The Role Of Ozone Transport In Reaching Attainment in the Northeast: Opportunities, Equity and Economics

Prepared for
Northeast States for Coordinated Air Use Management

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1. Introduction and Summary

Under the Clean Air Act, the Environmental Protection Agency (EPA) has established National Ambient Air Quality Standards for ozone that must be met in order to prevent significant damage to public health and the environment. Yet a large number of states, particularly those in the eastern US, do not meet these standards, and are expected to face great difficulty in meeting them for the foreseeable future.

In November of 1997 the EPA acknowledged that the transport of ozone and its precursors from upwind sources significantly contributes to the level of ozone in certain downwind states. Consequently, the EPA proposed a "SIP call" requiring certain upwind states to reduce NO_X emissions to prescribed budget levels by 2003.

The transport of ozone and its precursors imposes economic costs upon downwind states, as those states must implement increasingly expensive options to reduce local emissions of NO_X and VOCs in order to achieve attainment with the federal ozone standards. The objective of this study is to estimate the extent of the economic impact experienced by downwind states as a consequence of transported ozone. We estimate the costs to the Northeast states of reducing local NO_X emissions in order to offset the transported ozone.

Much of this study focuses on the opportunities and costs of controlling NO_X emissions from the electric utility sector. This sector is a large source of NO_X emissions -- contributing 37 percent of the total NO_X emissions in the Northeast, and 51 percent in the East-central region.[1] Electric power plants also offer the lowest-cost options for controlling NO_X emissions, in general.

As of 1990, power plants in the East-central region produced roughly twice as much NO_X emissions as power plants in the Northeast. This disparity is increasing over time as the Northeast states take greater measures than the East-central states to reduce NO_X emissions. In 1996, power plants in the East-central region produced nearly four times as much NO_X as those in the Northeast. If the East-central region does not meet the budget requirements of the EPA SIP call, then by 2003 the East-central power plants will be producing over seven times as much NO_X as those in the Northeast.

Because of the relatively large volume of NO_X emissions from the East-central region, the transport of ozone into the Northeast could be quite large relative to the amount of ozone that would be created by local NO_X emissions in the Northeast. We estimate, using a range of ozone transport scenarios provided by Northeast States for Coordinated Air Use Management (NESCAUM), that the amount of transported ozone generated by NO_X produced by East-central power plants, could be roughly one to three times as much as the local ozone generated by all of the NO_X emitted from Northeast power plants.

We estimate that even after the East-central sources install additional NO_X controls in accordance with Title IV of the Clean Air Act, the transport of NO_X and ozone from the East-central electricity industry alone would require the Northeast states to incur roughly \$1.4 to \$3.9 billion in additional local NO_X control costs each year. These costs would

[1] We define the Northeast to include New England, NY, NJ, PA, and MD; and the East-central region to include KY, IN, MI, OH, VA, and WV (see Section 3).

be incurred by controlling emissions from industrial point sources, motor vehicles, area sources, and the electric utility sector.

In addition, we have found that in some scenarios the Northeast sources are not able to offset all of the ozone transported from upwind sources -- even after utilizing all currently-known NO_X reduction options. This result suggests that the Northeast will be unable to reach attainment of the ozone standard unless the East-central sources meet the EPA's proposed NO_X budgets. This result also suggests that our estimates of costs imposed on the Northeast sources due to ozone transport might be significantly understated.

The rationale for requiring the East-central sources to meet the EPA's proposed budgets is supported by the fact that there are significantly more low-cost opportunities for reducing NO_X emissions in the East-central region than in the Northeast. We estimate that the East-central power plants can meet the NO_X emission budgets required in the EPA SIP call at an average cost of $662/ton. The Northeast power plants, on the other hand, will spend an average of roughly $1,031/ton to meet the EPA budgets -- roughly fifty percent higher than the average cost to the East-central region.[2]

It is important to recognize that even if all states were to meet the EPA SIP call NO_X budgets, the East-central sources will continue to emit relatively large volumes of NO_X that will contribute to ozone in the Northeast. We estimate that if the East-central sources were to reduce NO_X emissions from the electricity sector down to the levels implied by the EPA's SIP call budgets, the economic impact on the Northeast would be as high as roughly $0.2 to $1.1 billion each year.

Our study suggests that the overall costs of controlling NO_X emissions could be reduced if the EPA were to adopt some form of NO_X credit trading system -- to allow the Northeast sources to purchase some of the relatively low-cost NO_X reductions that are available from the East-central sources. A NO_X credit trading system will help mitigate the burden on the Northeast sources in reaching attainment of the ozone standard, and will also mitigate the net costs to the East-central sources of meeting the EPA SIP call budgets.

The public health impacts of the ozone transported into the Northeast are not considered in this report. Hence, the total health and economic costs of transported ozone are greater than the costs presented above.

2 While these Northeast control options are expensive relative to those available in the East-central region, they are less expensive than control options available from other sectors in the Northeast.

2. Background and Context

In general, the Clean Air Act provides each state with the responsibility for achieving compliance with the National Ambient Air Quality Standards. However, pollutant emissions and impacts within one state often affect the environment and compliance plans of downwind states. In 1990, the Clean Air Act Amendments established the Ozone Transport Region (OTR) in order to address the problem created by the transport of ozone across state boundaries in the Northeast.[3] In 1995, the Ozone Transport Assessment Group (OTAG) was established to investigate the significance of ozone transport among the 37 eastern-most states in the US.

After reviewing OTAG's findings and recommendations, the EPA found in October 1997 that the transport of ozone and its precursors from certain states within OTAG contributes to the nonattainment problems in other downwind states. Consequently, the EPA issued a "SIP call" under Section 110 of the Clean Air Act, requiring certain upwind states to revise their state implementation plans (SIPs) and to achieve NO_X emission limits in order to mitigate the problem of transported ozone (EPA 11/1997).

The SIP call proposes a specific summer NO_X emission budget for each of the 22 states (and the District of Columbia) that contribute to the ozone transport problem.[4] The summer NO_X emission budgets for the electricity sector are determined by assuming that fossil-fueled plants in each state install currently available, cost-effective control technologies, to achieve an average emission rate of 0.15 lb/MMBtu. Summer NO_X emission budgets are also derived for other industry sectors and mobile sources. While EPA derived NO_X budgets for each NO_X emission sector, the states have flexibility in determining how to achieve their overall NO_X budget. The EPA proposes that states be required to meet these summer NO_X emission budgets by 2003 or shortly thereafter.

Many electric utilities are already taking steps to reduce their NO_X emissions. Under Title IV of the Clean Air Act, all US utility coal plants larger than 25 MW are required to meet NO_X emission standards. Phase I of these standards began in 1996, and Phase II will begin in the year 2000. These NO_X standards range from 0.40 to 0.86 lb/MMBtu, depending upon the type of power plant boiler. Thus, they are significantly less stringent than the average emission rate used by the EPA to set the SIP call budgets.

