The Evolution of NO_x Control Policy for Coal-Fired Power Plants in the United States

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Abstract

Emissions of nitrogen oxides (NO_x) contribute to formation of particulate matter and ozone, and also to acidification of the environment. The electricity sector is responsible for about 20% of NO_x emissions in the United States, and the sector has been the target of both prescriptive (command-and-control) and flexible (cap-and-trade) approaches to regulation. We summarize the major NO_x control policies affecting this sector, and provide some perspectives as to their effectiveness. While both prescriptive and flexible approaches continue to play an important role, significant new proposals have wholly embraced a cap-and-trade approach.

Key Words: emissions trading, cap and trade, air pollution, cost-benefit analysis, electricity, particulates, ozone, nitrogen oxides, acid rain

JEL Classification Numbers: Q25, Q4, D62, Q28

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I. Introduction

Emissions of nitrogen oxides (NO_x) are precursors to secondary pollutants, including particulate matter and ozone, and contribute to nitrogen deposition and thus to environmental problems including acidification of ecosystems. Particulate matter is associated with both morbidity and mortality. Ozone has a widely recognized effect on human morbidity and potentially on mortality, although the latter effect is not firmly established. NO_x is also associated with other environmental problems such as reduced visibility.

Ozone is primarily a summertime problem, which is attributable to the photochemical process that leads to its formation. Both particulate matter and ozone pollution are widespread problems in the United States, and many metropolitan areas are not in compliance with the National Ambient Air Quality Standards (NAAQS) for these pollutants.

Like ozone and particulate matter, NO_x is, due to its ubiquitous nature, also one of the six criteria air pollutants for which there are NAAQS standards. However, it could be thought of as the unregulated pollutant through the 1970s and 1980s, especially insofar as emissions from stationary sources because they were so loosely regulated until the 1990 Clean Air Act Amendments. Nitrogen oxides are the only criteria pollutant that has increased nationally since 1970 (U.S. EPA, 2002a).

The electricity sector is an important focus of NO_x policies for two reasons. First, it contributes about 20% of NO_x emissions in the United States. Second, these emissions are often emitted through tall stacks at high velocity, causing wide dispersion and contributing to regional pollution problems.

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This paper surveys the important NO_x programs affecting the electricity sector. These programs have followed a path beginning with traditional command-and-control regulations leading to expanded use of flexible market-based approaches. Today both approaches play an important role. We provide a description of these programs and measures of their effectiveness. We pay particular attention to the effect of these policies on those coal-fired boilers subject to Title IV of the 1990 Clean Air Act Amendments (CAAA).

II. Background

This section provides an overview of 32 years of policy at the federal level affecting NO_x emissions from coal-fired power plants.

Traditional Command-and-Control Regulations and their Continued Importance

Emissions of NO_x from electricity generation had little binding regulation until the 1990s. The 1970 amendments to the Clean Air Act implemented performance standards for new sources, as well as those that undertake a major modification, based on emissions per unit of heat input. Collectively, these standards are known as New Source Performance Standards (NSPS). The new source standards were more specifically defined in the Clean Air Act Amendments of 1977, and the standards for NO_x were modified again in 1998. All new sources or existing sources that make major modifications built in areas that are in compliance with the ambient ozone standard set by the Environmental Protection Agency (EPA) must prevent significant deterioration of air quality by installing the “best available control technology,” which is defined as the best technology considering energy, environmental, and economic impacts. Such sources in areas that are not in compliance with the air quality standards must install the theoretically more stringent “lowest achievable emissions reduction technology.” Additionally, these sources must also offset their pollution increases through reductions at existing sources. Thus there is an overlay of a regional emissions cap of sorts coupled with a specific technology standard in nonattainment areas.

Existing sources were virtually exempt from NO_x regulations until the 1990 amendments to the Clean Air Act mandated a significant reduction in NO_x emissions at existing electricity-generating facilities. While the contribution of NO_x to particulate concentrations is usually identified as the most important impact of NO_x on the environment (Burtraw et al., 1998), the regulatory handles for NO_x emissions reductions have stemmed primarily from concerns about acid rain and nonattainment of the NAAQS for ozone.

Acid Rain Provision of the 1990 Clean Air Act Amendments

The contribution of NO_x emissions to acid rain was addressed for the first time in Title IV of the 1990 Clean Air Act Amendments. The most widely recognized focus of Title IV was emissions of sulfur dioxide (SO_2) from existing electricity generating units, and the establishment of the emission allowance trading program for SO_2. Yet Title IV also applied to existing sources of NO_x a traditional prescriptive approach similar to the type used for new sources. The requirements specified emissions-rate limitations expected to correspond to specific abatement technologies, which typically meant combustion modifications such as low-NO_x burners.

Figure 1 illustrates the emissions of NO_x from coal-fired boilers affected by Title IV, along with a measure of generation from electricity-dedicated coal-fired boilers, from 1990 to 2001. The units affected by Title IV represented about 85% of total NO_x emissions from the electricity sector. Over this period, NO_x emissions from these sources fell by 26%, while electricity generation from coal-fired plants grew by about 16%. Although this picture provides no information about the efficient level of emissions or cost-effectiveness of the programs, it does illustrate that a reduction in emissions has been achieved over a period of increased utilization of coal-fired power plants and tremendous economic growth in general.

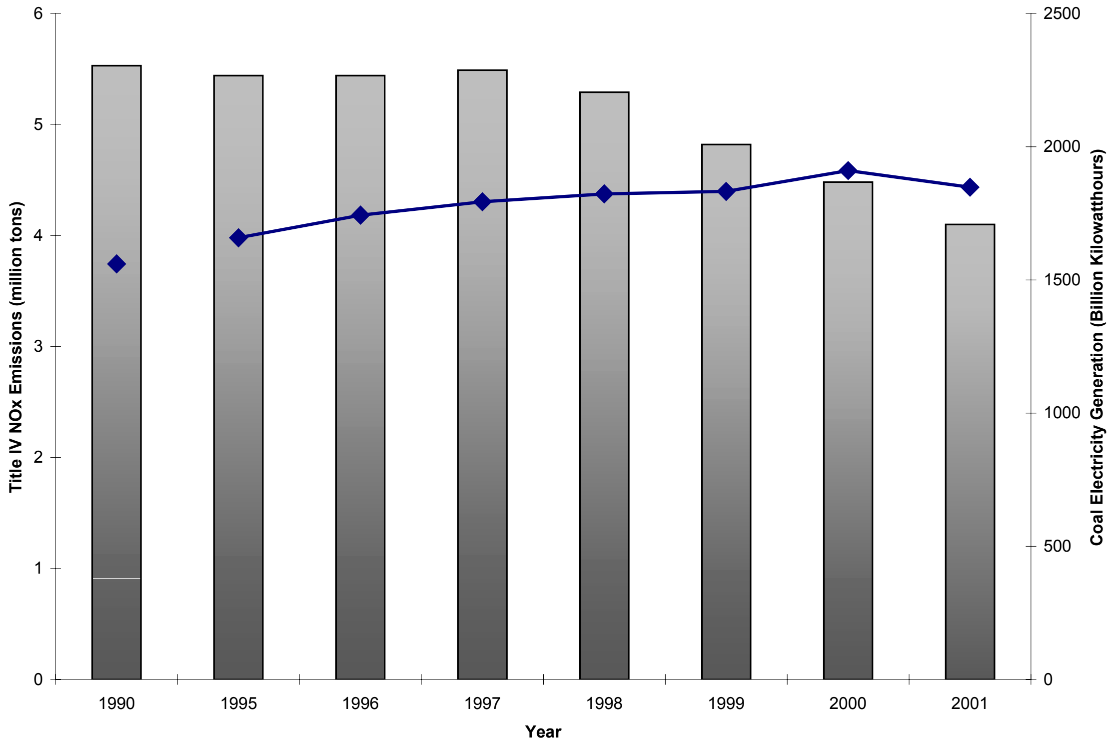

Figure 1. NO_x emissions and electricity generation from coal-fired power plants.

Sources: EIA, 2002, Table 8.2b; EPA, 2002b, Figure 11.

