopted the existing federal RACT performance standard, and phases 2 and 3 evolved into progressively stringent emission trading. Second, the OTC NO_x Budget had no methods for early price discovery before it went into effect. In contrast, the Acid Rain Program for SO_2 had a set of auctions several years before the regulatory period started. Although these auctions were criticized for not providing the most accurate and useful price information, they were helpful to market participants and facilitated the program's start-up. Third, banked allowances in the OTC NO_x Budget were slightly discounted because of a regulatory provision known as "flow control," which was designed to prevent spikes in emissions that would increase the formation of ozone. We will not discuss the details of flow control here except to note that flow control created some additional uncertainty and made banked allowances less valuable than current or future year allowances.

The prices of NO_x allowances were forecast by the EPA, various consultants, and other researchers. Generally, the costs in phase 2 were expected to be around \$1,200 to \$2,400, and the costs in phase 3, around \$2,500 to \$3,500 (Dorris et al. 1999; Farrell et al. 1999; ICF Resources 1995; STAPPA/ALAPCO 1994). Specific forecasts depended on highly variable factors such as the relative prices of gas and coal, but they were limited to some extent by relatively well understood economics of NO_x control engineering and technologies (Colburn, 1996). By the time that NO_x trading started in 1999, the RACT implementation phase had already captured a significant amount of "low-hanging fruit," or inexpensive emissions reductions, specifically through the use of low NO_x burners, sometimes in combination with overfire air. These control options were relatively cheap. For large, coal-fired utility boilers, costs ranged from \$100 to

8. On the north side of the OTC region, the electric power systems of New York and New England are connected to Canada, which exports mostly clean hydropower, so the leakage of emissions into Canada is not a major concern.

Figure 6. Market Prices, OTC NO_x Budget Program (nominal dollars)



Source: Argus Air Daily. For more information contact: airdaily@argusmediagroup.com. Further use of this data is prohibited without prior written consent.

$400 per ton of NO_x reduced (EPRI 2000); and for industrial boilers, the costs for retrofits were under $800 per ton (Amar and Staudt 2000). But once the RACT had been implemented, the remaining technology options for achieving additional reductions, such as selective catalytic reduction, became more expensive. The advent of trading was intended to provide flexibility to help alleviate the higher projected costs associated with these technologies.

Figure 6 shows the prices for NO_x allowances in the OTC NO_x Budget market from 1997 to 2004. Although the prices were quite volatile at the outset in 1999, most NO_x allowances sold at prices well below the forecasts. Since 2003, the NO_x allowance market has been incorporated in the federal NO_x SIP Call program. The effects of the changes in program status are clear. Note that trading takes place year-round, even though NO_x allowances are required to cover emissions only during the May-to-September ozone season.

A small amount of emission trading began in early 1998 as some regulated sources came to believe that the program would go ahead and that they could take advantage of the opportunity either to lower costs or perhaps even to generate revenue through allowance transactions. Trades began at about the level that most forecasts had predicted, approximately $1,500 per ton. During the middle of 1998, it became clear that most OTC states would in fact implement the NO_x budget in 1999. By the end of 1998 and the beginning of 1999, average monthly allowance prices had risen to more than $5,000 per ton, far above the cost of control for any regulated sources. Market participants thought that the market was short, meaning that together the regulated firms might not have installed enough emissions control equipment to meet the cap.

When the market participants came to this realization near the end of 1998, they did not have enough time to install control equipment for the upcoming ozone season. Some participants in the NO_x market also were surprised to find that the experience of the SO_2 market (low prices and an abundant supply of allowances) would not be repeated. These factors added up to a tight allowance market with an insufficient supply of allowances relative to demand. Allowance prices naturally rose. Only a few economically significant trades, meaning trades among different firms, took place during this period of high prices. It is not clear whether the program's multilateral nature (the multiple-state allocation plans) contributed to the uncertainty surrounding the availability of allowances, and therefore also the initial price spike, although this may be a useful area for additional research.

Prices stayed high for several months but fell back to the predicted range by July 1999 and to about $1,000 per ton by the end of the year. Several factors accounted for this decline. First, early reduction allowances began to enter the market, starting with New Hampshire's allowances in early April, followed by large distributions to New York and New Jersey. This dramatically expanded the supply of allowances. Second, several firms found that when they were given incentives, they could install additional emissions control equipment more quickly. Unexpected and much faster-than-normal installations of controls on plants in Massachusetts, New Hampshire, New Jersey, and Pennsylvania reduced the demand for allowances. Third, a lawsuit in Maryland further diminished the demand by removing, albeit temporarily, from the market those power plants that were expected to be net buyers of allowances.

The response of the state governments and regulated sources during the early price spike demonstrates the advantages of a cap-and-trade system. Regulators stood by the market system despite the high prices. They did not try to impose price caps, or price "safety valves," that would set a ceiling on allowance prices, effectively allowing the plants to exceed their emissions allowances in exchange for paying a fixed penalty (see, e.g., Pizer 1999). Firms also used the market to work out their difficulties rather than challenge them in court. In contrast, under a command-and-control system, uncertainty and delays would have caused industry to seek regulatory waivers (sometimes called "regulatory relief"), which in turn would have diminished the program's environmental effectiveness. Although a few firms faced higher costs, other firms gained a windfall, so the overall effect was relatively small. Most important, the OTC NO_x Budget provided powerful economic signals that the prudent management of NO_x emissions could reduce compliance costs.

Subsequently, the OTC NO_x market matured. Emission trading became more common, and prices became less volatile. For the remainder of the period that the OTC NO_x Budget was in force (2000–02), prices averaged slightly below $1,500 per ton. In addition, the prices for banked and for current-year allowances reflected the flow control restrictions on using banked allowances. Thus, the market was able to adapt readily to a complex regulatory issue. Most of the allowances sold between 1999 and 2002 for phase 2 of the program traded at prices below the range that had been forecast before their implementation.

By the middle of 2001, regulated sources were already looking ahead to the more stringent cap that would be in place in 2003, the phase 3 period. Although it was expected and later proved to be true that phase 3 would be replaced by the NO_x SIP Call, regulators in the OTC states had begun to issue rules governing how banked allowances from the OTC NO_x Budget would be converted to use for NO_x SIP Call compliance. Again, the market adapted readily.

Some firms, however, that were to be regulated under the NO_x SIP Call turned to lawsuits and delaying maneuvers. The resulting pattern of expectations and court-issued complications to the original regulations led to uncertainty that again drove up prices, this time to more than $7,000 per ton. Again, this was higher than predicted. In addition, uncertainties about the performance of new emissions control technologies added to the desire of some regulated sources to buy allowances. By early 2003, allowances in the NO_x SIP Call market itself had started to trade at relatively high prices, about $4,000 per ton, for similar reasons. But these prices quickly fell back to the $2,000-to-$3,000 range, which was at the low end or below the range predicted before the market's implementation.