In addition, the Northeast states have agreed to reduce NO_X emissions from the electricity sector by May 2003, as a consequence of their efforts in the Ozone Transport Commission (OTC). They have agreed to reduce NO_X emissions to 75 percent of 1990 levels, or to emit NO_X at a rate no greater than 0.15 lb/MMBtu, whichever is less stringent.[5] Hence, the Northeast states have already agreed to reduce their NO_X

[3] The OTR includes CT, DE, MA, ME, MD, NJ, NY, NH, PA, RI, VT, the District of Columbia (DC), and the DC metropolitan area that is within northern VA.

[4] The EPA assigned a NO_X budget to DC and the following states: AL, CT, DE, GA, IL, IN, KY, MD, MA, MI, MO, NJ, NY, NC, OH, PA, RI, SC, TN, VA, WV, WI (EPA 11/1997).

[5] In fact, the OTR is divided into three zones: Inner, Outer and Northern. The Northern Zone, which includes Maine, New Hampshire, Vermont, and northeastern New York, will be required to reduce NO_X

emissions to levels that are close to those required by the EPA NO_X SIP budgets. Even with these NO_X reductions, some Northeast states are expected to remain in nonattainment for the 1-hour ozone standard, and more are expected to be in nonattainment for the 8-hour ozone standard.

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emissions by 55 percent from 1990 levels, or to emit NO_X at a rate no greater than 0.2 lb/MMBtu, whichever is less stringent.

3. Methodology

Our analysis focuses primarily on NO_X emissions and controls in the electricity industry, because of large volume of emissions and the opportunities for relatively low-cost NO_X reductions from fossil-fueled power plants. We utilize a data base consisting of nearly all coal, oil and natural gas plants larger than 25 MW in the Northeast and East-central regions.[6] The data base includes information on the operating costs, electricity generation, NO_X emissions and existing NO_X controls for these plants in 1996. The data base was assembled using (a) unit characteristic data from the Energy Information Administration of the Department of Energy, (b) NO_X emissions data from the Environmental Protection Agency, and (c) power plant cost and operation data from the Utility Data Institute.

We also compiled information on the performance and costs of various NO_X control technologies for coal, oil and natural gas plants. All of our assumptions for NO_X control technologies in the electricity sector were the same assumptions used by the EPA in its analysis of the ozone transport proposed rulemaking (EPA 1996; EPA 9/1997). For coal-fired power plants, we considered low-NO_X burner (LNB) options, low-NO_X coal-and-air nozzles, gas reburn, selective non-catalytic reduction (SNCR), and selective catalytic reduction (SCR) technologies. For oil- and gas-fired power plants we considered gas reburn, SNCR and SCR. Combustion technologies were applied in combination with post-combustion technologies, where cost-effective.

NO_X control technologies often require significant up-front capital costs, as well as on-going annual operation and maintenance costs. We have levelized the capital costs in order to present total control costs in annual terms. All costs presented in this study are in 1995 dollars. We do not account for increases or decreases in NO_X control costs beyond inflation. A more detailed discussion of our assumptions regarding NO_X control cost in the electricity sector is provided in Appendix A.

Our general approach is to identify the NO_X control technologies that would likely be adopted on a plant-by-plant basis to meet various levels of NO_X standards in the Northeast and East-central regions. We begin with a snapshot of control technologies that are in place today. We then develop reference scenarios that account for all of the NO_X controls that utilities are expected to install by 2003 to comply with provisions of the Clean Air Act. We then look at increasingly stringent levels of NO_X standards, and identify the least-cost control technologies that would be installed and the costs that would be incurred in meeting them. This allows us to develop curves indicating the average and marginal costs of NO_X controls in the two regions.

We define the Northeast states as all of the New England states, New York, New Jersey, Pennsylvania and Maryland. We define the East-central states as Kentucky, Indiana, Michigan, Ohio, Virginia and West Virginia. These regions are presented in the map in Figure 3.1. These regions were defined this way because they correspond to regions that were modeled by OTAG.

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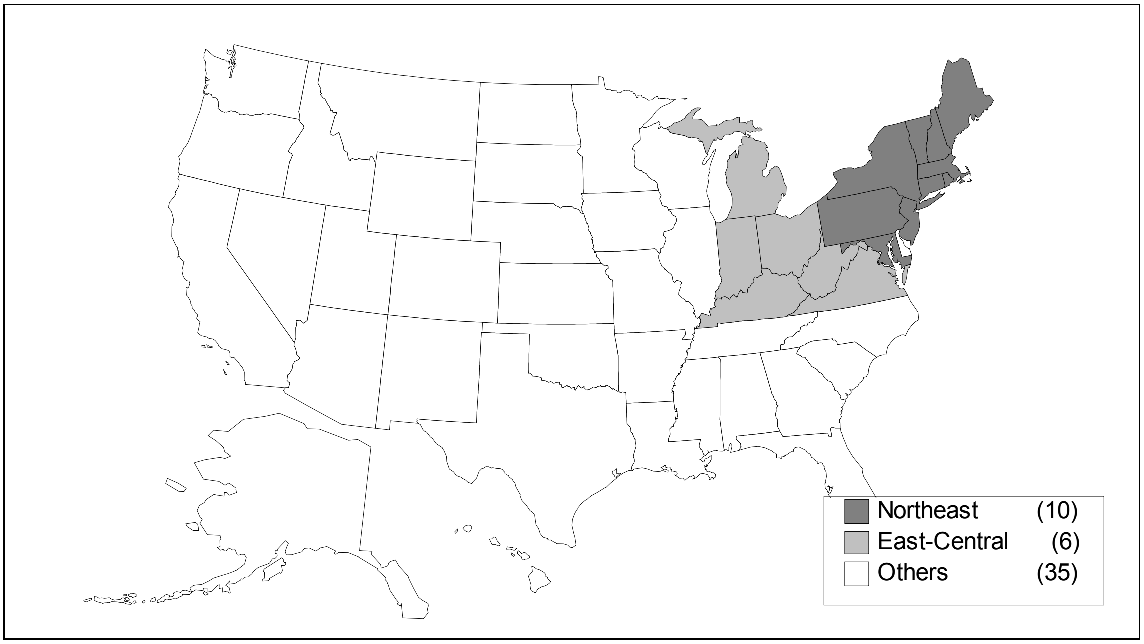
6 The data base does not contain information on gas turbines. The power plants in the data base represent 98 percent of the generation in the Northeast and 99 percent in the East-central region.

Figure 3.1 Map of Northeast and East-Central Regions



In discussing the transport of ozone, we generally refer to the Northeast region as "downwind," and the East-central region as "upwind." In fact, the transport of ozone is much more complicated than this. Some states within the Northeast (e.g. Pennsylvania) are upwind of other states in the Northeast. A number of states outside the Northeast are upwind from the East-central sources. In addition, other states contribute to ozone transport within and outside the East-central and Northeast regions. We have defined these two regions as upwind versus downwind in order to simplify our analysis. We do not mean to imply that states falling outside either of these regions do not contribute to (or suffer from) the ozone transport problem.