These reductions were achieved using a two-phased strategy with different technology-based emissions rate standards for each major coal-fired boiler configuration. Phase I of the NO_x reductions under Title IV was originally intended to begin in 1995, but litigation delayed the start until 1996. The first phase targeted 265 older coal-fired generating units and required tangentially fired coal boilers to meet an emissions limit of 0.45 lb NO_x per million Btu of heat input, and dry bottom wall-fired units to meet an emissions rate of 0.50 lb NO_x per million Btu. Phase II, which took effect in 2000, required further rate reductions for Phase I units and required additional types of coal boilers to reduce emissions levels to rates between 0.40 and 0.86 lb per million Btu, depending upon the boiler type.

In most cases, units affected by Phase I were retrofitted with low-NO_x burners or similar modifications that control fuel and air mixing to limit NO_x formation. However, a considerable amount of flexibility was introduced to insure that these requirements did not impose unreasonable targets. The annual basis for the rate standards introduced the ability to average over hours in the year, providing much more flexibility in compliance than the hourly-based standard that characterizes new source standards. Second, firms were given the flexibility to average emissions among commonly owned and operated facilities. Third, the law allows a unit to obtain a waiver, called an alternative emissions limit, if it could not meet the performance standard even after installing the control expected to attain that standard. Further, if units exempted from Phase I chose to voluntarily meet Phase I standards by 1997, they were exempt from Phase II rate requirements until 2008.

Ozone Policy

In addition to acid rain, the second major regulatory handle for controlling NO_x emissions has been the failure in many jurisdictions to attain the ambient ozone standard (NAAQS). In the period 1998 to 2000, 30 of the 98 regions that in 1991 were determined to be in nonattainment with the one-hour ozone standard continued to fail to meet the standard, and six additional areas fell into nonattainment since 1991.[1] The EPA issued revised standards for ozone as well as particulate matter in 1997, and in 2001 the Supreme Court upheld the standards. The new ozone standard averages air quality measurements over eight-hour time blocks, increasing the difficulty of compliance with the ozone standard.[2,3] If the new ozone standard had been in effect during 1998–2000, 329 counties would have been found in nonattainment.

The main sources of the precursor emissions of ozone—NO_x and volatile organic compounds (VOCs)—are fossil fuel-fired electricity generating units, industrial boilers, and internal combustion engines. Before 1990, VOCs were indicted as the limiting type of emissions in the formation of ozone. This is often true in urban areas with high NO_x emissions where there are not many trees, which are a source of VOCs. As a result, past

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[1] Currently, an area meets the current ozone NAAQS standard if the daily maximum one-hour average concentration measured by a continuous ambient air monitor does not exceed 0.12 ppm (parts per million) more than once per year, averaged over three consecutive years.

[2] Eight-hour averaging is more consistent with the health information that prompted EPA to propose revisions to the standard. Also, by averaging over eight hours, the standard helps protect people who spend a significant amount of time working or playing outdoors: a group that is particularly vulnerable to the effects of ozone.

[3] The classifications (status designations) of areas under the new ozone standard are expected to occur in 2004. State Implementation Plans (SIPs) based on the new standard are due in 2007. To attain the eight-hour standard, the three-year average of the fourth-highest daily maximum eight-hour average of continuous ambient air monitoring data over each year must not exceed 0.08 ppm. Areas are expected to achieve the standard by 2009, although it is possible to extend the attainment deadline until 2014.

efforts that focused on controlling ozone in urban areas emphasized VOC control. However, in areas with high VOC concentrations, such as rural regions with high biogenic emissions of VOCs, ozone production is NO_x limited. When high NO_x concentrations from cities (or power plant plumes) disperse in suburban/rural regions, they cause major ozone episodes. In fact, more recently it was determined that ozone concentrations reach their maximum levels outside of cities and have a regional characteristic (Mauzerall and Wang, 2001).

In 1989, a federal scientific report suggested NO_x controls as a "new direction" for the Clean Air Act and discussed the state of the science on VOC versus NO_x controls at the time, which included model results for a half-dozen cities and from EPA's Regional Oxidant Model for the Northeast (U.S. Congress, 1989). The results for urban areas were mixed, but studies in the late 1980s were fairly consistent in finding that reducing NO_x would be more effective than reducing VOCs for rural and transported ozone. Chameides et al. (1988) and Trainer et al. (1987) offered convincing demonstrations of the need for NO_x controls in areas with high biogenic VOC emissions. Recently, most science and policy analysts have recommended a strategy for achieving attainment of the ozone standard that focuses on reducing NO_x emissions.

Provisions to address nonattainment of the ozone standard are found in Title I of the 1990 CAAA. Title I required emission rate limits consistent with reasonable available control technology (RACT) for large point sources of both NO_x and VOCs in nonattainment regions and the Ozone Transport Region (described below). These controls were to achieve a 15% reduction in 1990 levels of both of these ozone precursors by 1996. As such, this policy is referred to as the 15% rate-of-progress plan. EPA suggested RACT rates to states that were essentially the same as rates under Title IV for coal-fired boilers. Implementation of Title I came sooner and allowed firms less flexibility than Title IV.

For regions that may not achieve the ozone standard even with the 15% rate-of-progress rule, the 1990 CAAA provides a schedule for an acceptable rate of progress toward attainment. Beginning in 1997, these regions must achieve an average 3% annual reduction in NO_x or VOC emissions, or a combination thereof, over every three continuous years until the standard is achieved. This policy, known as the 3% rate-of-progress rule, applies to summertime emissions in some regions while in others it applies annually.[4]

However, atmospheric modeling demonstrates that precursor emissions from sources outside the boundary of nonattainment areas, in particular NO_x emissions from large, rural, fossil-fuel-fired power plants, has a great effect on ozone concentrations in urban areas. Indeed, many jurisdictions found that they would not be in compliance with the ozone standard even if their own emissions were reduced to zero.

Interstate Atmospheric Transport of Air Pollution

To address interstate transport of air pollution, one major element of the 1990 CAAA was the creation of the northeastern Ozone Transport Region (OTR) and its associated Commission (OTC).[5] The role of the Commission is to promote cooperation among the member states in ozone abatement strategies. In 1994 the states, with the exception of Virginia, signed a memorandum of understanding to establish a coordinated three-phase effort to reduce NO_x from large stationary sources, primarily electric utility and large industrial boilers.[6] Annual control requirements mandated by the 15% rate-of-progress requirement (RACT rules) were viewed in the memorandum as Phase I of the plan.[7] Unlike most of the country, where the tightening of NO_x RACT standards was only required in regions of nonattainment with the ambient ozone standard, the states in the Ozone Transport Region were required to submit RACT plans for the entire state. These control requirements became effective in the Ozone Transport Region between 1993 and 1995. However, the memorandum anticipated that these requirements would not be sufficient to bring the region into attainment with the ozone standard.

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[4] An important caveat to the 15% rate-of-progress rule was that a state did not need to reduce NO_x in the nonattainment region if it demonstrated that those reductions would result in an increase in ozone concentrations. In some circumstances where VOCs are the limiting precursor to ozone formation, additional NO_x will lead to a reduction in ozone. This phenomenon, known as "NO_x scavenging of ozone," typically happens only within 50 miles of an emissions source. At least 12 waivers were granted based on this provision. Occasionally, where NO_x abatement from sources in nonattainment regions was seen as undesirable, the burden for ozone control would fall upon VOC regulation under the 3% rate-of-progress. However, a strict focus on VOC control is an extremely burdensome way to achieve compliance.

[5] The OTR comprises 11 northeastern and mid-Atlantic states stretching from Maryland to Maine, plus the District of Columbia and the northern counties of Virginia.

[6] The program includes all fossil fuel-fired boilers with a 250 million Btu/hour or greater maximum rated heat input capacity and all electricity-generating facilities with a rated output of 15 MW or more.

[7] In New England states, RACT is defined as category-wide emissions rate limitations or control technology requirements. In Pennsylvania, RACT is explicitly defined as the implementation of low-NO_x burners. Throughout the New England region this technology was a common compliance strategy.

Introduction of Flexibility

Phases II and III of the NO_x abatement plan in the northeast are collectively referred to as the Ozone Transport Commission NO_x Budget Program. These phases of the program establish emissions "budgets", or caps on total allowable emissions, for the period when ozone is commonly a problem, May 1 through September 31.[8] The Phase II seasonal NO_x budget for the region, which applied in 1999 to 2002, is 219,000 tons (U.S. EPA 1997). In Phase III, scheduled to begin in May 2003, the summer allocation would be reduced further to 143,000 tons. These budgets represent a substantial reduction from the 490,000 tons of summer emissions in the region in the baseline year, 1990.