Electricity markets in the OTC states

Using average values for the 2000 ozone season, NO_x emission allowances were priced at $0.40 per MWh. Electricity prices averaged $42 per MWh and peaked at more than $1,500 per MW in at least one market. Given these prices, it is likely that power plant operators would favor reliability in generating electricity over slight changes in the emissions control equipment to optimize NO_x control costs. Interviews with plant operators and environmental managers of power companies indicated that this was the case. They emphasized generating electricity to meet contract requirements and/or spot market demands, not trying to come as close to the emission limits as possible. They agreed, too, that the structure of contracts in electricity markets tended to reinforce this effect, since they punished both over- and undergeneration relative to the amount promised in day-ahead markets.

It is not possible to observe the average cost of controlling NO_x emissions, since this information is proprietary to each firm. But long-run market allowance prices can serve as a proxy for long-run marginal control costs, which tend to approach average costs. Using the emissions for 1999 to 2001, a high estimate of allowance prices ($1,500 per ton), and 1998 base-year emissions, we can roughly calculate the total cost of emission controls beyond the NO_x RACT program. This estimate is subject to numerous uncertainties and is probably accurate only within a factor of two or three, but it provides some idea of the cost of the OTC NO_x Budget Program. Using this approach, the total cost of the program beyond the NO_x RACT phase is about $60 million from 1999 to 2001, or approximately $0.15 per MWh. This contrasts with the average wholesale cost of electricity of approximately $35 per MWh over the same period. Thus, the cost of the OTC NO_x Budget Program is less than 0.5 percent of the cost of electricity, which is the same order of magnitude of other market-based emission-control programs. Indeed, the percentage would be even smaller if it were calculated on a retail basis, or what the consumer pays.

Overall performance of the OTC states' economies

We also can estimate the impact of environmental regulation on overall economic performance. Using the values calculated above and data from the U.S. Department of Commerce, we find that the economic impact of the OTC NO_x Budget is negligible compared with the gross state product (GSP) of the OTC states, representing less than 0.0005 percent. It is difficult to see how anything so minute could have a significant economic impact on overall activity, growth, or jobs. There is no evidence that the OTC NO_x Budget slowed those state economies to which it was applied. For the years that inflation-adjusted GSP data are available (1987–2001), the OTC states showed a lower average annual growth rate of 2.55 percent before the OTC NO_x Budget was implemented, relative to that of the non-OTC states (3.46%). For the first three years of the OTC NO_x Budget Program, however, this pattern was reversed. The OTC states averaged a higher annual growth rate (3.30%) than did the non-OTC states (3.15%), but this does not prove that greater environmental regulation leads to higher growth. The health benefits and associated economic gains from reduced air pollution can be significant (EPA 1999) but are not factored into this analysis. The relatively high growth rate in the OTC states does suggest that the higher cost of electricity production was compensated by countervailing factors in the state economies.

INDUSTRIAL SOURCE PARTICIPATION

In addition to EGUs, the OTC NO_x Budget regulated some industrial operations, including more than 120 unique emissions sources located at 43 facilities. A wide variety of industries were included, such as petroleum refining, pulp and paper, and "electric, gas, and sanitary services," an eclectic group of facilities like cogeneration and central steam plants.

Emissions from industrial sources declined between 1999 and 2002 and were consistently lower than the annual allocations by an average of 20 percent. In reducing their emissions, these sources displayed flexibility in a wide range of compliance strategies, including switching to cleaner fuels, modifying production processes, replacing boilers, modifying combustion, installing control technologies, and retiring or deferring units (EPA 2004b). Industrial sources were active buyers and sellers of allowances as well. Some firms even made a net profit from trading (Swift 2003), and others found greater operational efficiency as a result of the new emissions-monitoring systems.

More telling is the fact that on a net basis, industrial sources sold 9 percent of their allowances to EGUs and market participants, suggesting that in sum, industrial sources had lower control costs than EGUs did. This is not surprising given the breadth of control options that industrial sources employed. More emissions control options are available to industrial plants than to EGUs (which simply produce and sell power), including changes to base technologies as well as power supply, thus facilitating the development of low-cost responses (Swift 2003). By including industrial sources in the NO_x trading program, the OTC was able to become more flexible, achieve greater reductions in emissions, and lower the overall program costs.

Perhaps the greatest challenge for the industrial sources was the monitoring and reporting requirements. Unlike large EGUs, these sources did not have CEMs in place and therefore had to develop or modify their NO_x emissions measurement systems, which often meant upgrading the software for their plant control systems.

OPT-IN AND SET-ASIDE PROVISIONS

Opt-in provisions allow nonregulated sources to join a cap-and-trade program. The purpose of opt-in provisions is to attract the participation of sources with low control costs. These sources can decrease their emissions below the number of allowances allocated to them and then sell the excess allowances. Opt-ins were seldom used in the OTC NO_x Budget, however. Only two states, New York and New Jersey, offered opt-in provisions in their regulations, and only three sources in New York were designated as opt-in units. Of these, only one received any allowances, the 59th Street generator in New York City, which was allocated only 327 allowances for 1999–2003, or 0.03 percent of all allowances allocated.

Set-aside provisions place a fixed number of allowances into a pool for use by a particular category of sources, such as renewable energy or energy efficiency. During the 1999–2002 period in the OTC NO_x Budget Program, 21,136 allowances were allocated under set-aside provisions by four states (Massachusetts, New Hampshire, New Jersey, and New York). This represented less than 3 percent of all allowances in the budget, and the majority were earmarked for new sources. Of the total pool of available set-asides, only 6,677, or 32 percent, were actually awarded. A small number of set-asides were distributed to renewable and efficiency projects in a few states. The vast majority that were used were allocated to new sources. Even so, the number of allowances awarded to new sources was far smaller than the available pool of set-asides.

Based on the small fraction of allowances allocated under opt-in and set-aside programs in the OTC NO_x Budget and on the fact that not all the allowances available under these programs were claimed, it is unlikely that these programs had a great effect either environmentally or economically, although specific sources that participated may have gained additional flexibility and cost reductions.

STATE-BY-STATE ALLOCATION

The OTC NO_x Budget Program gave each state the flexibility to set certain provisions within the overall framework of a regional cap-and-trade system. This avoided a “one-size-fits-all” approach that could hinder the program’s implementation. The key area of flexibility was in the allocation of allowances.

Allocation is a major economic and political issue. Economic models offer some evidence that auctioning allowances and using the revenues to cut distortionary taxes is the most efficient and least expensive approach (Fullerton and Metcalf 2001; Goulder et al. 1999). In addition, there is evidence that auctions tend to stimulate greater innovation and may lead to more efficient investments in technology (Kerr and Newell 2003; Milliman and Prince 1989; Popp 2003). Real-world complexities, however, such as multiple distortionary policies, monopoly power, and differences among regulated firms, complicate the issue, making the optimal choice less clear (Babiker et al. 2003; Fischer, Parry, and Pizer 2003). If the allocation is free rather than auctioned, the options for distribution are complicated, and the optimal choice, again, becomes less clear. For example, regulators must decide whether the allocation should be based on historic emissions, production output, or (in the case of power generation) heat input.

Politically, the issue is not necessarily economic efficiency but how any allocation mechanism will affect the specific interests of a particular participant or stakeholder. Auctions that make regulated sources pay for all allowances are presumably more difficult to implement, owing to political resistance. Furthermore, potential new sources that would prefer an auction may not be sufficiently organized (or even exist) to lobby for it.