Given that the EPA has proposed NO_X budgets for the year 2003, we have modified our data base to reflect the operation of existing power plants in that year. We use the same assumptions for the growth in power plant utilization that were used by the EPA in its analysis of NO_X budgets in the proposed rulemaking. The existing fossil-fired power plants can meet all of the EPA's assumed growth in utilization by increasing their capacity factors. Therefore, we have assumed that no new power plants will be operating in 2003.

Our assumptions regarding NO_X control options for the electricity sector are limited to "bolt-on" control technologies. We do not consider other options such as fuel-switching, repowering, plant retirement, alternative dispatching approaches or power plant efficiency improvements. In addition, we do not account for technological improvements and cost reductions for NO_X control measures as the market demand for them increases over time. Consequently, our estimates of NO_X control costs for the electricity sectors in both the Northeast and East-central region represent high-side estimates.

4. The Sources of NO_X Emissions in the Northeast and East-Central Regions

Table 4.1 presents an overview of the anthropogenic NO_X emissions in both the Northeast and East-central regions in 1990. The same information is presented in Figure 4.1 below. Two points are relevant for our analysis. First, electric utilities are responsible for a large portion of NO_X emissions -- accounting for roughly 37 percent of emissions in the Northeast and 51 percent of emissions in the East-central region. Consequently, the potential for NO_X reductions is greater in the electricity sector, simply on the basis of the volume of emissions.

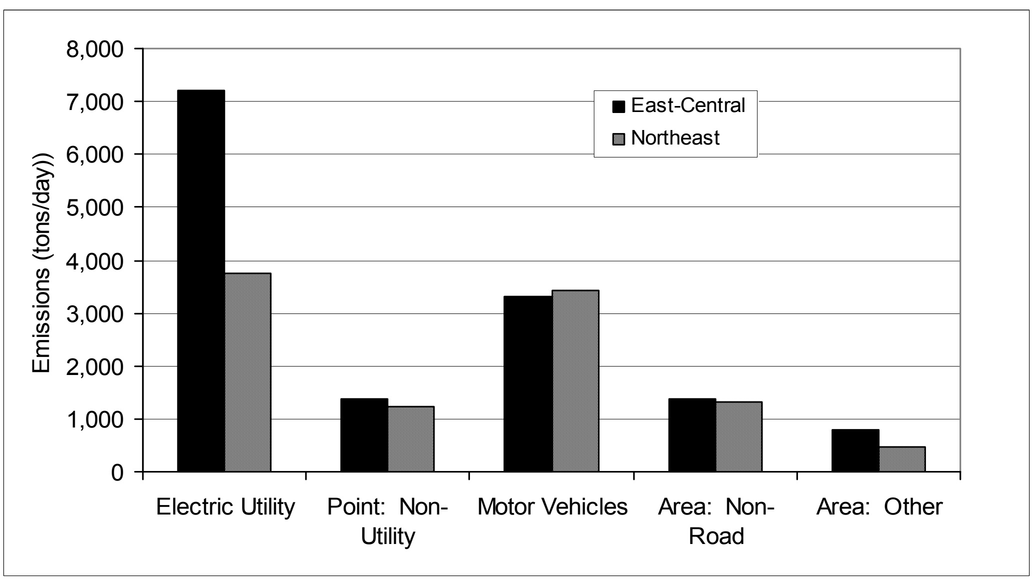
Second, power plants in the East-central states are responsible for roughly twice as many NO_X emissions as power plants in the Northeast states. As a result, the power plants in the East-central region provide the greatest opportunity for reducing NO_X emissions.

Table 4.1 Volume of 1990 NO_X Emissions, by Sector (tons/summer day).

	Northeast	East-Central
Electric Utility	3,740	7,205
Point Sources: Non-Utility	1,229	1,363
Motor Vehicles	3,439	3,318
Area Sources: Non-Road	1,324	1,380
Area Sources: Other	460	794
Total	10,192	14,060

Source: The Ozone Transport Assessment Group.

Figure 4.1 Volume of 1990 NO_X Emissions, by Sector (tons/summer day).



The high emissions of NO_X from the East-central electric utilities are due in part to the fact that the East-central region relies upon coal-fired power plants for the majority of its electricity generation. In 1996 the East-central region obtained nearly 87 percent of its generation from coal-fired plants, whereas the Northwest relied upon coal plants for only 46 percent of its generation.

In addition, the Northeast states have already taken more steps than those in the East-central region to reduce their NO_X emissions. In the Northeast, electric utilities have installed low-NO_X burners on roughly 75 percent of coal plants, 41 percent of oil plants, and 54 percent of gas plants. Electric utilities in the East-central region, on the other hand, have to date installed low-NO_X burners on only 43 percent of their coal plants and none on their oil and gas plants.

As a result of these NO_X control efforts, the average NO_X emission rate from all fossil-fired power plants in the East-central region is currently significantly higher than that in the Northeast. In 1996 the average NO_X emission rate from fossil plants in the Northeast was 0.42 lb/MMBtu, whereas the average rate in the East-central region was 0.69 lb/MMBtu -- roughly 67 percent higher than in the Northeast.

In addition, the Northeast relies less heavily on fossil-fired plants for generating electricity than the East-central region. Consequently, the difference in the average NO_X emission rate across all electric generation is even greater than for the emission rate that only includes fossil units. In 1996 the average NO_X emission rate from all power plants in the Northeast was 2.6 lb/MWh, whereas the average NO_X emission rate from all power plants in the Midwest was 6.6 lb/MWh -- roughly 2.5 times higher than in the Northeast.

5. Opportunities for NO_X Reductions in the Electric Utility Sector

We investigate the likely cost of NO_X controls in the East-central and Northeast regions under different future scenarios. For the East-central region, our reference scenario assumes that utilities meet the NO_X standards required by Phase II of Title IV of the Clean Air Act. In other words, this scenario accounts for all of the NO_X controls that East-central utilities are expected to install by 2003 in the absence of any requirements of the EPA SIP call. Under this scenario we estimate that East-central utilities would reduce their NO_X emissions to an average rate of 0.5 lb/MMBtu.[7] We refer to this scenario as the "Title IV Only Scenario."

For the Northeast region, our reference scenario assumes that utilities meet the much more stringent standard of 0.15 lb/MMBtu, as required by the EPA SIP call. We therefore refer to this scenario as the "EPA Budget Scenario."[8]

We then analyze scenarios where greater NO_X controls are applied in the East-central and the Northeast electricity sectors. For each scenario we estimate the types of NO_X control technologies likely to be applied on a plant-by-plant basis, as well as the associated costs. For the East-central region, we analyze an "EPA Budget Scenario" in order to estimate the impact of meeting the NO_X budgets in the EPA SIP call. For the Northeast region we also analyze a "Beyond EPA Budget Scenario," which goes beyond the requirements of the EPA SIP call and utilizes all of the reasonably available bolt-on control technologies. Our results are presented in Table 5.1 and Figure 5.1.