Phases II and III employ a regional emissions cap-and-trade program among all affected sources. A cap-and-trade approach ensures that the regional budget is met while attempting to minimize the cost of meeting it. Unlike the Title IV provisions for NO_x, where emissions are allowed to grow in tandem with economic growth, a key feature of the NO_x budgets and the associated cap-and-trade program is that emissions are fixed and it is the emissions allowance price that fluctuates.

Unlike the SO_2 trading program that is administered at the federal level, the cap-and-trade program in the Ozone Transport Region required a high level of coordination among state rules to implement it. To move this process along, a model rule was developed that identified key elements that should be consistent among the participating states' regulations.[9] These regulations were then to be included in each state's implementation plan (SIP) submitted to EPA. Experience with the trading program is described below.

Trading in the NO_x SIP Call Region

The Ozone Transport Region in the Northeast is a subset of the larger eastern U.S. region that is subject to substantial transboundary drift of NO_x. Because the states in this larger region were concerned that they could not achieve the one-hour ozone NAAQS without a coordinated effort, they participated along with EPA in a structured process known as the Ozone Transport Assessment Group to study the issue. The goal of the process was to develop consensus among the states for a coordinated effort to reduce

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[8] The NO_x budget for the entire OTR is calculated by applying emissions reduction factors to each source. Each state has discretion in allocating its share of the NO_x budget to its respective sources of emissions. Note that sources that do not fit these criteria may voluntarily participate in the program.

[9] Environmental Science Services (1996).

ground-level ozone in the eastern United States. The Group's final report was released in June 1997 and provided few actionable recommendations. For example, while there was considerable effort to promote an emissions trading program to control NO_x emissions, no such recommendation materialized from the process (Keating and Farrell, 1999). However, it did contribute to a consensus understanding of the problem at a regional level.

EPA has the authority to require states to impose restrictions on sources of NO_x emissions to assist downwind states in compliance with the ozone standard via Sec. 110 of the 1990 Clean Air Act. In late 1997 EPA published a proposed rule relying on this statutory, and in 1998 EPA formalized the proposal. This rule is widely referred to as the "NO_x SIP Call," because it required states to submit revisions to their state implementation plans (SIPs) outlining their strategies for complying with state-level summertime NO_x emissions budgets.[10] The revisions were to be submitted by 1999 and to be effective by May 1, 2003. Although the rule allows states to develop their own strategies and rules for reducing NO_x emissions, participation in a regional cap-and-trade program similar to the Ozone Transport Region program has been strongly encouraged by EPA.[11]

The NO_x SIP Call originally targeted 22 states and the District of Columbia, where nearly 90% of the boilers covered in the Title IV program are located. After various court proceedings, the date for submitting revised SIPs was delayed until October 2000, and the date for achieving the reductions was postponed until May 31, 2004.[12,13]

[10] While Sec. 110 of the 1990 CAAA allows the EPA administrator to determine a need for controls on upwind sources to ensure attainment of the ozone NAAQS in downwind states, Sec. 126 of the act allows states to petition the administrator to require controls on these sources. In August 1997 eight northeastern states (joined by three other states in 1999) filed petitions under Sec. 126 requesting that EPA address emissions from these upwind sources. On April 30, 1999, EPA accepted the validity of these requests and initiated the Sec. 126 Federal NO_x Trading Program, which affects 13 states (a subset of the states affected by the NO_x SIP Call). The Sec. 126 program remains outside the bounds of the SIP process and is thus fully implemented by the EPA (with allocations much like the SO_2 trading program). However, it was agreed by the petitioners and EPA that the Sec. 126 program would be subsumed by the NO_x SIP Call as the goals of the two programs are the same, provided that the SIP Call program survived legal challenge.

[11] The EPA program for the SIP region, when fully implemented, would subsume the smaller OTC program in the Northeast.

[12] The NO_x SIP Call is designed for attainment with the new eight-hour ozone NAAQS promulgated by EPA in July 1997. However, on May 14, 1999, the U.S. Court of Appeals for the District of Columbia Circuit (D.C. Circuit) ruled that the eight-hour standard for ozone was unenforceable. The court also granted a motion to stay the NO_x SIP Call deadlines for state SIP submissions on May 25, 1999.

The courts also modified the SIP Call region so that, in the end, the region will encompass 19 states and the District of Columbia.[14] States that participated in the Ozone Transport Region program began complying with the SIP Call on May 1, 2003, following their original plan of a third phase for that program.

At the national level, the NO_x SIP Call would lead to reductions of 22% from an annual baseline level of 5.4 million tons in 2007 to a new annual level of 4.25 million tons, according to EPA estimates. Summer-season emissions in 2007 would fall by 40% from 2.4 million tons to 1.45 million tons. In the SIP Call region, the program would lead to annual reductions of 34%, from projected baseline levels of 3.51 million tons to 2.33 million tons in 2007. In the summer season, the program is expected to reduce emissions by 62%, from 1.5 million tons to 0.56 million tons.[15] Most of these reductions will come from coal-fired power plants.

Nationwide Trading as Part of the Multi-Pollutant Legislative Proposals

The NO_x program in the 19 eastern states and the District of Columbia comes at a time when calls for more drastic reductions of several pollutants are taking shape as part of a possible reauthorization of the Clean Air Act. In the 107th Congress, three Senate bills proposed market-based approaches to regulating multiple pollutants. These legislative proposals seek reductions in emissions of SO_2, carbon dioxide and mercury as

Without a schedule for NO_x SIP Call in place, EPA separated action on the Sec. 126 petitions from the SIP Call on June 15, 1999. The Sec. 126 program thus became the basis for proceeding with the reductions required by the SIP Call program. However, as it became more certain through subsequent court action that the NO_x SIP Call would proceed in generally the same form originally envisioned by EPA, the agency essentially amended the 126 program so that it could be subsumed by the SIP Call program.

[13] After 2004, the trading season will begin May 1 and continue through September 31. While the first year will have a shortened trading season, seasonal budgets (and thus NO_x allowances) are unaffected. This allows an average emissions rate that is higher than in subsequent years.

[14] In March 2000, the Court of Appeals excluded Wisconsin from the program and raised questions about the inclusion of Georgia and Missouri. In August 2000, the court ruled that the compliance date would be May 2004.

[15] U.S. EPA 1998, Figure 2-4 and Table 2-4. The EPA baseline includes the 1990 Clean Air Act Amendments, but only RACT controls in the Ozone Transport Region. There are two reasons these numbers are approximate. One is that the reductions pertain to EPA's original program that targeted 22 states and the District of Columbia. The second is states have some latitude to change the portion of their emissions budget that is covered under the cap-and-trade program.

well as NO_x from the electricity sector.[16] An important difference in the bills is whether or not carbon dioxide is included. The electricity industry is already switching from coal or oil to natural gas as the preferred fuel for new generation facilities, and the proposals have implications for the rate at which that transition will continue. Emissions of all the mentioned pollutants are much greater from coal or oil than from gas; emissions of SO_2 and mercury are virtually zero for gas. Taken in isolation or as part of a moderate multiple pollutant proposal, the NO_x emissions reductions under the SIP Call are expected to prompt the installation of post-combustion controls at coal-fired plants and many gas-fired facilities as the primary means of compliance. They are not expected to accelerate significantly the transition to natural gas. However, the inclusion of strict mercury reduction requirements, and especially the inclusion of carbon dioxide emissions targets, will accelerate a transition from coal to natural gas.

III. The Performance of Prescriptive Approaches

In this section, we analyze prescriptive regulations affecting investments at new power plants and major modifications to existing plants, and subsequently we review prescriptive regulations affecting existing sources. These regulations are usually characterized as an emissions rate-based standard that might be interpreted as a performance standard. However, in practice, these regulations often take the form of technology standards because the allowable emissions rates are usually written to correlate to a specific technology choice. Firms may have the latitude to deviate from a specific technology that is pre-approved by EPA or the state, but in doing so the firm assumes the burden of proof to demonstrate compliance, and that can be a difficult hurdle.[17]

Prescriptive Regulation for New Investments: NSPS

The New Source Performance Standards (NSPS) program constitutes traditional source-specific prescriptive regulation for new units and any existing units undertaking a

[16] The Jeffords (I-VT) bill (S. 556) caps annual allocations of NO_x emissions allowances at 25% of their 1997 levels (about 1.5 million tons). The Bush administration's "Clear Skies" proposal, sponsored by Sen. Smith (R-NH) as S. 2815 caps annual emissions of NO_x at 2.1 million tons in 2008 and 1.7 million tons in 2018. The Carper (D-DE) bill (S. 3135) caps annual emissions of NO_x at 1.87 million tons in 2008 and 1.7 million tons in 2012.