Free historical allocations, or grandfathering, became the norm for the OTC NO_x Budget presumably because of political resistance to auctioning. The details of how the allocation was determined varied from state to state. For instance, Delaware, New Hampshire, New York, Pennsylvania, and the District of Columbia had fixed allocations from 1999 to 2002. In contrast, Connecticut, Maryland, and New Jersey periodically adjusted their allocations according to various factors. Furthermore, some states held public meetings, but others did not; and some simply issued regulations, while others used legislation. These variations do not appear to have had an appreciable effect on the environmental or economic performance of the system.

Stakeholders in the OTC NO_x Budget Program had varying levels of interest and influence depending on their stake in the outcome, degree of organization, size, and resources. Furthermore, state-by-state differences among stakeholders correlated to different design preferences, including the size of the individual state caps. The method for determining the state caps, or "apportionment" of the total allowance budget among the states, was consistent across the region and was based on heat input. Specifically, the terms and principles stated in the 1994 memorandum of understanding among the OTC states held each affected facility in each state to certain heat rates generally pegged to a 1990 baseline (Donovan et al. 1996). This in turn translated into an amount of allowable emissions for each facility, which, when added up for all the facilities in a state, amounted to the total amount of allowances (the cap) for that state. In this way, the process yielded a uniform burden on similar activities across the OTC region. Once the state caps were set, however, each state could decide how it would allocate the allowances to the individual sources.

One outcome of NO_x program implementation is that it helped fracture industry opposition to regulating air pollution, which was aided by the introduction of competition to the power industry (Farrell 2001). Before competition, the power sector was relatively unified in opposing new environmental regulation, but by the late 1990s, several northeastern power companies recognized that their interests diverged from those of the midwestern and southern firms over NO_x controls on upwind sources. The costs for the northeastern firms would rise because of the OTC NO_x Budget, which gave a competitive advantage to the midwestern and southern firms. But they could eliminate this advantage by extending the regulatory program to the upwind states. The clearest example of this new division was the departure of several long-standing members of the Utilities Air Resources Group, a nationwide lobbying firm. These firms acted independently with various environmental groups to support greater emission controls on their competitors (NRDC/PSEG 1998).

In addition to the upwind/downwind split, potential new entrants to the northeastern electricity generation market had their own interests. These firms were less concerned with the location where new NO_x control regulations would be applied as with the way in which new power plants would be treated. The main concern was that an emissions-trading program would bar their entry into the market by distributing all the allowances to existing firms. Thus the competing interests of the old versus the new emissions sources contributed to the fracturing of the regulatory position of the power industry.

3. Observations and Lessons for Multistate GHG Emissions Trading

The OTC NO_x Budget Program provides useful information for developing multistate GHG trading systems. At the same time, though, the differences between NO_x and GHGs, and the environmental problems they cause, also must be considered.

Based on this review, one simple yet critical observation of the OTC program is that it reduced NO_x emissions at relatively low cost with essentially perfect compliance by regulated sources. In other words, the program can be deemed effective on economic, environmental and administrative grounds. The OTC NO_x experience provides further evidence that emissions trading is an effective approach to reducing some types of air pollution.

The results of the program also prove that the states can work collectively to achieve significant environmental goals. This in turn supports the notion that the states can serve as "laboratories" for the creative design of effective environmental policies (Rabe 2004). In addition, the success of the OTC states in reducing NO_x emissions while expanding their economies refutes the claims by opponents of environmental regulation that such protections are antithetical to economic growth.

More specific observations and lessons can be drawn for (1) the design of a GHG emissions-trading system, (2) program implementation and multistate coordination, and (3) coordination with other policies.

THE DESIGN OF A GHG EMISSIONS-TRADING SYSTEM

In contrast to NO_x emissions, GHG emissions are more widely dispersed across the major sectors of the economy, and a greater fraction is associated with large stationary sources. This is important because an emissions-trading system generally benefits from a large and diverse set of participating sources that expands the pool of opportunities to reduce emissions. This in turn increases the likelihood of discovering inexpensive reductions, often achieved through innovation, which drives down the overall program

costs for both the regulated facilities and society. The OTC NO_x experience supports the axiom that broad participation is good. Although EGUs were the prime source for regulation and the single largest stationary source of NO_x emissions, the program was extended as well to other industrial sources, such as refineries and chemical plants. These plants significantly reduced their emissions and were net sellers to the EGUs, indicating that their marginal cost of reducing NO_x emissions was lower and therefore helped cut the program's overall costs.

The states should therefore give priority to integrating a broad set of sources and sectors into a GHG emissions-trading system, although administrative complexity may dictate a staged approach. Steep reductions in GHG emissions are needed to avert dangerous climate change, but at the same time, the cost of achieving these reductions is a cause for concern. In addition, "end-of-pipe" solutions to cutting GHG emissions are unlikely to be widely used in the near term. The installation of end-of-pipe "scrubbers" was an important compliance option for both the NO_x and SO_2 emissions-trading programs. In contrast, comparable GHG technology, known as "carbon capture and storage," is currently limited to such uses as enhanced oil recovery, and the technology is expensive. It will not gain wide application unless it becomes less expensive and/or emissions caps become so stringent that all cheaper reduction options are exhausted. As a result, a GHG emissions-trading system is needed that can exploit diverse technological solutions through the inclusion of a broad array of emissions sources and gases (including non-CO_2 gases).

Broad participation is necessary as well to meet the long-term environmental challenge. To illustrate, the OTC NO_x Budget covered only large stationary emissions sources, which represented less than half the total NO_x emissions. Although the program was successful in reducing emissions from EGUs and industrial sources, high levels of ozone persist in the northeast United States and are partly caused by rising emissions in the transportation sector (OTC/EPA 2003). The OTC and EPA concluded that mobile source programs and broader geographic participation were needed to achieve greater NO_x reductions and thus lower the formation of ozone. Emissions trading still is a powerful and effective means of cutting emissions, but its narrow application in the case of the OTC NO_x Budget meant that it could not solve the problem of ozone formation without additional measures and source participation.

The need for broadly inclusive control strategies is similar for GHGs, although the circumstances are different from those for NO_x. First, NO_x control technologies were well known when the OTC program was begun, and the necessity and feasibility of steep reductions in emissions were widely accepted. Moreover, NO_x is partly an inadvertent by-product of fossil-fuel combustion. In contrast, CO_2 is the natural product of combustion, making the challenge of controlling CO_2 emissions more difficult.

Given that a reduction in GHG emissions of 50 percent or more is likely necessary to avoid dangerous interference with the climate system, climate policy implies a wholly different energy supply system than the one that exists today (Hoffert et al. 1998). It would have different energy resources and greater efficiency in both the distribution and use of energy, and may call for large-scale capture and storage of CO_2. The pace of this change may be spread across a longer period of time than the control of regional ozone, perhaps several decades or more, but the scale of the challenge is much greater too, as are the barriers to policy development. In broad terms, an effective climate policy entails several factors, including the stimulation of energy technology innovation, changes in investment patterns in the energy industry, global participation, and broad cooperation throughout the public and private sectors, including factions historically opposed to climate policy (Baer et al. 2000; Hoffert et al. 2002; McCright and Dunlap 2003; Morgan 2000).