Table 5.1 Costs of Controlling NO_X in the East-Central and Northeast Electricity Sectors in 2003.

	Average NO_X Emissions (lb/MMBtu)	NO_X Reduction From Current (1000 tons/year)	Control Cost From Current (million$/year)	Average Control Cost ($/ton)
Northeast:				
1996 Control Level	0.40	n.a.	n.a.	n.a.
EPA Budget	0.15	344	354	1,031
Beyond EPA Budget	0.10	412	472	1,145
East-Central:				
1996 Control Level	0.68	n.a.	n.a.	n.a.
Title IV Only	0.50	571	59	103
EPA Budget	0.15	1,641	1,087	662

Notes: All costs are in 1995 dollars. See Appendix A for control cost assumptions. The Average NO_X emission rates for the 1996 Control Level Scenario are slightly lower than the actual rates in 1996 because they are based on generation that has been adjusted to 2003 levels.

7 The NO_X emission standards required by Title IV range from 0.40 to 0.86 lb/MMBtu, depending upon boiler design. The majority of boilers are required to meet standards of 0.4 and 0.46 lb/MMBtu.

8 We choose the EPA Budget Scenario as our reference scenario because it is similar to the standards already agreed to by the OTR states in the OTC Memorandum of Understanding, where states have a choice of meeting a 0.15 lb/MMBtu average emission rate or achieving a 75 percent reduction from 1990 emissions. (OTC 1994).

Our results in Table 5.1 indicate that the costs of controlling NO_X in the Northeast is significantly higher than in the East-central region. If the Northeast states meet the EPA Budget Scenario, while the East-central power plants meet the Title IV Only Scenario, then their average control costs (in $/ton) will be ten times higher than for the East-central region. Even in the scenarios where the two regions meet the same average NO_X emission rate of 0.15 lb/MMBtu, the Northeast will incur average NO_X control costs of $1,031/ton -- roughly 56 percent higher than the $662/ton incurred by the East-central region. This difference in control costs is partly because the Northeast has already taken many measures to control NO_X emissions under the OTC Memorandum of Understanding.

Marginal costs provide another indication of the extent to which NO_X control costs in the Northeast are higher than in the East-central region.[9] Figure 5.1 presents a graphical representation of the marginal NO_X control costs for both the Northeast and East-central regions, at various levels of NO_X controls. The X-axis indicates the cumulative amount of NO_X reductions relative to the 1996 control levels, while the Y-axis indicates the marginal NO_X control costs (in $/ton) for each level of NO_X reduction. The Northeast control cost curve intersects the Y-axis at the 1996 Control Level Scenario emission rate of 0.40 lb/MMBtu, and climbs up to the Beyond EPA Budget Scenario emission rate of 0.10 lb/MMBtu. The East-central control cost curve intersects the Y-axis at the 1996 Control Level Scenario emission rate of 0.68 lb/MMBtu, and climbs up to the EPA Budget Scenario emission rate of 0.15 lb/MMBtu.

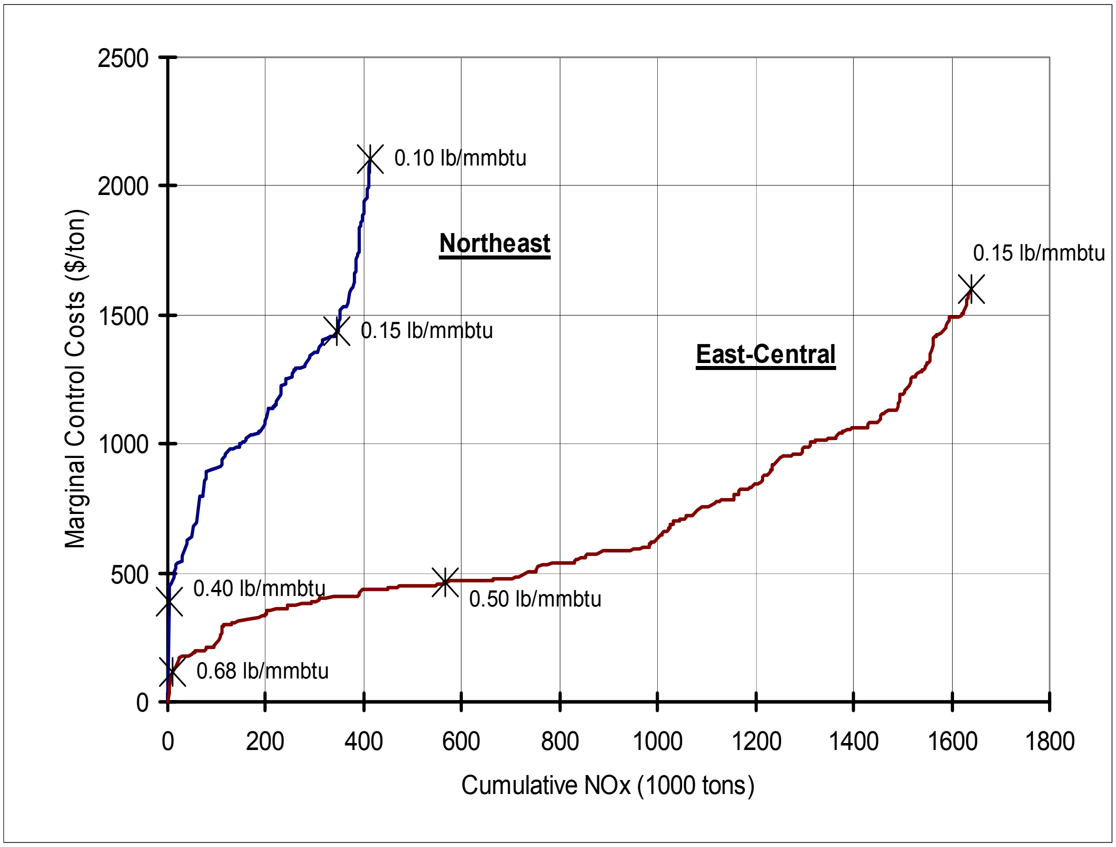
The two control cost curves in Figure 5.1 indicate the extent to which there are significantly greater low-cost opportunities to control NO_X emissions in the East-central region relative to the Northeast. In the Northeast the low-cost options have already been adopted, and there are fewer plants on which to apply the higher-cost options. The Northeast curve becomes quite steep after the average emission rate of 0.15 lb/MMBtu is achieved. Our analysis indicates that it is difficult to achieve further NO_X reductions in the Northeast after the 0.10 lb/MMBtu average emission rate is achieved.[10]

In the East-central region the marginal control cost curve is much less steep than the Northeast, and there are many more opportunities for low-cost emission reductions. For example, in the Title IV Only Scenario the East-central power plants would be able to achieve 571,000 tons of NO_X reductions -- more than the amount available in the Northeast under the Beyond EPA Budget Scenario -- at a marginal cost of less than $500/ton and an average cost of roughly $103/ton.