[17] However, it has become easier for firms to demonstrate the effectiveness of alternative control strategies due to continuous emission monitoring required by Title IV of the 1990 CAAA.

major modification. The first generation of the Standards followed the 1970 CAAA and applied to generating units that were constructed or modified between August 1971, and September 1978. The standards were modified in the CAAA of 1977, which were applicable from September 1978, until July 1997. The limits specified emissions per unit of heat input to the electric boiler, and they varied for plants based on the type of fuel used and, in the case of coal, the quality of the fuel. However, these standards were not constraining for most projects. In 1998, EPA issued new standards that were retroactive to 1997. These revised standards are fuel-neutral and based not on the ratio of emissions to heat input, but on emissions to electricity output.

The levels of the Standards are summarized in Table 1. An important observation is that the current standards are neutral among fuels, which was not the case in earlier versions of the standards that were more lenient for coal generation than gas and oil. The current standard for new sources is 1.6 pounds of NO_x per MWh, without regard to fuel type. Hence, this does not distinguish among fuels and also does not distinguish among the efficiency of the generation technology (heat rate) of different types of facilities. Along with existing combustion controls, the standard is expected to require some form of post-combustion control, typically selective catalytic reduction, at new steam boilers. The standard is estimated to result in a decrease in emissions of 26,000 tons in 2000, primarily from coal-fired electricity generating boilers, relative to the previous standard (63 FR 49450).

Table 1. New Source Performance Standards for NO_x

Affected Boilers	Standard (pounds NO_x per million Btu)	Date for Compliance
Units greater than 73 MW	0.8 for lignite from North Dakota, South Dakota, or Montana; 0.7 for solid fossil fuel; 0.6 for other lignite; 0.3 for oil; 0.2 for gas	8/17/1971
Units greater than 73 MW	0.8 for lignite from North Dakota, South Dakota, or Montana; 0.7 for solid fossil fuel; 0.6 for other lignite, bituminous, and anthracite and 65 percent NO_x removal; 0.5 for subbituminous and 65 percent for NO_x removal; 0.3 for oil; 0.2 for gas; 0.3 for oil; 0.2 for gas	9/18/1978
Units greater than 25 MW	0.15 lbs./MMBtu for modified sources 1.6 lbs/MWh for new sources	7/9/1997

Sources: EIA 1998; Krolewski and Mingst 2000.

The New Source Performance Standards appear to have had an effect on the emissions rates from coal-fired power plants. Figures 2 and 3 illustrate the percent of NO_x emissions from coal plants, arrayed by vintages. In each figure, the vertical axis represents the emissions rates of the units, and clearly there is a reduction in emissions rates over vintage. The first three groups include units brought into service before 1970, and roughly correspond to the units built before the implementation of the 1971 standards. The fourth group of plants, built in the 1970s, corresponds roughly to the original NSPS that were in effect between 1971 and 1978. The group of plants built after 1980 corresponds roughly to those affected by the 1977 NSPS that took effect in late 1978, and were in effect until 1997. The vertical bar to the far right of Figure 2 corresponds to the group of plants affected by the standard that took effect in 1997.

Figure 2. NO_x emissions and share of generation from coal-fired boilers.

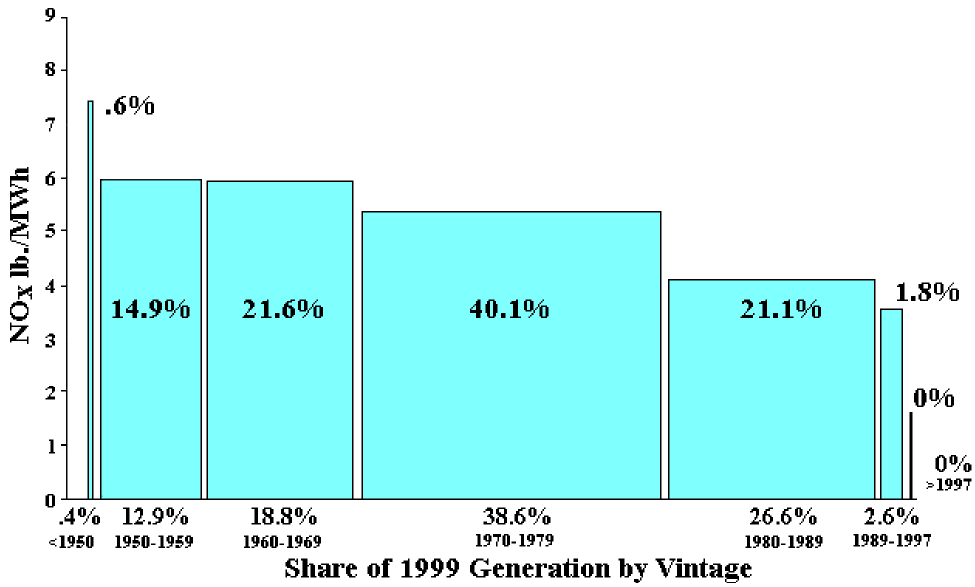
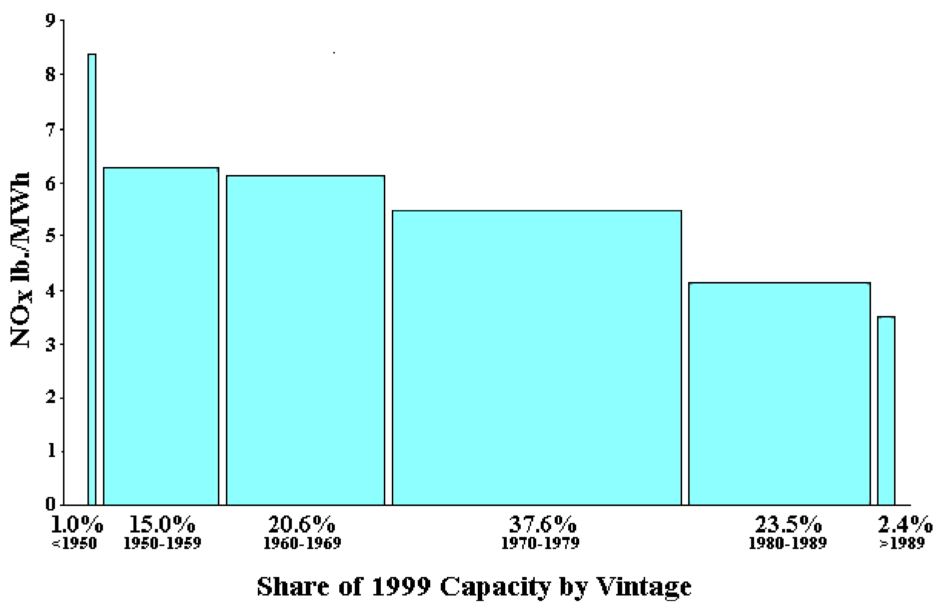


Figure 3. NO_x emissions and share of capacity for coal-fired boilers.



In Figure 2, the horizontal axis represents the share of 1999 generation by coal-fired units. The graph is a histogram, with the areas within each rectangle representing the percent of all NO_x emissions by these units. The average emissions rate of units built before the New Source Performance Standards is about 6 lb NO_x per MWh, dropping to 5.37 in the 1970s, 4.09 in the 1980s, and 3.55 in the 1990s. Absent other considerations, if units built after 1970, approximately when new source standards came into being, had the same emissions rate as units built before 1970, their NO_x emissions would increase by about 14%.

In Figure 3, the horizontal axis represents the share of installed capacity. The areas in the rectangles represent relative potential emissions, but since units are utilized differently, this does not correspond directly to emissions actually observed in Figure 2. One can observe in comparing the two figures that older units have a somewhat larger share of capacity than generation, reflecting the fact that newer units operate for more hours due to their greater efficiency and reliability.