A GHG cap-and-trade system need not start with a cap as stringent as the OTC NO_x Budget, though near-term GHG reductions and a steep ratcheting down of the cap over time would be necessary. Adopting a cap—even if it is not particularly stringent at the outset—is a major step in creating incentives for innovation and investment to meet the long-term goals of climate policy (Nordhaus and Danish 2003). A predetermined schedule of long-term, downward adjustments to the cap may be useful, however, to avoid entrenchment in the status quo, that is, a situation in which regulated sources are invested in the initial target level and thus strongly opposed to stricter targets later on.

Given the importance and interrelation of innovation and broad participation, including the option of expanding the cap-and-trade program over time, we next consider several features of a trading system that can reach various emissions sources, including allowance allocation, opt-in provisions, set-asides, and offsets.

Allowance allocation

States in the OTC NO_x program chose to allocate allowances based on heat input, which effectively limited participation to EGUs and industrial operations that combust fossil fuels. Other allocation methods may attract greater participation.

An output-based model, for example, would grant allowances based on actual production (i.e., output). In the case of the power sector, the output approach is based on megawatt-hours of generation. If renewable generators are included in the allocation, this approach can be particularly useful to encouraging clean, renewable power generation. Some renewable power plants, like wind plants, have no GHG emissions, so they can sell all of their allocation back to the market. The money raised in this way can be used to finance new generation. Accordingly, the output-based allocation method can accelerate the market's penetration of clean-generation technology, a vital step in reducing GHGs in the long term.

Another allocation option is based on historic emissions. Because GHG emissions come from various gases, sources, and sectors, regulators may want to focus on emissions when determining allocation rather than on parameters that are specific to one sector. An emissions-based approach could facilitate multisector allocation, either at the outset of the program's implementation or over time, by allowing for intersector comparisons and assessment of fairness and equity. Emissions-based allocation may create a profitable "windfall" for polluters, however, because companies with historically high emissions would be awarded the most allowances. One solution is to use a performance benchmark, such as emissions per unit of fuel consumption, which rewards companies for being efficient.

Another approach is simply to regularly auction off the pool of allowances, which would level the playing field for regulated sources, regardless of economic sector, and then to use the revenue to lower distortionary taxes. Despite the aforementioned economic advantages of this approach, political factors have constrained its use in practice. One compromise would be to start with a system that relied on mostly free, or "grandfathered," allocations and gradually to shift a small percentage of auctioned allowances to an all-auctioned approach. Another solution would be to allocate only enough allowances to keep the existing sources financially whole and to auction off the rest. Research suggests that this would be possible at a relatively low level of allocation (Morgenstern 2002).

Opt-in provisions

Opt-in provisions can expand a GHG trading system, introduce inexpensive emissions reductions, and offer innovation in reduction technologies and processes. In practice, however, these provisions either have been seldom used or have been exploited by firms that would have seen their emissions decline anyway under a "business as usual" scenario, a problem known as "adverse selection."

The OTC NO_x Budget almost never used opt-in provisions, mainly because the costs of opting in, including monitoring and reporting, tended to be larger for many sources than the potential value of the NO_x allowances. This was especially true for smaller sources. If the designers of cap-and-trade systems want to encourage opt-ins, they need to pay more attention to the costs of participating. Although the Acid Rain Program for SO_2 used opt-in provisions, it suffered from adverse selection, so even though it cut allowance prices only slightly, it led to higher emissions than would have occurred otherwise (Montero 1999).[9] Thus, a key issue for policymakers considering opt-ins is a familiar theme in environmental policy: striking a balance between the cost of participation and the stringency of the rules. Moreover, because the preparation and application of the rules come with an administrative cost, policymakers also must be careful not to offer a solution whose benefits (emissions reductions) outweigh their own time and expense.

Although opt-ins invariably lead to some adverse selection, they may have a trade-off that favors long-term emissions reduction and environmental protection. When a GHG emissions-trading program begins with relatively few emissions sources, the program's long-term effectiveness relies on its ability to expand. Opt-in is one way in which a program can expand, leading to a greater inclusion of economic sectors and speeding up innovation in reducing emissions. In this sense, adverse selection under an opt-in provision could be a near-term trade-off in return for long-term environmental and economic gains.

9. One of the reasons for using the SO_2 opt-in was that certain emissions sources, which were not required to participate in the first phase of the program, were nonetheless required to install CEMS. With the expensive monitoring equipment already in place, a major impediment to opting in was removed.

Opt-ins can reach beyond individual firms and be applied on a sector level, such as the chemicals sector, in which the companies negotiate their entrance as a whole, perhaps through a trade association. This can help standardize the requirements for each company and allay concerns about the potential impact on an individual firm's competitiveness. To coordinate action by the industry, the opt-in incentive must serve the sector's interests. For example, the probability of future regulation might compel an industry to opt in early if it believed that near-term voluntary negotiation would lead to a better outcome than would waiting for a mandatory requirement.

Related to opt-ins is the "reverse auction," in which nonregulated sources bid for a pro rata share of government funds in exchange for adopting an emissions reduction target below a historic baseline. The winning bidders join a GHG trading system and are effectively paid for meeting the level of emissions reductions that they pledged. This approach was used to launch the United Kingdom's GHG emissions-trading system in 2001. It was coupled with a regulatory incentive that provided relief from a carbon tax on other companies participating in the trading program. It is not clear, however, whether the U.S. states have the resources or the will to use public funds and taxation to create such incentives. Furthermore, as with opt-in provisions, the principal issue with a reverse auction is establishing appropriate emissions baselines and thus avoiding adverse selection. Additional research would be useful to determine whether the United Kingdom's reverse auction ultimately benefited companies that were reducing emissions anyway.

Set-asides

Advocates of set-aside incentives believe they can unlock a large pool of cost-effective GHG reduction projects, particularly by energy end users. Also, because set-asides are taken out of the cap, use of the allowances cannot inflate the emissions goal established for the program. Unlike offsets, which are discussed later, set-asides are essentially part of the allocation formula and can alleviate concerns about environmental integrity.

The OTC NO_x program had set-aside incentives for renewable energy and energy efficiency, but these provisions were implemented in only a few states and were rarely used. For the subsequent NO_x SIP Call program, the EPA suggested a more ambitious use of set-asides, recommending that up to 15 percent of the cap be used for incentives for renewable energy and energy efficiency. Following the EPA's guidance, six states adopted renewable energy and energy efficiency set-asides, amounting to a pool of 4,323 tons of NO_x allowances that could be awarded under the NO_x SIP Call Program (EPA 2004a). Assuming a market price of $3,000 per ton, the set-asides could deliver about $13 million in incentives for renewable energy and energy efficiency projects.

Several factors will ultimately determine the subscription rate for set-aside provisions, including the market price for an allowance, the allocation formula by which the set-aside allowances are distributed, the timing and duration of the award, and the transaction costs, for example, the expenses incurred for verification. As with opt-in provisions, one of the challenges is ensuring that the effort to obtain set-aside allowances is sufficiently rewarded while maintaining environmental integrity. To obtain the set-aside allowances, the process should not be too difficult, and therefore expensive, relative to their market value. A high market price for allowances would drive investment in projects that qualify for the set-asides, but also implies higher overall program costs, which are undesirable. In fact, one of the reasons for using set-asides in the first place is to stimulate innovation and participation, which in turn is meant to lower costs, at least over the long term. Policymakers should focus on minimizing the transaction costs associated with obtaining set-aside allowances. They also need to weigh the administrative costs of developing and implementing the rules against the intended benefit.