9 Marginal control costs represent the cost of controlling a small increment of NO_X at a particular level of control (e.g., at the 0.15 lb/MMBtu point). Average control costs, on the other hand, represent the cost of controlling all of the NO_X emissions from a baseline level (e.g., 1996 control levels) to a higher level of control.

10 A few plants remain without SCR control technologies in this scenario, but their capacity factors are so low that installing SCR does not significantly reduce NO_X emissions. Power plant owners could begin repowering with natural gas or retiring coal-fired plants to achieve additional reductions beyond the 0.10 lb/MMBtu average level, but we have not evaluated the economics of these options.

Figure 5.1 Marginal NO_X Control Costs in the Northeast and East-Central Regions in 2003



Figures 5.2 and 5.3 present the extent to which the Northeast and East-central utilities are expected to install NO_X controls in the various scenarios that we investigate. For simplicity we group NO_X control technologies into two categories. The combustion control category includes the relatively low-cost options, such as low-NO_X burners, low-NO_X coal-and-air nozzles, coal reburning, and others. The SCR category includes the more expensive SNCR and SCR post-combustion controls. In some cases, plants are assumed to install both combustion controls and SCR post-combustion controls to achieve the maximum amount of NO_X reductions.

As indicated in Figures 5.2 and 5.3, the Northeast has currently installed significantly more low-cost combustion controls than the East-central region. In order to meet the requirements of the EPA Budget Scenario, the Northeast will have to install combustion controls on almost all of its fossil-fired generation units, as well as SCR controls on 82 percent of the fossil-fired units. If the East-central utilities simply meet the Title IV Only Scenario, they could install only combustion controls on roughly 80 percent of their fossil-fired generation units. In order to achieve the average emission rate of 0.15 lb/MMBtu, the two regions will both have to install combustion controls on nearly all fossil-fired generation units, as well as SCR controls on over 70 percent of the units. If the Northeast utilities wish to achieve the lower average emission rate of 0.10 lb/MMBtu, they will have to also install combustion controls and SCR controls on nearly all fossil-fired units.[11]

Figure 5.2 NO_X Control Technologies Applied in the Northeast in 2003.

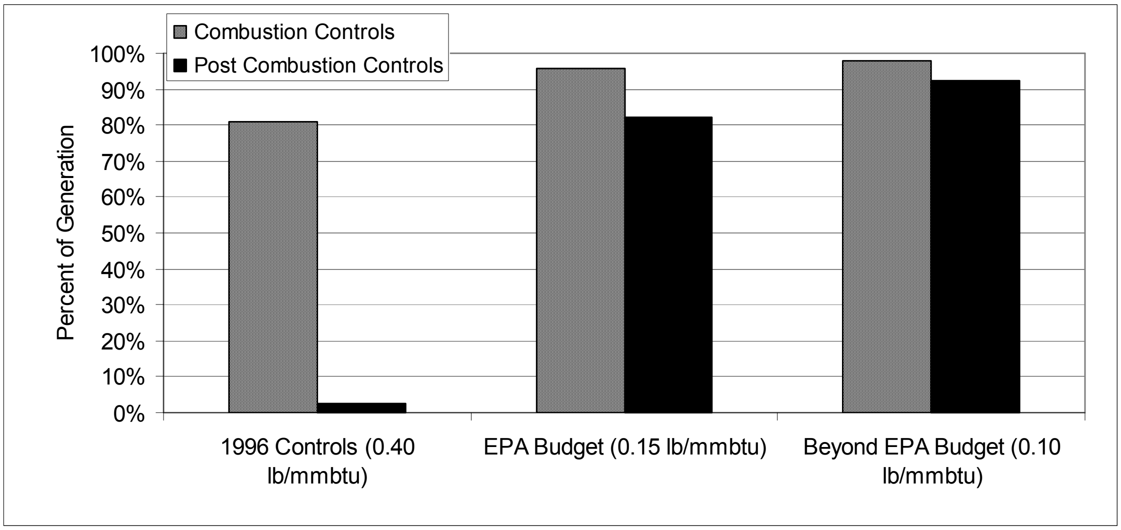
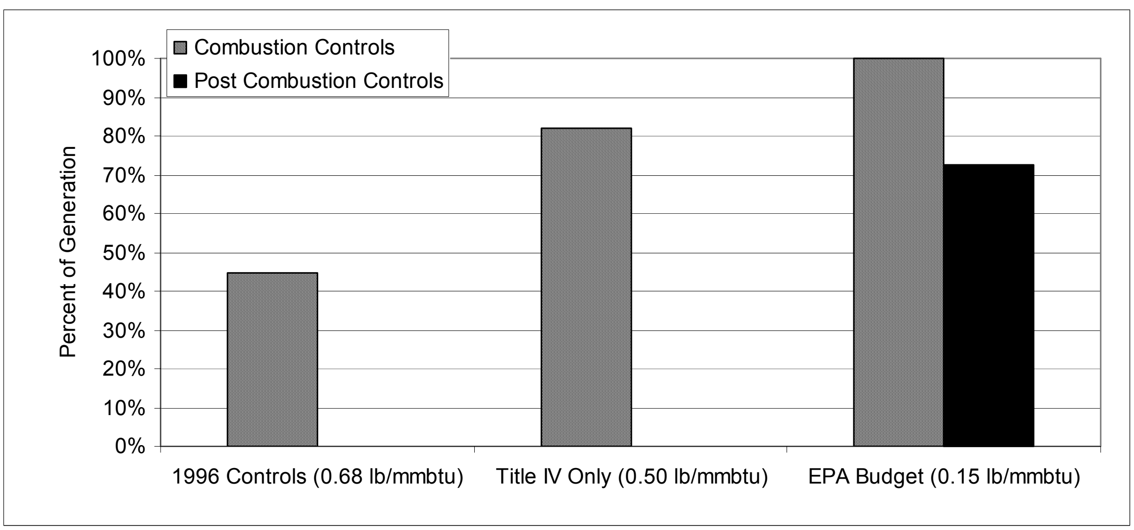


Figure 5.3 NO_X Control Technologies Applied in the East-Central Region in 2003.



[11] As described in Section 3, we do not consider all of the power plant control options available, such as fuel-switching, repowering or coal unit retirement. In practice, therefore, it may not be necessary to implement all of the control options presented in Figures 5.2 and 5.3.