Nonetheless, when the 1970 CAAA was written, the implicit assumption was that the power plant capital stock would turn over on a schedule that roughly approximated their book life (30 years). In fact, many older power plants have received extensive maintenance, as well as new electronics and other innovations, which have increased their lifetimes (Ellerman, 1998). The New Source Performance Standards have been ineffective at reaching these plants. New plants are subject to regulations for NO_x and other pollutants that put them at a competitive disadvantage, at least as far as expenditures for pollution control. Many authors have argued that this has contributed to the extension of the lifetimes of existing plants, a result that is both uneconomic and harmful to the environment (Swift, 2000). Furthermore, although the assumption implicit in the NSPS was that it would be cheaper for new sources to reduce emissions, today it is often cheaper for existing sources to reduce pollution because of the strict standards applied to new sources. The cost per ton of NO_x reduction at new sources is about \$565 for new coal, with the installation of selective catalytic reduction. The cost per ton at existing uncontrolled units ranges from \$0 for cyclone units, to \$161 for wall-fired units, to \$631 for tangentially fired units (Swift, 2001).

Prescriptive Regulations for Existing Units: OTR RACT and Title IV

Ex ante, EPA projected annual NO_x reductions during Phase I of the Title IV program of 0.6 million tons (ICF, 1990). The anticipated direct costs of achieving these NO_x reductions are difficult to ferret out because they were combined with expected costs of SO_2 reductions, but they appear to be about \$100 million (ICF, 1990). By 1995, the abatement estimate was updated to reflect the expectation that only 0.5 million tons would be reduced, because of changes in the expected baseline against which emissions reductions were measured (ICF, 1995). At that time, the average cost per ton of emissions reductions was expected to be $180.

In Phase II, beginning in 2000, the annual emissions of NO_x were expected to fall by 2–2.2 million tons compared to a baseline forecast in 1990 (ICF, 1990). Whether these emissions reductions were achieved depends again on one's interpretation of the baseline against which emissions are measured.[18]

NO_x emissions in 2000 from all Title IV-affected sources totaled 5.1 million tons. This represents a 3 million ton reduction relative to the forecast 2000 baseline of 8.1 million tons offered in EPA (2002b). Relative to 1990 NO_x emissions, 2000 emissions from these sources are 23%, or 1.55 million tons, lower. If we limit our comparison to only those sources affected by the NO_x provisions of Title IV (i.e., coal-fired units), emissions in 2000 were 4.48 million tons and only 19%, or 1.05 million tons, lower than in 1990. The smaller percentage reduction from facilities affected by NO_x provisions of Title IV, which are only coal-fired, reflects the decline in oil-fired electricity generation. The reduction from NO_x affected sources was not as great as expected due to reductions in electricity consumption, as noted, but also due to the compliance flexibility allowed by the NO_x program. The number of units adopting each form of compliance (as described above) in Phase II is identified in Table 2.

[18] Annual demand growth in the early and mid-1990s was forecast by ICF (1990) to be 0.005% greater than what actually occurred. Adjusting the forecast of emissions in the baseline to account for lower emissions would lead to a lower measure of emissions reductions. Later estimates adjusted for this lower growth rate. ICF (1996) estimates emissions reductions of 2.06 million tons in 2000, but assumes more stringent controls than ICF (1990), as a result of a lower baseline. Similarly, Burtraw et al. (1998) estimate emissions reductions of 1.97 million tons in 2000 (Phase II), based on the lower estimate of baseline emissions.

Table 2. 2001 Compliance strategies for Title IV (EPA, 2002b, Figure 14).

Compliance Option	Number of Units
Standard Emissions Limitation	140
Early Election	274
Emissions Averaging	638
Alternative Emissions Limitation	27
TOTAL	1,079

The total does not equal the total number of 1,046 affected units because 28 units have both early election and emissions averaging compliance plans, and five units have both AELs and emissions averaging plans.

We conjecture the cost of the program was lower than expected because many units avoided installation of low-NO_x burners, the technology typically anticipated to achieve the standard, often due to the ample flexibility afforded by the multiple compliance options in the program. There also were more low-cost opportunities for abatement than originally anticipated. At units that complied in the standard way by achieving emissions rate reductions at the unit, the initial response to the regulation by plant operators was to optimize the operation of boilers by adjusting air/fuel mixtures and temperatures (Swift, 2001). Second, many units reduced emissions through operational modifications, sometimes called "trimming," that typically reduce boiler temperature slightly, incurring a penalty in the "heat rate" of the facility, but resulting in lower NO_x emissions.[19] Optimization incurs almost no cost, and may result in savings, while operational modifications incur fuel costs. Of the 265 coal-fired units affected under Phase I, only 175 met the emissions rate limits through the installation of low-NO_x burners, which involved greater capital costs as well as a slight heat rate penalty. Emissions averaging allowed 52 units to continue to operate above the average emissions limit. Overall, units lowered their average NO_x emissions rates to 0.4 lb/million Btu, below the average rate of 0.7 lb/million Btu in 1990 (Swift, 2001).

Cost and operation data available from the Federal Energy Regulatory Commission (FERC) Form 1 allow us to see the impact of both the RACT regulations

[19] The heat rate is the amount of energy, usually measured as million BTU, required as an input in order to obtain a unit of electricity, usually measured as kilowatt-hours. The lower the heat rate, generally the more efficient is the facility .

required in the Ozone Transport Region and Phase I of Title IV of the 1990 CAAA. The plants represented in Figures 4 and 5 are those that can be tracked in the FERC Form 1 every year in the sample period that contain boilers that must comply with Title IV of the CAAA. Plants with units that installed scrubbers to comply with the Title IV SO_2 provisions are removed from the sample. The plants are divided into two categories; those affected by the Ozone Transport Region (OTR) policies and those only affected by the Title IV provisions (nonOTR)[20] Recall that the RACT rules are typically very similar to the unit-specific Title IV requirements, accept that they don't allow the alternative compliance methods available in the Title IV program.

Figure 4. Average heat rate of Title IV coal-fired boilers.

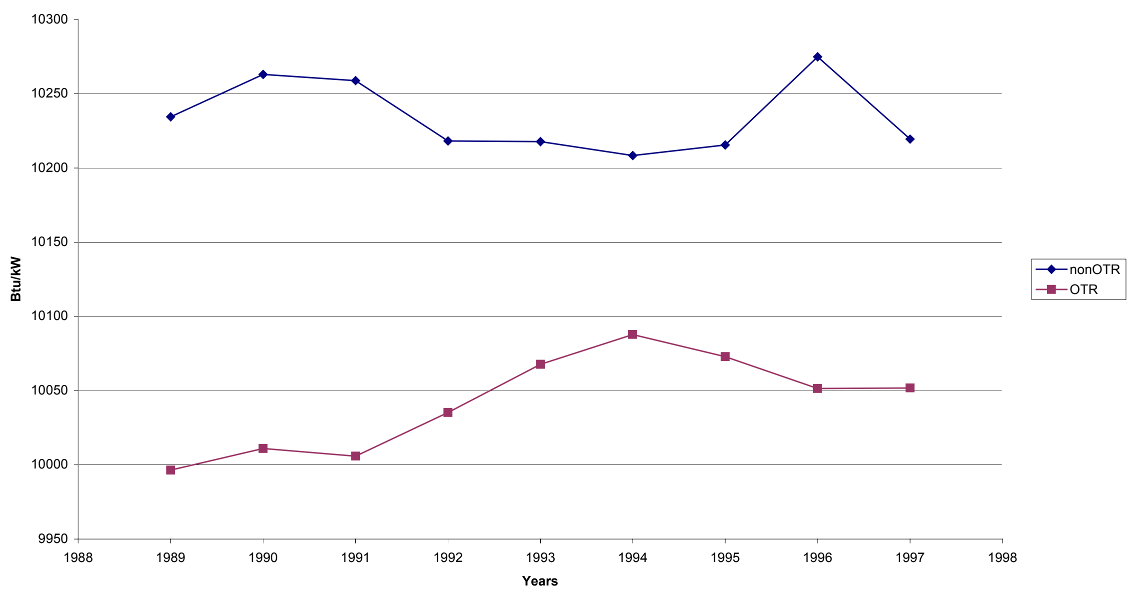


Figure 4 illustrates the effect on variable cost of trimming and combustion control modifications, such as the installation of low-NO_x burners, which typically lowers plant efficiency and thus raises a plant's heat rate. Although Title IV standards were established earlier, they were implemented later than similar standards in the Ozone Transport Region. Hence, one would expect to find an increase in the average heat rate in the region previous to similar increases at the national level. This is evident in Figure 4. Beginning in 1992 and continuing through 1995, when initial experimentation with

[20] The sample is further limited to plants where generation from coal is at least 90% of total generation. The sample is about two-thirds of total coal-fired capacity in each case—the OTR sample and the Title IV sample not in the OTR. Some of the units in the Title IV sample are also subject RACT rules given their location in nonattainment regions, but this is likely a small number of facilities.

operating controls occurred in the Ozone Transport Region, corresponding to the introduction of RACT regulations. Figure 4 indicates that a similar increase in heat rates occurred in the remainder of the country in 1996 as Phase I of Title IV came into effect. The heat rate increase outside the Ozone Transport Region is dampened by the inclusion of units that are not affected by the Title IV provisions until Phase II. Nonetheless, one also sees an increase in the heat rate in the region in the first year of compliance.