Offsets

Another aspect of an emissions trading system that can affect both source participation and program costs is offsets. Offsets were not used in the OTC

NO_x Budget but have been widely discussed in regard to GHG emissions trading. They can unlock a large pool of potential emissions reductions, but the tradable credits derived from offset projects are outside the emissions cap. As a result, offsets have the effect of incrementally inflating the cap. Experience with offsets has not been encouraging, though such experience is still limited. Regulatory complexities, uncertainty, and high transaction costs have prevented any significant use of offset provisions, such as those provided under the Kyoto Protocol's Clean Development Mechanism. Useful experience has been gained, though, and may provide insights into institutional and/or technical approaches that could yield effective credit generation. Also, work being done on both offsets and opt-ins may encourage the entry of other countries into an emissions-trading market, especially developing nations that may not have the resources or the ethical responsibility to reduce emissions in the near term (Baer 2000; Parson and Fisher-Vanden 1999).

PROGRAM IMPLEMENTATION AND MULTISTATE COORDINATION

The OTC NO_x experience provides valuable information for the development of GHG institutions and commitments. These can be grouped in several parts, including: model rule development; infrastructure; compliance and enforcement; reduction of initial market volatility; and conditions for success.

Model rule development and implementation

The OTC NO_x rules were drawn up in stages, beginning with a memorandum of understanding among northeastern and mid-Atlantic states and followed by the model rule. This rule required the states to be consistent in most areas, including program applicability, control period, NO_x emissions rates, emissions monitoring, record keeping of emissions and allowances, and electronic-reporting requirements. Beyond these standards, the states could (and did) vary the allocations to individual sources.

A multistate system for GHG emissions is only partly analogous, however. Multistate negotiation for GHGs may suffice to develop guidelines for rules and program implementation but may face a challenge in setting a long-term aggregate target level, at least with the stringency of that under the OTC NO_x program. The OTC NO_x Budget had a health- and science-based goal that could be addressed through regional action. It offered measurable health and environmental benefits from cutting NO_x emissions in local and regional air sheds. These unambiguous, cost-effective benefits encouraged action and justified the added costs to both the regulated sources and society.

GHG emissions and climate change are global and arise not from local emissions but from changes in global concentrations of gases, for which even a GHG-intensive region is only partly responsible. The harmful economic and environmental effects of climate change can be modeled and predicted at regional levels, but not at the level of accuracy or certainty for ozone formation from NO_x. This uncertainty extends to any attempt at measuring the benefits of emissions reductions in monetary terms. As a result, the added expense incurred by regulated sources is harder to justify.

This problem may be overcome, however, through a political agreement on action by a set of states, particularly if it serves as an example to and is subsequently supplemented with commitments by additional states that strengthen the overall reductions. Modeling the economic impact of regulation, in a manner similar to that undertaken by the OTC for the early NO_x work, could help determine the targets. Some states and other jurisdictions do recognize their responsibility of protecting the climate, and while GHG targets need not be overly stringent in the near term, the establishment of a target is a good first step. For example, the OTC NO_x cap set in 1999 did not solve the ozone problem in the Northeast, but it was a critical step and led to broader action and greater cuts in emissions, including upwind emissions that contributed to ozone formation in the region. Similarly, the states' action to cap GHG emissions is an important part of an evolving solution, beginning with the development of institutions, the opportunity to learn and innovate, and a first step in reducing emissions.[10]

The OTC NO_x Budget and the control of GHGs differ in their legislative and regulatory context. In the NO_x case, federal requirements drove the states to act together, whereas for GHGs, the absence of federal action is driving states to act together. The OTC NO_x Budget Program benefited from a national regulatory framework in which the EPA provided technical support and assistance and ensured that individual states' implementation plans were adequate to meet air-quality goals. Similarly, the EPA authorized several states not to participate in the OTC trading system, confirming that their state compliance plans were sufficient to generate the necessary reductions in NO_x and to avoid potentially unfair competitive advantages. Although there is no federal regulatory framework for GHGs, it is not clear that such a framework is necessary in order for the states to develop a model rule and agree to joint action. The states have the legal authority to compel action within their borders, such as reducing GHG emissions, and to enforce those orders. The success in developing and operating the OTC NO_x Budget should give states the knowledge and confidence they need to move toward a multilateral GHG cap-and-trade program.

Another difference between the OTC NO_x Budget and a possible GHG program is the existence of a central body to provide technical support. For the OTC program, the EPA provided information about modeling the impacts, expertise on designing the trading system, technical assistance in establishing monitoring programs, and workshops for state officials on planning and implementing the trading system. For states working together on a GHG program, similar services could be provided through a joint commission or technical contractor, though these services require funding, which may be scarce in state budgets.

Infrastructure: emissions monitoring, reporting, and allowance tracking

An emissions-trading program must monitor and report emissions and track both emissions and allowances. The EPA did this for the OTC NO_x Budget by administering an emissions-monitoring system alongside a "NO_x allowance tracking system," or NATS. This database maintained the allowance accounts and recorded the allowance transfers.

The OTC model rule outlined steps for handling emissions data. The owners and operators of the emissions sources were required to monitor and report the emissions for each affected unit, with the methods varying somewhat according to the type of facility. Most large EGUs used a certified CEM and reported their emissions quarterly under existing EPA guidelines for the Acid Rain Program. Industrial units and smaller EGUs generally did not use a CEM but were given several options for monitoring emissions, such as periodic stack testing combined with fuel-flow data. For these sources, emissions were to be reported to the EPA by October 30, one month after the end of the ozone season.

The reports for all facilities were required to contain hourly emissions data. Reports were submitted electronically to EPA, and those units with CEMs had an automated data acquisition and handling system. Upon receipt, the EPA reviewed the information for accuracy and worked with the sources to correct any errors.

A similar set of rules for GHG emissions will be necessary, and at least in terms of process, the system used in the OTC NO_x program is a useful guide. In regard to monitoring, large EGUs with CEMs are already recording and reporting CO_2 emissions infor-

10. For example, the RGGI initiative has the "Guiding Principles for Program Design," which state: "The program will be expandable and flexible, permitting other states to seamlessly join in the initiative when they deem it appropriate. The program … may serve as a platform and model for the implementation of future additional emissions trading programs and initiatives that individual or multiple states might deem appropriate." See **http://www.rggi.org/goals.htm**.

mation. It is not clear that CEMs are necessary, though, because accurate CO_2 emissions data can be obtained from information on fuel-use. If an emissions-trading system is to expand beyond CO_2 to include other important GHG emissions, such as methane and nitrous oxide, the monitoring requirements will generally be more complicated because emissions will vary in accordance with different technologies and process conditions. As a result, CO_2 emissions may require regulated sources to implement new monitoring systems, and the regulators will incur new administrative costs. Despite this, non-CO_2 gases can be an important source of inexpensive emissions reductions and therefore may be worth adding to a trading system.