6. The Economic Impact of the Transport of Ozone

6.1 The Extent of Ozone Transport from the East-Central Power Plants

The transport of ozone and its precursors from the East-central region to the Northeast will require the Northeast states to adopt more local NO_X and VOC controls than they otherwise would adopt to meet ozone attainment standards. These local NO_X and VOC controls will be relatively expensive because most of the low-cost NO_X and VOC controls would have already been implemented by the Northeast states.

In order to estimate the extent of the additional costs to the Northeast, we begin by estimating the approximate amount of NO_X and ozone that is transported from the East-central region to the Northeast. While OTAG has addressed this question in its air quality modeling analyses, there still remains considerable debate about the extent to which ozone is transported between the two regions.

In order to provide an illustration of the plausible extent of ozone transport, we assume a range of amounts of ozone transported from the East-central region. This range was developed by NESCAUM, and is described in a companion document prepared by them. In our Low Transport Case, we assume that 20 percent of the NO_X emissions from the East-central power plants are transported to the Northeast states, as either NO_X or an equivalent level of ozone. In our Medium and High Transport Cases, we assume that 30 and 45 percent of the NO_X emissions from the East-central plants are transported to the Northeast, as either NO_X or an equivalent level of ozone.[12]

We estimate that the NO_X emissions from East-central power plants in the Title IV Only Scenario will be roughly 1,525 thousand tons per year. Consequently, our Low, Medium and High Transport Cases imply that the ozone transported from the East-central region to the Northeast is equivalent to roughly 305, 457 or 686 thousand tons of NO_X emissions. For comparison purposes, in the EPA Budget Scenario the Northeast states are expected to produce roughly 232 thousand tons of NO_X emissions. Therefore, the amount of ozone transported from the East-central power plants could be roughly one to three times as much as that generated by the NO_X emissions from the power plants located in the Northeast.

6.2 The Costs of Controlling NO_X Emissions in the Northeast

We then identify the options available for reducing NO_X emissions in the Northeast. Under most scenarios the potential NO_X emission reductions from Northeast power plants are not sufficient to offset all of the ozone that is transported from the East-central power plants, so we investigate options for reducing NO_X from other sectors of the economy. The details of our control cost assumptions for the non-utility sectors are provided in Appendix B.

[12] In fact, a significantly larger portion of NO_X emissions from the East-central region will be transported to nearby regions in the Northeast (e.g., Pittsburgh) than to regions farther away (e.g., Maine). Our assumptions here about the percent of NO_X that is transported to the Northeast represent an average impact across the entire Northeast region.

A summary of our Northeast NO_X control cost assumptions is provided in Table 6.1.[13] These costs represent the control options available after the various sectors have already reduced NO_X emissions down to the level required by the EPA budgets in the SIP Call. As indicated in Table 5.1 above, the Northeast could reduce NO_X emissions in the electricity sector by roughly 68 thousand tons/year, by lowering the average emission rate from 0.15 to 0.10 lb/MMBtu. These reductions would cost an average of $1,717 per ton.

The other sectors that create NO_X emissions are characterized as point sources, area sources, and motor vehicles. We rely upon OTAG information as the primary source for estimates of NO_X control costs in these sectors (Pechan). As indicated in Table 6.1, the average cost of controlling NO_X from these sectors is significantly greater than from the electric utility sector.

Table 6.1 NO_X Reductions Available in the Northeast From Utility and Non-Utility Sectors, After the EPA SIP Call Budgets Have Been Met.

	Potential Reduction (1000 tons/year)	Average Cost Low Case ($/ton)	Average Cost High Case ($/ton)
Electric Utilities	68	1,717	1,717
Point Sources: Industrial	56	5,000	7,000
Point Sources: Incinerators	7	5,000	7,000
Point Sources: Other Industrial	24	5,000	7,000
Area Sources: Industrial	67	5,000	7,000
Motor Vehicles	235	6,800	11,500
Area Sources: Off-Road Diesel Fuel	6	8,000	23,000
Area Sources: Off-Road Gasoline	5	10,000	10,000
Total Potential Reductions	468	----	----

Source: See Appendix B. These reductions and costs represent those available after the Northeast states achieve the NO_X budgets proposed in the EPA SIP call. Note that this table only lists options identified by OTAG. There are, however, additional cost-effective measures which may have not been considered by OTAG, such as heavy-duty diesel controls, that will be feasible options for additional NO_X reductions.

Figure 6.1 provides a graphical representation of the costs of controlling NO_X in the Northeast from the various sectors of the economy. The control options are presented in order of the lowest to highest cost, beginning at the left and moving to the right. The X-axis indicates the cumulative volume of NO_X reductions available from each sector. The Y-axis indicates the average costs (in $/ton) required to achieve the associated volume of reductions.[14]

Figure 6.1 indicates that the majority of NO_X emission reductions in the Northeast is available from point sources (at $5,000 to $7,000/ton), and motor vehicles (at $6,800 to

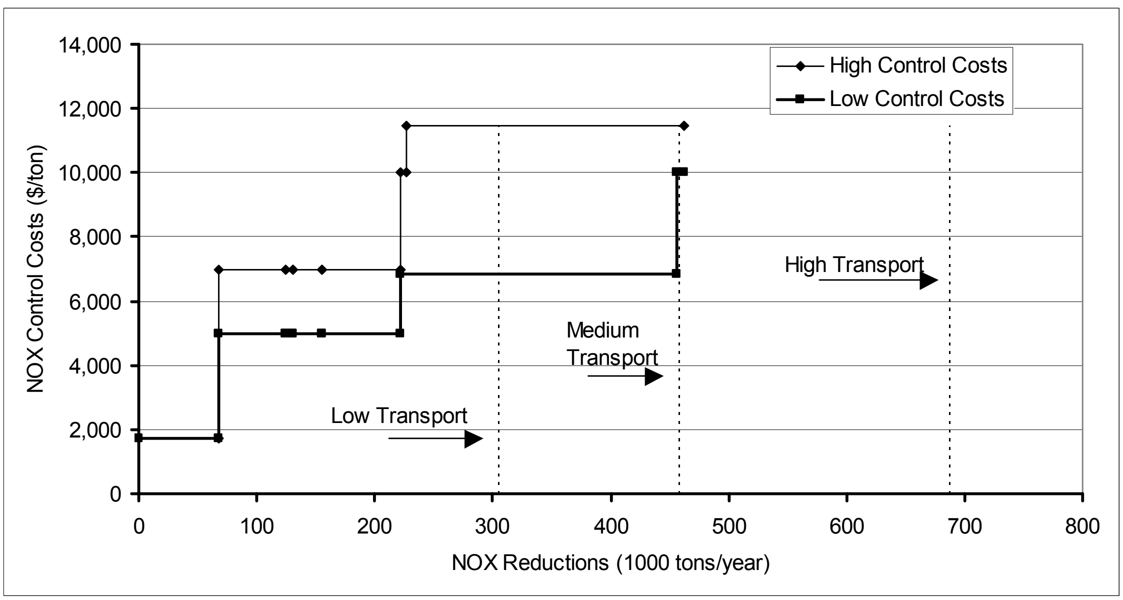
[13] We do not consider opportunities for reducing VOC emissions in the Northeast. Regional scale modeling indicates that reductions of VOC emissions are likely to affect only local ozone formation, with relatively little impact on transported ozone.