Also evident in Figure 4 is a period of learning, which corresponds with the learning process at individual facilities as the boiler operations were modified in a period of experimentation in the search for compliance strategies. By 1996, heat rates had stabilized at levels higher than those prior to Phase I of the program in the Ozone Transport Region, but well below levels during the initial years of compliance. One sees a similar decline after learning had occurred for the Title IV-affected sources in the remainder of the country. Inevitably, there was fleet-wide learning and, as companies took advantage of the ability to average emissions over commonly owned-units under Title IV, production moved from inefficient to efficient units.

Modifications necessitated by RACT standards and the Title IV NO_x program also imposed capital costs. Figure 5 tracks the average change in physical plant (equipment and structures) capital cost at coal-fired boilers affected by Title IV of the 1990 CAAA. Significant increases in new capital expenditures in the Ozone Transport Region coincide with the introduction of RACT performance standards for NO_x in the region. These costs reflect the installation of low-NO_x burners, but in addition a number of power plants in this region installed post-combustion controls.

EIA (1998) reports that the cost of retrofitting a boiler with low-NO_x burners is about 9.3–44/kW.[21] A direct comparison between this cost and the changes in capital cost is difficult given that the signal in Figure 5 is confounded by the inclusion of expenditures not related to NO_x controls. Also, there is more flexibility in Title IV than is allowed by the RACT standards in the Ozone Transport Region, which would provide greater ability for firms to avoid capital costs. Nonetheless, the capital cost changes in Figure 5 are consistent with what would be expected from these policies.

[21] The costs are reported in current dollar terms, but the exact year is not indicated.

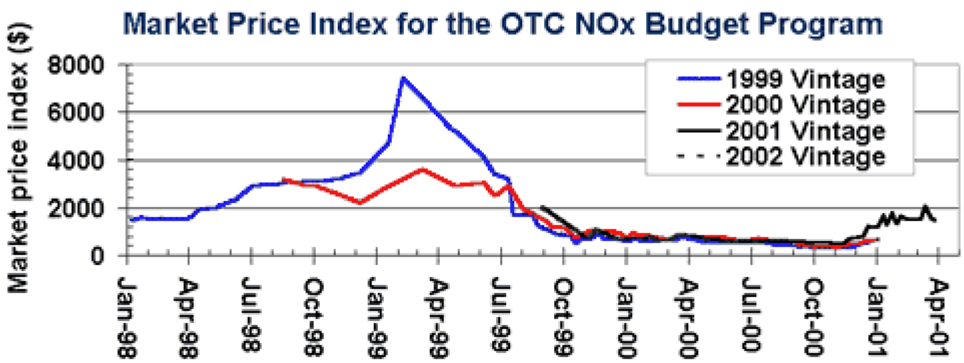
Figure 5. Annual additions to capital cost from new equipment and structures at coal-fired plants.

IV. Flexible Regulation: Cap-and-Trade in the Ozone Transport Region

Beginning in 1999, the second phase of the Ozone Transport Region achieved further reductions in summertime NO_x emissions through a tightened cap on aggregate emissions coupled with trading of emissions allowances. In general, the trading program can be considered a success, especially when one considers that it was developed before many of the lessons of the Title IV SO_2 program, the only trading program of similar scope, were realized. Trading between economically unrelated sources and across state lines has been robust, suggesting that trading provided an opportunity to realize cost savings. Enforcement has been very good. Between 1999 and 2001, only eight sources were in violation of their allowance holdings. Meanwhile, emissions reductions have exceeded targets, and the program also served as the model for the NO_x SIP Call program.

Although the Ozone Transport Region's trading program can generally be considered a success, it got off to a rocky start. This is evident in the wild price allowance fluctuation in the first half of 1999. Figure 6 tracks the allowance prices of the different vintages of allowances in the program.

Figure 6.



Source: U.S. EPA, http://www.epa.gov/airmarkets/trading/noxmarket/pricetransfer.html, accessed December 2, 2002

The greatest source of uncertainty at this time can be attributed to the difficulty in achieving the coordination necessary to implement such a program (Krolewski and Mingst, 2000). This was manifested in the participant states finalizing their allocation and participation rules less than six months before the season began. For example, early reduction credits, which represented about 10% of the total number of allowances allocated in 1999, were not distributed until April and May. The rulemaking delay also raised questions about whether certain states would participate in the program at all. The most notable case in this regard is the state of Maryland, which in fact did not participate in the 1999 trading season.[22,23]

Another source of uncertainty and market volatility resulted from the use of compliance strategies such as load shifting and trimming that did not rely on a significant number of retrofits. The cost and performance of retrofits could be fairly well anticipated by the market; the success of operational strategies was uncertain, but ultimately

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[22] The realization that Maryland would not participate in the first season eventually resulted in downward pressure on the allowance price, as Maryland sources were expected to be net-demanders of allowances (Farrell, 2000). Maryland's participation was held up by a legal challenge from two utilities. Maryland signed a consent decree with the utilities that outlined their phased in participation, which started in 2000.

[23] Maine and Vermont, which were already in compliance with the ozone standard (U.S. EPA, 2002c) and, along with D.C., have few sources that would have been subject to the program (Farrell, 2000), never participated in the trading program. Virginia was never expected to participate in the program as it was not a signator of the agreement that established it.

exceeded expectations (Farrell, 2000). Once these uncertainties were resolved, prices dropped dramatically as it was realized that there would be sufficient allowances to cover emissions, even to the extent that a substantial number would be banked.

Although there was considerable heterogeneity in the state laws and/or regulations implementing the trading program (even with a generally agreed upon model rule), this dimension of the program seemed to have little affect on how it functioned. In part this was because the heterogeneity is found in allowance allocation mechanisms and allowance set-asides, not in anything that would affect the compliance or trading process. States avoided implementing trading restrictions to micro-manage the allowance market (Rhode Island being the notable exception). It was the delayed implementation of state rules, and the difference in the timing of their ratification, that proved more of a problem than the actual text of those rules.

The program demonstrates promise for more decentralized multi-jurisdictional emissions trading programs. The final allocation for 1999 for the states that participated in the trading program was 218,738 tons, including 24,635 early reduction credits (U.S. EPA, 2000). This budget reflects a 54% reduction from the five-month summer 1990 baseline of 417,444 tons for these states. Total emissions amounted to 174,843 tons, with the remainder being banked.[24]

V. Costs of NO_x Control under Cap-and-Trade

The cap-and-trade approach is expected to result in substantial cost savings compared to a prescriptive approach that would achieve the same level of emissions overall. Farrell et al. (1999) use a deterministic, dynamic, mixed integer-programming model of the proposed allowance market in the Ozone Transport Region to predict a total Phase II (1999-2002) compliance cost of about $900 million (1996$). Unfortunately, no ex-post estimates of the total abatement cost of the program are available. However, we surmise that the total compliance cost was likely lower than this estimate. The Farrell et al. model does not allow for changes in dispatch and the option of reducing NO_x through trimming. These compliance measures were evident and, in the case of trimming, surprisingly ubiquitous in the OTR's trading program.

[24] The trading program has a unique constraint on banking, called progressive flow control, which limits the number of allowances that can be withdrawn from a source's allowance bank on a one-to–one basis when the aggregate bank totals more than 10% of annual allocations. The NO_x SIP Call program also has this rule.