With respect to the reporting, record keeping, and tracking of both emissions and allowances, history suggests that a central coordinating body—rather than a decentralized state-by-state system—is necessary to provide consistency and to connect monitoring to compliance. The federal government, through the EPA, did this for the OTC NO_x Budget and the Acid Rain Program. A coordinated effort may not need to be managed at the federal level, however. For example, the Northeast States for Coordinated Air Use Management (NESCAUM) is working with a group of stakeholders to create a public regional registry (or database) for GHG emissions, which may prove adequate for implementing the RGGI trading system. While some design functions have yet to be finalized, the registry is being constructed to support emissions and allowance tracking and to record project-based emissions reduction projects and/or offset credits that may be recognized by the RGGI. To be effective, the participating states must agree on this registry and follow its guidelines in order to ensure commonality and consistency.

Compliance and enforcement

Under the OTC NO_x program, emissions reports submitted to the EPA were systematically audited using a computer software program, initially focusing on large emitters but extending over time to check all emissions reports for inconsistencies. If the EPA detected fraud during an audit, it reported it to the relevant state, which was then responsible for enforcement. The sources had until December 31, two months after the emissions-reporting deadline, to transfer or buy allowances to cover their emissions. The EPA then compared the emissions from each unit with its allowance holdings—a process known as "reconciliation"—and prepared a compliance report. In cases of noncompliance, that is, when a unit had a shortfall of allowances, the EPA assessed an automatic penalty of three allowances for every ton of excess emissions. The deduction could be taken from the pending allocation for the following period.

The strict and certain compliance penalties in the OTC program were a key factor in producing exceptional compliance, which was also enhanced by the public and transparent nature of the data and reporting. Individual power-plant data on both emissions and allowances also were available to the public, enabling civil society to play a watchdog role. Analogous penalties and transparency under a GHG regime should be equally effective. The establishment of a central coordinating body to determine compliance, assess penalties, and detect fraud is important. A group of states could designate a third party to perform these functions, perhaps overseen by a regional council and backed up by individual state powers if enforcement is needed.

Regulated sources could also form an institution to accomplish coordination. This approach led to the creation of the North American Electricity Reliability Council (NERC). NERC was created to avoid regulation following a blackout in 1965 (Brennan et al. 1996). Its mission is to ensure that the bulk electricity system in North America is reliable, adequate, and secure. It is a voluntary organization, working through reciprocity, peer pressure, and mutual self-interest. It appears to have worked adequately, provided that electric power companies are monopoly franchises and do not compete and the power systems remain centrally oriented. However, the advent of competition, new technologies, and the Northeast blackout in 2003 has called the voluntary approach into question and has raised electricity reliability as a regulatory issue (Ilic et al. 2001; U.S.-Canada Power System Outage Task Force 2004)

The Chicago Climate Exchange, which trades GHG emissions, is an industry-sponsored, self-regulated trading system launched in 2003. The participating companies make commitments through written agreements and negotiate the rules for organizing the exchange, including committees to handle various functions such as compliance. The market is supported by liquidity providers, or brokers, matching the buyers and sellers in the market.

An alternative approach to industry-sponsored coordination is to create a hybrid organization with both private and government participation. Other areas of collaboration may provide useful insights, such as water-quality management in the Northeast by the Interstate Environmental Commission. Another example is water resources management in the western United States and the associated Colorado River Compact.

Reduction of initial market volatility

Transparency in the market, including information about technologies for compliance as well as on individual plant costs, is generally likely to mitigate price volatility. More specifically, the OTC NO_x Budget Program highlights several emissions-trading design features relevant to market volatility, including allowance auctioning, early action credits, banking, and price caps (or the lack thereof).

To improve price discovery at the outset of a GHG trading program, the program administrator could hold a preliminary auction for a batch of allowances. This would give the market participants at least a general expectation of the value of allowances, and therefore facilitate market liquidity. Another approach might be to allocate early action credits, or allowances granted by regulators in recognition of emissions reductions before the start of trading. If the credits were allocated in addition to the total allowance budget, as opposed to being carved out of the budget, then the credits could bolster supply and alleviate speculation in regard to a short market. An extrabudgetary allocation like this would inflate the cap, however, and ultimately allow more emissions under the trading program. But early credits are awarded in anticipation of emissions reductions ahead of schedule and thus provide an incentive for proactive, environmentally beneficial behavior. Similar to opt-ins, set-asides, and offsets, the mechanism for determining early action credits carries an administrative burden that must be weighed against its potential benefits, specifically mitigation of market volatility and early emissions reductions.

Because banking allowances can reduce volatility over time by providing liquidity in the market, it should be encouraged for GHG emissions trading. The OTC NO_x Budget used some banking restrictions because NO_x poses acute health impacts tied to episodes of high emissions and these episodes can be exacerbated by the accumulation and subsequent use of banked tons. GHG emissions, however, not pose acute health or environmental impacts that would merit banking restrictions. Indeed, such restrictions may limit flexibility with no apparent benefit.

Finally, the OTC NO_x Budget showed that the use of price caps, or price safety valves, for allowances was not necessary. The OTC NO_x market experienced a volatile price spike but quickly stabilized without intervention, and ultimately allowance prices performed well. In fact, market interference in the form of price caps may have altered the market participants' behavior and impeded the price correction. In addition to these possible distortionary effects, price caps permit more emissions above the cap and thus undermine the program's environmental effectiveness.

Conditions for success

Some of the political and technical conditions that led to the success of the OTC NO_x Budget Program may be helpful to consider when deciding how to implement a multistate GHG control program. The three topics that we look at here are coordination, interests, and trust.

First, coordination among different political jurisdictions is central to a regional emissions trading program, and the OTC NO_x Budget showed that such coordination is possible, which is a useful finding in itself. The coordination of regulatory development in that case proceeded from a prior history of the regulators' cooperative technical assessment and interaction. More important, the coordinated, multistate cap-and-trade program was established after a political agreement to control emissions. The original memorandum of understanding committed the states only to NO_x controls. Although it explicitly left open the option of emissions trading, it was not clear in 1994 when the memorandum was signed that the efforts to create it would be successful.

Second, the OTC NO_x Budget Program provides evidence that participation varies according to the interests of the potential participants and that greater similarity implies a greater likelihood of participation. Three main interests seemed to be operating: potential abatement costs, potential administrative costs, and improved air quality. Those states that did not meet the ozone NAAQS, for example, New Jersey and Pennsylvania, and faced high abatement costs most actively promoted an emissions-trading program within the OTC. Those states that faced relatively lower abatement costs (due to a lower level of industrialization) but still wanted cleaner air, for example, Maine and Vermont, tried to minimize the administrative costs of regulation and supported the OTC NO_x Budget but implemented traditional command-and-control regulations instead of an emissions-trading program. Those states that did not have a problem complying with the NAAQS standard and did not have a strong local interest in lowering their emissions did not support the emissions-trading programs and did not implement any. Virginia, for example, refused to participate in the NO_x trading system.