[14] In practice, each sector offers a number of NO_X control options, each with costs that may be above or below the averages presented here.

$11,500/ton). The extent to which these NO_X reductions would be used to offset ozone transported from the East-central region depends upon the transport assumptions:

- In our Low Transport Case, the Northeast will have to offset the equivalent of roughly 305 thousand tons of NO_X per year from the East-central region, which can be done by utilizing additional NO_X controls from the electric utility sector, the point source sectors, and part of the motor vehicle sector.
- In the Medium Transport Case, the Northeast will have to offset the equivalent of roughly 457 thousand tons of NO_X emissions from the East-central region, which requires essentially all of the control cost options presented in Table 6.1.
- In the High Transport Case, the Northeast will have to offset the equivalent of roughly 686 thousand tons of NO_X emissions from the East-central region, which would require roughly 218 thousand tons of reductions beyond those presented in Table 6.1.

Figure 6.1 NO_X Reductions Available in the Northeast Beyond the EPA Budgets



All data are taken from Table 6.1. In the Low-Cost Case, the options are presented in the same order as in Table 6.1. In the High-Cost Case, the options are slightly re-arranged. This graph does not include data for off-road diesel area sources.

6.3 The Economic Impact of NO_X Transported From East-Central Power Plants

We use the data in Table 6.1 and Figure 6.1 to estimate the economic impact upon the Northeast as a consequence of transported ozone. Our analysis is summarized in Table 6.2. The public health impacts of not attaining the ozone standard in the Northeast are not considered in this report.

In the Title IV Only Scenario, the Northeast states would have to reduce local NO_X emissions by 305 thousand tons per year under our Low Transport Case. Roughly 68 thousand tons of NO_X reduction could be achieved by installing additional controls on Northeast power plants (our Beyond EPA Budget Scenario). At an average cost of roughly $1,717 per ton, these NO_X reductions from the electricity sector cost a total of approximately $117 million

The remaining 237 thousand tons of NO_X would have to be obtained from sources in other sectors. This amount of reduction could be achieved from point sources and motor vehicles, at an average cost of $5,600 to 8,500 per ton, requiring a total cost of $1.3 to $2.0 billion. The total economic impact imposed upon the Northeast states under the Title IV Only Scenario and the Low Transport Case would therefore be roughly $1.4 to $2.1 billion.

Table 6.2 Control Costs in the Northeast Due to NO_X Emissions from East-Central Power Plants

	Low Transport	Medium Transport	High Transport
Title IV Only Scenario: (East-Central NO_X = 0.50 lb/MMBtu)			
Total Emissions from East-Central Power Plants (1000 ton/year)	1,525	1,525	1,525
Emission transport from East-Central to NE (1000 ton/year)	305	457	686
NO_X Reductions from NE Power Plants (1000 ton/year)	68	68	68
NO_X Reductions from Other NE Sectors (1000 ton/year)	237	389	618
Average Cost of NO_X Reductions from NE Power Plants ($/ton)	1,717	1,717	1,717
Average Cost of NO_X Reductions from Other NE Sectors ($/ton)	5,600 - 8,500	6,100 - 9,700	>7,500
Total Cost of NO_X reductions (billion$/year)	1.4 - 2.1	2.5 - 3.9	>3.9
EPA Budget Scenario: (East-Central NO_X rate=0.15 lb/MMBtu)			
Total Emissions from East-Central Power Plants (1000 ton/year)	454	454	454
Emission transport from East-Central to NE (1000 ton/year)	91	136	205
NO_X Reductions from NE Power Plants (1000 ton/year)	68	68	68
NO_X Reductions from Other NE Sectors (1000 ton/year)	23	68	136
Total Cost of NO_X reductions (billion$/year)	0.2 - 0.3	0.5 - 0.6	0.8 - 1.1

In the Medium Transport Case the Northeast would have to achieve reductions in local NO_X emissions of 457 thousand tons. This requires utilizing almost all of the control options listed in Table 6.1 and Figure 6.1, and therefore causes a much higher total cost ranging from $2.5 to $3.9 billion.

In the High Transport Case the Northeast would have to achieve reductions in local NO_X emissions of 868 thousand tons. This requires utilizing all of the control options listed in Table 6.1 and Figure 6.1, as well as 281 thousand tons of additional NO_X reductions. However, it is not clear whether there will be many additional sources of NO_X reductions beyond those identified in Table 6.1 Consequently, it may not be possible for the Northeast states to offset the full amount of ozone transported in from the East-central sources. If such reductions are available, they will most likely cost more than those reductions assumed in the Medium Transport Case. We therefore simply note in Table 6.2 that the total cost of NO_X reductions in the High Transport Case will be greater than $3.9 billion per year.

In sum, the economic impact on the Northeast could range from $1.4 to over $3.9 billion per year, if the East-central sources do not meet the EPA SIP call budgets. To put these costs in perspective, the Northeast states will have to incur roughly $354 million to reduce their average emission rates from today's level to the 0.15 lb/MMBtu level. Thus, the transport of NO_X and ozone from the East-central region creates an economic impact on the Northeast that could be anywhere from roughly four to over ten times as much as its own costs required to achieve the budget levels proposed by the EPA.

Our EPA Budget Scenario assumes that the East-central sources reduce their NO_X emissions to the levels required in the EPA SIP call. In this scenario the economic impact on the Northeast would be considerably smaller. In the Low Transport Case, all of the transported ozone could be offset through reductions in the electric utility sector, for a total cost of $0.2 to 0.3 billion. In the Medium Transport Case, the transported ozone would be offset by equal amounts of emissions from the utility and point sources, resulting in a total cost of $0.5 to $0.6 billion. In the High Transport case, the costs could be as high as $0.8 to $1.1 billion.

The difference between the costs of the Title IV Scenario and the EPA Budget Scenario indicates the economic impact that the East-central utilities are likely to place on the Northeast as a consequence of not meeting the budgets in the EPA SIP call. In our Low Transport Case this difference is roughly $1.2 to 1.9 billion, and in the Medium Transport Case it is roughly $2.0 to $3.3 billion. In the High Transport Case, it will be significantly higher.

6.4 Limitations, Uncertainties and Approximations

Our results should be seen as approximate illustrations of the costs of offsetting ozone transported from the East-central region. The complexity of the issue makes accurate calculations challenging. The two greatest uncertainties in our analysis are the amount of ozone transported from the East-central region, and the costs of controlling NO_X from utility and non-utility sectors. The more important uncertainties in our analysis are addressed in turn below.