The Farrell et al. model also predicts a NO_x allowance price of $1,331 in the first year of the trading program, rising to $1,718 by 2002 (1996$). Significant program uncertainty kept the allowance price above this range until the end of the first trading season. The subsequent downward movement in prices can be attributed to the unexpectedly large number of allowances banked in the first year of the program. As mentioned above, sources also realized that more low-cost abatement methods were available than initially anticipated (indeed, more allowances were banked the following season). In later years, the limitation on the number of banked allowances that could be converted into NO_x SIP Call allowances also kept downward pressure on allowance prices in the market for the Ozone Transport Region's program.

Krupnick et al. (2000) examine the costs of NO_x emissions reductions in an annual trading program in a larger region of 12 states and the District of Columbia, which represent the major sources of emissions in the eastern United States, and is intended to capture most of the emissions within the broader SIP Call region. They find emissions reduction targets can be met at roughly 50% cost savings under a trading program when there are no transaction costs, compared to a command-and-control approach. This provides a rare explicit analysis of the cost savings of trading for NO_x.

Burtraw et al. (2001) find that the seasonal NO_x trading program for the 19-state region is expected to reduce annual emissions within the region from 3.45 million to 2.43 million tons in 2008. The annual cost of post-combustion controls to achieve these reductions is expected to be $2,146 million (1997$). They predict the cost of emissions allowances—presumed equal to the marginal cost of adopting post-combustion controls per ton of NO_x reduction—will be $3,401 (1997$). This compares to a marginal cost of $1,356 for a policy applied just within the northeast Ozone Transport Region.

Although the SIP Call policy will incur important costs, it is not expected to have a large impact on electricity prices. Burtraw et al. forecast that the average price in the SIP Call region in 2008 will increase from $64.4/MWh to $65.1/MWh (1997$). The reason that the effect on price may be negligible has to do with how the cost of capacity is reflected in electricity price. These forecasts assume that the current pattern of electricity regulation continues into the future. The authors assume slightly more than half the generation in the SIP Call region remains in areas characterized by regulated pricing, under which capital and variable costs are annualized and spread over total sales to calculate the price of electricity. In these areas, introducing a new environmental policy that increases the costs of electricity supply leads directly to an increase in the electricity price.

However, the other part of generation in the SIP Call region is in the market pricing areas where the electricity price is determined by the variable cost of the marginal generator plus the incremental capital cost of the marginal reserve unit. Policies that change the relative costs of facilities affect which facility is at the margin, which in turn affects prices and revenues earned by each facility, and thereby capacity investment and retirement. In these areas, introducing a new environmental policy that increases the costs of electricity supply may lead to an increase or decrease in the electricity price.

The primary analysis of the expected cost of NO_x reductions for EPA (1998) finds the average cost per ton of NO_x emissions reduction achieved by the NO_x SIP Call is $1,807; the study does not report an estimate of marginal cost.[25] The change in prices in the EPA study (1998) is about 1.6% assuming marginal cost pricing throughout the electricity sector, and about 1.2% assuming average cost pricing. The EPA study does not clarify whether this applies to the SIP region or the nation. Burtraw et al. (2001) forecast a rise in prices in the SIP region, which combines average and marginal cost pricing, of about 1.1%.

The estimates above are limited to compliance costs. The economic literature recognizes a broader definition of cost from environmental programs. The interaction of regulations with pre-existing regulations or taxes is expected to cause the social cost of new regulations to be higher than the measure of compliance cost in a partial equilibrium analysis. In a general equilibrium framework, the cost of new regulations act like additional taxes in the economy, and they magnify the distortions away from economic efficiency associated with pre-existing regulations or taxes.[26]

Goulder et al. (1999) find that the social costs under a cap-and-trade program actually may be higher than under command-and-control.[27] This can occur because the

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[25] The EPA baseline includes only RACT controls in the Ozone Transport Region, while Burtraw et al. includes the Region's trading policy and its lower average emissions rates. Hence, there exist relatively low-cost abatement options in the EPA analysis that have already been included in the Burtraw et al. baseline. Also, Burtraw et al. assumes 8.7% greater generation in 2008 than does the EPA baseline (for 2007). In addition, the emissions cap is 544,000 tons in the EPA study, but the cap is 444,300 in Burtraw et al. Subsequently, total reductions are 958,000 tons in the EPA study and 1,090,000 in Burtraw et al. The EPA study includes the original 22 eastern states plus the District of Columbia; the Burtraw et al. SIP region varies slightly.

[26] Williams (2002) demonstrates an important corollary that there also may be important hidden benefits within a general equilibrium framework due to the effect of pollution on the productivity of labor.

[27] Although this is an important possibility, the analysis does not account for the heterogeneity in generation technology (Burtraw and Cannon, 2000) and the way that electricity price is determined at the margin (Palmer et al., 2002).

opportunity cost reflected in permit costs might increase product prices to a greater degree than would a command-and-control policy. However, an important distinction between these policies is that a cap-and-trade program has the potential to generate revenues, which a command-and-control policy does not. An auction of emissions allowances can generate revenue that might be used to reduce pre-existing distortionary taxes, thereby offsetting much of the hidden costs. In neither the cap-and-trade program in the Ozone Transport Region or the SIP Call program are allowance auctions widely used.[28] Rather, permits are almost always distributed at zero cost, so no revenue is available to reduce taxes. In any case, the approach to distributing emissions allowances is one of the important issues in the design of future emissions trading programs.

VI. Conclusion

Policy affecting NO_x emissions from coal-fired power plants in the United States has evolved from prescriptive approaches to more flexible cap-and-trade approaches. Both approaches remain important today, but the future is likely to show an expanded role for the use of cap-and-trade.

Prescriptive approaches include standards on new sources that can claim to have led to emissions reductions; however, the perverse bias against new sources associated with New Source Performance Standards is likely to have undermined the accomplishments of the program to some degree. A prescriptive approach also characterizes the first phase of the Ozone Transport Region and the Title IV NO_x programs. These programs also can claim substantial emissions reductions, and their costs appear to be lower than anticipated. Although the Title IV program is prescriptive in nature, it nonetheless shows considerable flexibility through emissions averaging at commonly owned plants, alternative emissions limits, and so forth. To some degree, this may have undermined the effectiveness of the program because there is no cap to limit aggregate emissions.

The cap-and-trade program that began in 1999 in the Ozone Transport Region provides the maximum flexibility, but it also provides the maximum effectiveness by capping emissions. That program also can claim significant emissions reductions, at costs that are low, compared to a command-and-control approach.

[28] Only a couple states have considered an auction under these programs, and even then only for a small portion of allowances.

Both prescriptive policies and the cap-and-trade programs provide incentives to find low-cost ways to achieve reductions. Unlike the prescriptive policies, however, the cap-and-trade program provides an incentive to harvest low-cost emissions reductions at specific facilities even after the performance standard is achieved because those reductions can avoid investments at other facilities.

The Future of NO_x Policy for Power Plants

Two issues pertaining to the future of NO_x policy for power plants are in the forefront: extending NO_x trading spatially and throughout the year, and reevaluating how emissions allowances are distributed in cap-and-trade programs.

In the near term, NO_x controls, currently limited to the five-month summer season, should be extended year-round. The ozone problem is limited to summertime, and this has been the regulatory handle for the cap-and-trade programs we have discussed. However, other problems associated with NO_x occur throughout the year and, based on the public health and economics literature, are more serious than ozone. Particulate formation and its effect on health is especially important, from an economic perspective, and occurs year-round. Recent studies have shown hundreds of millions of dollars in annual net benefits (incremental benefits in excess of incremental costs) from extending the summertime NO_x trading programs to a year-round program.[29] The adoption of annual trading programs has already begun at the state level. New Hampshire adopted legislation that caps annual NO_x emissions from its three largest plants starting in 2006. In New York, proposed regulations would create a cap-and-trade program during the portion of the year outside the NO_x SIP Call trading season.[30]

In the long term, a critical issue in measuring the economic success of cap-and-trade programs is the way in which emissions allowances are distributed. While there is

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[29] Burtraw et al. (2001) find net benefits to be about $400 million (1997$). Burtraw et al. (2002) conduct a sensitivity analysis and find that in 18 out of 18 scenarios, net benefits are positive, even in the western (upwind) coal producing states in the SIP Call region.