Last, trust is a necessity among the participants in a regional cap-and-trade system. Some of participants' trust in the OTC NO_x Budget Program came from their working closely together on problems that were to some degree shared and from a prior history of working together through groups such as NESCAUM. A closer examination, however, shows that in practice, "trust" meant different things. The states came to trust that the process in which they were participating could not be manipulated against their interests. In this sense, they trusted the other states only as far as they could verify their actions. While they were developing the NO_x Budget, the OTC members came to trust that emissions trading would work to solve their problems and to trust one another to accurately represent their own situation during group meetings. This trust grew over several years as a result of repeated personal interactions and through the realization that duplicitous behavior could be detected relatively easily.

Third parties such as the EPA aided in this process. So did communications among experts from different states. Political leaders in the OTC negotiations often were unable or unwilling to make the technical judgments on which many decisions depended, so they relied on their own experts, who had already verified the technical part of the decision, often in careful cooperation with experts from other states. When they finally agreed to control emissions, the OTC members verified that none had behaved duplicitously. This verification included submissions of texts of new regulations, emissions inventories, and reports of progress on control technology deployments. A key feature was the emissions-monitoring regime that had been established by Title IV of the Clean Air Act Amendments by the time the OTC NO_x Budget was being negotiated.

COORDINATION WITH OTHER POLICIES

Although our analysis has focused on the application of the OTC NO_x rules to a multistate GHG trading system, a number of other policies are relevant and can influence the effectiveness of an emissions-trading program. In particular, a GHG program has the following potential synergies and conflicts arising from simultaneous policies dealing with renewable energy, electricity deregulation, and energy supply security:

Renewable portfolio standard (RPS): The adoption of RPS is a relatively recent development in the Northeast power markets and elsewhere. An RPS requires power providers to acquire a certain percentage of their supply from renewable resources, and one of the goals of RPS policy is the reduction of air pollution. Depending on the policy's design, an RPS may take a market approach that allows trading "renewable energy certificates," or RECs. One REC is created for each MWh of renewable generation, and regulated power providers can trade them to satisfy their compliance obligations. Additional demand for RECs stems from businesses, municipalities, universities, and other energy consumers, leading to the formation of a "voluntary market" (Hanson and Van Son 2003).

In relation to the emissions markets for NO_x and GHGs, a question emerges as to whether the holder of a given REC can ultimately own any emissions reductions that can be attributed to the renewable generation, perhaps leading to the award of emissions credits. The significance of such credits for spurring renewable energy is that they have a tangible market value and can therefore be an additional revenue stream allowing project developers to finance new renewable generation. The emissions-trading markets and REC markets can therefore be linked, potentially enhancing the market penetration of clean, renewable technology. Policymakers must resolve a number of complex issues, however, including the ownership of emissions reductions from renewable generation, the emissions reductions that are (or are not) represented by a REC, the calculation methods and accounting for the reductions, and the rules for exchanging RECs with emissions allowances and/or the creation of extrabudgetary credits.

The prospect of linking emissions and REC markets also raises the question of whether a single policy approach would be simpler and more effective. For example, would an emissions-trading market designed to encourage renewable energy eventually make an RPS superfluous? The answer to this question would have to consider the desired market penetration of renewable technologies, based on not only clean-air goals but also other policy objectives such as energy diversity. In turn, this answer would have to determine which policy approach, emissions trading or an RPS or a combination of the two, achieved the goal on time and at the least cost. While such an analysis is beyond the scope of this report, we should point out that an emissions market with a sufficiently stringent cap could eventually make an RPS unnecessary but that in the near term, the states' RPS policies are providing valuable information and lessons about their effects on renewable power generation and therefore are useful. Indeed, both RPSs and emissions markets may effectively stimulate renewable power generation, albeit through different buyers and sellers in different parts of the electric power market.

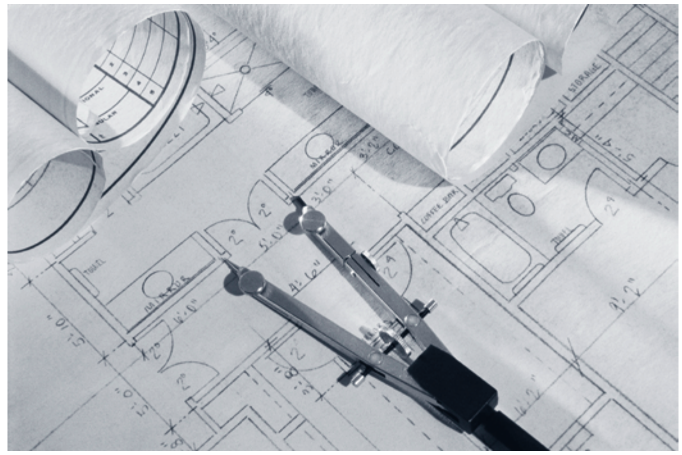
Electricity deregulation: During the 1990s when the NO_x markets were being established, the U.S. electric power sector also was undergoing significant market reform. Deregulation was being promoted as a way to increase competition in the industry, promising both lower prices and greater innovation in the sector. A key focus of electricity deregulation was opening the transmission lines to all electricity producers. As a result, the high-emitting NO_x sources outside one power-producing region could compete with the low-emitting NO_x sources in the region, opening the door to the leakage of emissions. In the Northeast, deregulation may have changed generation patterns somewhat, but the OTC NOX Budget had only a nominal effect on financial incentives, and the leakage does not appear to have been significant. The implications for GHG markets, however, may depend on the relative costs of GHG control technology as a function of electricity costs. With CO_2 prices at, for example, \$5 per ton of CO_2, coal-fired power plants might see costs rise by approximately \$5 per MWh—a much larger increase than that from NO_x controls but still less than the differences in costs between the OTC and the midwestern states.[11]

11. Calculated using typical coal energy content and generator heat rate values.

If a GHG emissions trading system were to increase the cost of electricity generation, the affect on electricity prices and the behavior of generators in the deregulated electricity markets is not entirely clear. Coal-fired power plants rarely set electricity prices since they tend to have fairly low costs compared to gas-fired plants. Thus, increases in costs for coal-fired electricity would simply reduce the profits of those plants and not likely increase electricity prices. Studies that have modeled relatively modest CO_2 restrictions on electric power systems tend to forecast slight changes in the use of existing capital (less coal, with more gas and renewables), with similar changes in new generation investment (Johnson and Keith 2004). Given the cost and public opposition to increased electricity transmission, it is hard to see how the location of power generation would change very much, even in a deregulated system, thus limiting the potential for emissions and/or economic leakage. Moreover, changes in the long-term path of technological innovation, which are arguably the most important outcome of deregulation, are far less clear. In theory, firms in deregulated electric power markets will innovate faster and better than traditional monopoly franchises will, though this is yet to be demonstrated in practice.

Energy supply security: Over the past several years, the issue of energy security has gained political prominence (Farrell et al. 2004). Concerns about the diversity of supply, electricity grid failure, and reliability of individual power sources all have received much attention. Inasmuch as the consequences of NO_x regulation have had little effect on the power generation mix, there has been little interaction between the issues of NO_x control and energy security. Even in the most extreme case, namely California's experience during the 2001 energy crisis, careful analyses of the interaction between California's electricity problems and its emission-trading program for NO_x (known as "RECLAIM") were found to be unrelated (Israels et al. 2002; Joskow 2001; Kolstad and Wolak 2003). To the contrary, this research provides evidence that problems in the California NO_x program were used as an excuse to withhold electricity in order to drive up electricity prices and that the problems of the NO_x program were due to the regulated sources' failure to install NO_x control equipment, despite indications and warnings that the equipment would be needed.