[30] Other states have adopted policies to reduce NO_x emissions outside the ozone season, but they have not used a pure cap-and-trade program. Massachusetts has adopted stricter annual output-based performance standards for its largest generating units. In Connecticut, sources are subject to a stringent input-based performance standard. Both of these states allow emissions averaging across all sources in a facility similar to the averaging provision in the Title IV program. North Carolina has adopted legislation that, starting in 2007, places annual NO_x emissions caps on the two largest utilities in that state. The plants affected by this policy will not participate in the NO_x SIP Call starting in 2007. The utilities agreed to these caps in exchange for a five-year rate freeze and accelerated depreciation of pollution control equipment.

evidence of cost savings from the cap-and-trade approach, this is limited to the measure of compliance cost. In a general equilibrium framework, the measure of the cost (and benefits) of environmental regulations will be greater than the measure of compliance cost, potentially to a significant degree. Unfortunately, the free distribution of emissions allowances precludes the possibility to use revenues from distributing allowances to reduce preexisting tax distortions in the economy that could reduce the costs of the program. How emissions allowances are distributed has large efficiency and distributional implications that were not widely appreciated in the design of previous programs, and will be central in the design of programs in the future.

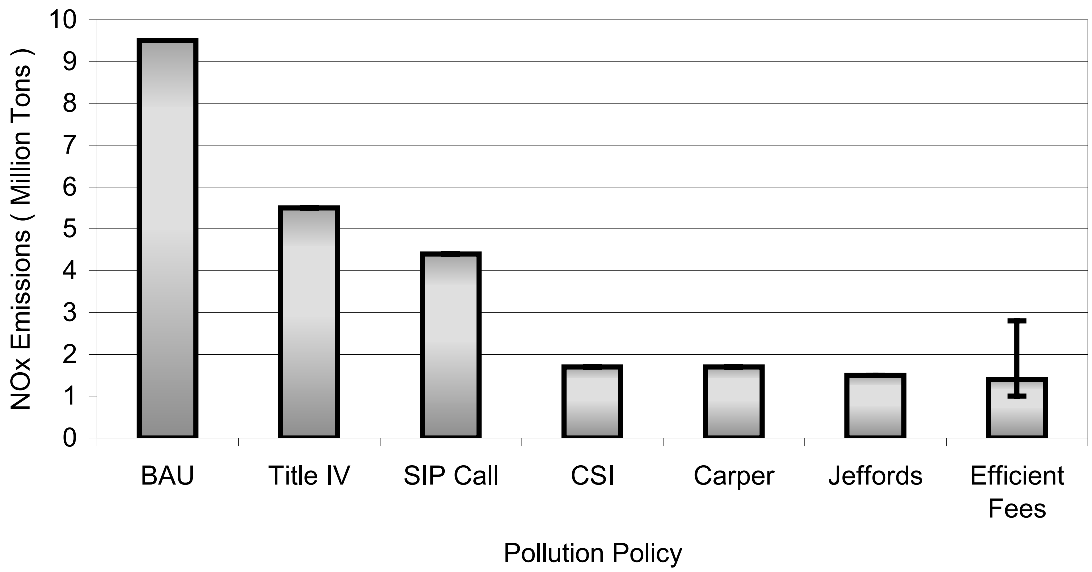
Meanwhile, the evolution to the next stage for NO_x cap-and-trade policies is already underway. The trading program in the Ozone Transport Region, coupled with the success of the SO_2 program, provides momentum for expansion of the cap-and-trade approach under the NO_x SIP Call. In 2003, the NO_x SIP Call will subsume the Ozone Transport Region trading program by significantly expanding the summertime trading program to 19 eastern states, thereby providing the second major experiment in emissions trading in the U.S. electricity industry.

The long-run constraints on NO_x emissions from the power sector may be tightened much further. As we have noted, a new wave of legislative proposals are aimed at further reducing NO_x and other emissions from power plants and would expand the use of a cap-and-trade approach to achieve these emissions reductions, They would extend use of the cap-and-trade approach for NO_x to the national level and to an annual basis.

The potential long-run annual emissions levels under the SIP Call and the multi-pollutant proposals are illustrated in Figure 7. The figure portrays expected emissions from the electricity sector in the year 2020 under various scenarios. The first bar is a business-as-usual scenario (BAU), reflecting a forecast of emissions levels that may have occurred in the absence of Title IV and other provisions of the Clean Air Act, such as the new particulate standard, which ultimately could force major emissions reductions independent of further legislation. The second bar shows annual emissions under Title IV and the Ozone Transport Region programs as of 2000. The third bar shows annual emissions when the SIP Call program is implemented.

The next three bars represent forecasts for annual emissions under the leading three multi-pollutant proposals currently before Congress. The proximity of the long-run targets in these proposals is striking. Finally, at the right is an estimate of the efficient level for NO_x emissions under a cost-effective regulatory policy such as emissions fees or a cap-and-trade program coupled with an allowance auction. This estimate is the result of an integrated assessment linking the Tracking and Analysis Framework (TAF) model of atmospheric transport and health benefits from reduction in exposures to NO_x and nitrates, but excluding ozone from reductions in NO_x emissions, with a market model of the electricity sector. The bar indicates the 90% confidence interval around the mortality, morbidity, and valuation estimates in the benefits model (Banzhaf, et al., 2003).

Figure 7. Electricity Sector NO_x Emissions in 2020



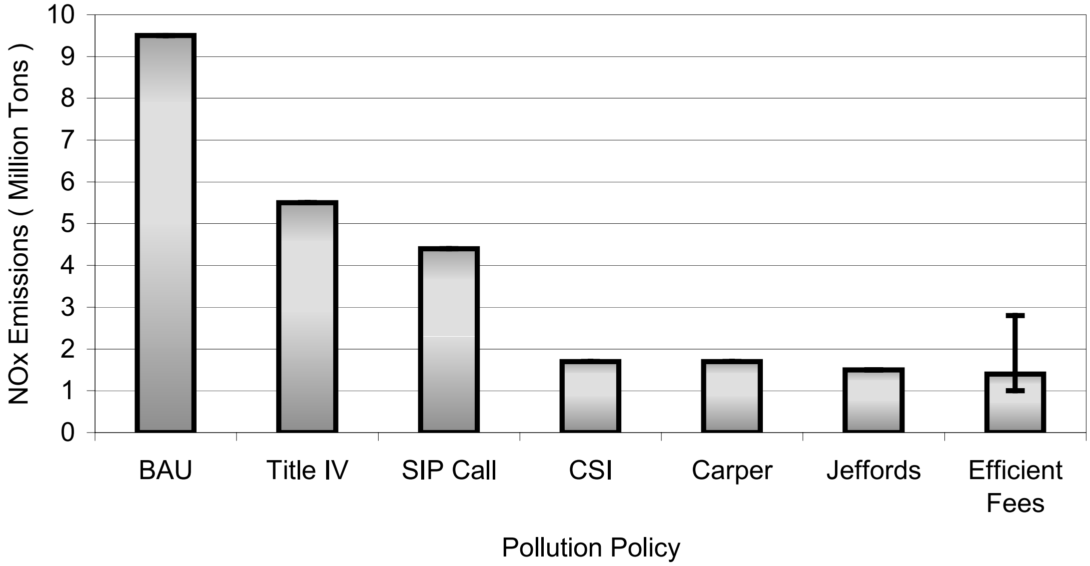


Figure 7 illustrates that, if any of the multipollutant proposals on the table were to pass, emissions would fall within the range identified as efficient by benefit-cost analysis. All of these proposals would use a cap-and-trade approach, which is an important consideration. If the program were more expensive than modeled, perhaps because of hidden social costs associated with the tax interaction effect, because of technology standards implemented simultaneously, or because of interference in compliance planning by state utility regulators, then benefit-cost analysis would suggest a greater level of emissions as the efficient target.[31] On the other hand, the exclusion of benefits from reducing ozone in the graph suggests benefits could be greater than illustrated.

Both prescriptive and flexible approaches are likely to play important roles for NO_x controls at power plants in the future. However, the sun is rising for flexible cap-and-trade policies. At one time, a cap-and-trade approach was viewed by many as a sell-out to business. Today, this approach is embraced across the political spectrum as an important strategy for achieving emissions reductions at less cost than prescriptive regulation.

[31] The Jeffords bill would distribute a large fraction of allowances through an auction, but it would not yield revenues to the federal government that would be available to reduce taxes. The Clear Skies Initiative would distribute a small but growing share of allowances through a revenue-raising auction.

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