Moreover, an analysis of the reliability impact of the NO_x SIP Call by the organization charged with ensuring electrical reliability in North America indicated no major challenges (Reliability Assessment Subcommittee 2000), and reports documenting the sources of reliability problems in North America do not mention environmental regulations or controls as important issues (North American Electric Reliability Council 2001). Indeed, the major blackout in August 2003 in the United States and Canada was caused by inadequate maintenance of the electric power grid and control systems, improper system operation, and substandard training by the relevant firms (Amin 2003; ELCON 2004; U.S.-Canada Power System Outage Task Force 2004). No evidence has been presented suggesting that environmental regulations played any significant role in causing the 2003 blackout.



4. Conclusions and Recommendations

Efforts to create a GHG emissions-trading program among U.S. states may be informed by experience with the OTC NO_x Budget Program. Conclusions from this review fall into two categories: those involving the OTC NO_x Budget Program itself, and those that may be taken from the NO_x experience and applied to state-based GHG emissions trading.

Regarding the OTC NO_x Budget Program, we have concluded that

- The program was successful on economic, environmental, and administrative grounds and provides additional evidence that market mechanisms are an effective way of reducing some types of air pollution.
- For the four years that NO_x trading program was in place, emissions were consistently lower than the allocation. By 2002, emissions were reduced 34 percent below the level in 1995 when the RACT standards were being implemented.
- Environmental integrity was maintained with 99.99 percent compliance, and leakage of emissions was negligible or nonexistent. Concerns that regulated power generators might shut down generating capacity in the region and expand in unregulated areas proved unfounded.
- Overall, the OTC market operated at costs well below forecasts. By the time that trading began in 1999, the implementation of RACT had captured cheap reduction opportunities associated with low NO_x burner technology, leaving the more expensive technology options to achieve additional reductions. Despite forecasts in the range of $1,200 to $2,400 per ton, the average prices for NO_x allowances were in the range of $1,000. This suggests that markets can and will find economically effective ways of reducing emissions. Technology standards can be used in conjunction with emissions trading when well-known, economically efficient technology options exist.
- Despite short periods of price volatility, particularly at the start of various program phases, the NO_x market routinely achieved stability. Regulators stood by the market system during the periods of high prices and did not invoke a price cap, and firms used the markets to work out their difficulties rather than seek legal challenges in court. The OTC NO_x Budget offered economic signals that the prudent management of NO_x emissions could reduce compliance costs.
- The participation of industrial sources enabled significant reductions that cost less than the reductions made internally by EGUs. Opt-in and set-aside provisions were little used and therefore did not affect the performance of the overall system.
- The program had no discernable effect on the states' economies.
- The apportionment of allowances among the OTC states, or the establishment of the state caps, was accomplished in a uniform manner based on heat input. However, allocation of allowances to regulated sources was left to each state. State-specific allocation plans were part of the political calculus that made the model rule acceptable. Differences in allocation did not affect compliance or, evidently, the system's economic efficiency.
- The OTC NO_x Budget Program benefited from federal support, but succeeded without centralized federal control. The example of the program's success supported the development of a larger federal system with similar features, leading to larger-scale adoption of emissions controls.

Based on the results of the OTC NO_x Budget Program, we can make a number of general conclusions about the design of a state-based GHG trading system. At the same time, important differences between GHGs and NO_x must be taken into consideration. In particular, GHGs are more dispersed across the economy, and there is no readily available end-of-pipe control technology to reduce GHG emissions.

For a multistate GHG emissions-trading system, we have concluded that

- States can work together to negotiate, design and implement a GHG cap-and-trade system that would be cost effective, environmentally beneficial, and administratively manageable. States can serve as a vital source of innovation in GHG policy development.
- A successful regional GHG emissions-control program can provide valuable data and information about costs, technological innovation, compliance strategies, implementation, administration, and other factors. In turn, this can enable expansion to other states, regions, or the federal level. Such expansion would be aided by existing stakeholders committed to the environmental goal and by the example of a regulatory program working toward that goal.
- A GHG cap-and-trade system should strive at the outset and over time to incorporate a broad and diverse set of emissions sources. This serves to lower costs, achieve the environmental objective, accelerate innovation, and spur deeper engagement by the private sector in climate policy. Policy innovation and the improvement of various emissions-trading design elements, such as allocation, opt-in, set-asides, and offsets, could help achieve these aims.
- A common set of rules and guidelines are required for monitoring and reporting to ensure market transparency and compliance. Allocation can be left to the states to decide, with no diminution in environmental or economic effectiveness. Flexible, state-level allocation is conducive to the adoption and expansion of a multistate trading system.
- The target-setting process used in the OTC NO_x Budget Program may not be replicable with GHGs, given the global nature of climate change and uncertainty surrounding the environmental impacts and benefits. It is not clear that the stringency of the OTC NO_x cap can be mirrored in a GHG regime, at least at the outset, although the establishment of a GHG cap is a critical first step toward an evolving, global solution. Setting a cap is recognition of the responsibility to reduce emissions and sends economic signals for innovation and investment in low-emission technologies.
- A GHG trading system will require a central coordinating body to monitor and report emissions, track allowances. reconcile differences, and assess compliance. This body does not necessarily need to be the federal government, as in the case of the OTC NO_x Budget Program. It could be a third party, perhaps overseen by a regional council and backed up by individual state enforcement powers.
- To minimize price volatility during the start-up of a GHG market, the states should support price discovery, for example, through a preliminary auction of allowances. Banking GHG allowances can also calm volatility over time by providing liquidity in the market, and banking should be encouraged for GHG emissions trading. The use of price caps is not supported by the experience with NO_x trading.

In conclusion, U.S. states working together have the ability to lead and innovate on GHG emissions trading. Although there is presently little federal prompting for GHG emissions reductions, the experience with NO_x trading should provide confidence for states to take the initiative. Their action can be a great contribution to U.S. and global efforts to cut GHG emissions and to reduce the threat of climate change.

SUGGESTED AREAS FOR ADDITIONAL RESEARCH

We found several topics during our review that would benefit from additional research. First, it is not clear whether the multilateral nature of the OTC NO_x Budget Program, meaning the multiple state allocation plans, contributed to uncertainty surrounding the availability of allowances and, therefore, the initial price spike in 1999.

A reverse auction is one way in which regulators can bring companies under an emissions cap. Although this was the approach used in the United Kingdom, it may have led to adverse selection and thus benefited companies that were reducing emissions anyway. Accordingly, the system's baseline methodologies, participation, and performance should be examined to determine the most effective method for using a reverse auction to reduce emissions.

The effectiveness of both opt-in and set-aside provisions relies on their ability to balance transaction and administrative costs against the intended environmental benefit. A closer analysis of the shortcomings of these provisions as they were used in the OTC NO_x Budget Program and the Acid Rain Program could show how they could be appropriately adapted to and better used for GHG emissions trading.

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