The transport of ozone. We believe that our assumption of 20 to 45 percent represents a reasonable range of likely ozone transport scenarios. (Please refer to the companion document prepared by NESCAUM.) Evidence indicates that in some regions of the Northeast the transport will be significantly greater. In some regions it will be lower. On average, our assumptions cover the plausible range of ozone transport.

Non-utility NO_X control costs. We have used conservative assumptions for the cost of controlling NO_X emissions from non-utility sectors. Many of the reductions will be available from point sources, which OTAG has estimated to cost greater than $5,000 per ton. In some cases, they may cost significantly more than this. We have assumed that these reductions will cost only $5,000 to $7,000 per ton.

Utility NO_X control costs. We have not accounted for some important electricity sector NO_X reduction opportunities, such as fuel-switching, coal-to-gas repowering, or coal unit retirement. These opportunities might be more cost-effective than some of the utility control costs assumed here -- particularly if the benefits of reducing other pollutants (e.g., CO_2) are accounted for.

Improved efficiencies and economies of scale. Our assumptions for NO_X control costs in both the electric sector and the non-utility sectors might overstate the actual control costs, as a consequence of efficiencies that might be achieved over time. As industries come under increasing pressure to reduce NO_X emissions, they can be expected to identify new control options and to achieve reductions more efficiently than in the past. In addition, increased demand for NO_X control technologies may allow for them to be produced with increased economies-of-scale.

Annual versus seasonal control costs. Our analysis estimates the costs of achieving annual NO_X reductions from the electric utility sector, as opposed to the seasonal reductions required in the EPA SIP call. Annual NO_X reductions are likely to be more expensive than seasonal reductions, because some of the power plant NO_X controls might not have to be operated during the off-season periods. However, we believe that using annual control costs does not overstate our control cost results significantly, and does not affect our overall conclusions. The control costs we assume for reducing NO_X from non-utility sources are based on seasonal control costs; it is only the utility sources that are based on annual costs. The non-utility sources represent the greatest contribution to the total control costs in our analysis, both in terms of dollars per ton and number of tons. For example, in our Medium Transport Case the non-utility control costs represent 95 to 97 percent of the total cost of NO_X reductions reported in Table 6.2.

Transported ozone from non-utility sources in the East-central region. Our estimates of the costs imposed upon the Northeast only present a portion of the economic impact of NO_X transport, because they only account for the NO_X emissions from East-central electric power plants. As indicated in Table 4.1 above, power plants are responsible for only about one-half of the total NO_X emissions from the East-central region. Consequently, we have accounted for only a portion of the transported ozone problem. The NO_X emissions from other sectors in the East-central region will impose additional costs on the Northeast states.

Insufficient NO_X control measures in the Northeast. As indicated in Figure 6.1, the Northeast states may have to apply nearly all currently-known NO_X controls to offset the volume of the ozone transported from the East-central region. In the High Transport Case, there is unlikely to be enough NO_X control options available to offset the transport of ozone generated from all East-central sources.[15] Consequently, the economic and residual environmental costs could be much higher than we have identified here.

Low-cost NO_X control measures are needed to address local NO_X emissions first. OTAG modeling has indicated that the Northeast states might not be able to reach attainment of the 1-hour ozone standard -- even after they meet the NO_X budgets proposed in the EPA SIP call. Therefore, they may need to implement some of the control options presented in Table 6.1, regardless of whether there is any ozone transported from the East-central region. A more appropriate estimate of the economic impact caused by transport would

[15] While there is likely to be some NO_X reduction measures available in the Northeast beyond those presented in Table 6.1 and Figure 6.1, they are likely to be increasingly expensive and difficult to find.

therefore assume that such options are not available for offsetting transported ozone. Consequently, the control options that are used to offset the transported ozone will be more expensive -- if they are available at all.

In sum, our analysis generally indicates that the transport of ozone and its precursors from the electricity sector in the East-central region is likely to require the Northeast states to implement a large portion of the available local NO_X control options, including control options from all NO_X-emitting sectors. This will require the Northeast states to incur costs on the order of billions of dollars per year, and might still leave some regions in the Northeast in non-attainment of the ozone standard.

If the East-central sources achieve the NO_X reductions proposed in the EPA SIP call, then this economic impact will be significantly reduced. Even then, however, the impact imposed upon the Northeast will still be on the order of hundreds of millions of dollars, if not more. Even in this scenario, the transport of ozone will make it more difficult for the Northeast states to reach attainment of the ozone standard.

7. Conclusions

Our analysis finds that there is a clear need to reduce the inter-regional transport of ozone and its precursors. Simply put, ozone is a regional problem with regional implications, and upwind states cannot act without regard for the NO_X and ozone that is transported out of their borders.

NO_X emissions from East-central power plants significantly contribute to the nonattainment of ozone standards in the Northeast -- in addition to contributing to the local ozone problem in the East-central region. Not only does this East-central contribution threaten public health by preventing the Northeast states from reaching attainment, it also requires the Northeast states to incur significantly higher NO_X control costs than they would in the absence of transported ozone.

Based on OTAG modeling to date, the Northeast states will likely have to take additional aggressive measures to reach attainment of the ozone standard even after the EPA NO_X SIP call is fully in place throughout the eastern United States. As this study shows, the most effective approach is to implement low-cost upwind NO_X controls so that a greater portion of the additional local measures can be applied towards reaching attainment, rather than compensating for outside transport. Therefore, the East-central sources should be required to meet the state NO_X emission budgets in the EPA's proposed rulemaking.

The EPA NO_X SIP call is a good first step in addressing the regional ozone problem in the eastern United States. Even at the EPA NO_X budget levels, however, upwind sources will continue to impose significant costs on downwind states, and will continue to impede the ability of downwind states to reach attainment. The U.S. EPA and the states should monitor the ozone transport problem over time to determine what additional measures might be necessary to reduce ozone transport further beyond the EPA NO_X SIP call budgets.

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Appendix A. NO_X Control Options For the Electric Utility Sector

Table A.1 presents a summary of the NO_X control technologies for achieving NO_X reductions in the electricity sector. All of the data in Table A.1 are taken from the same study (EPA 1996) that EPA used in its ozone transport rulemaking (EPA 9/1997).

The majority of the NO_X controls available are designed for coal plants, due to their high emission rates. Some controls are applied in the combustion process itself, while others are applied after the fuel has been burned. On any one unit it is possible to apply both combustion and post-combustion controls. In such case the removal rates are multiplicative.

It is important to note that in practice, the cost of these control measures, and the amount of NO_X removal, might vary considerably from the costs presented in Table A.1. The cost might depend upon the unique characteristics of a unit's design, location, and operating patterns. For example, the costs of the few SCR technologies installed to date have varied significantly (Andover Technology Partners 1998).

Figure A.1 indicates the removal rates from some of the key NO_X control options. It presents the NO_X removal rate and control cost for a typical coal plant operating at 50 percent capacity factor, for six different combinations of combustion and post-combustion controls. The greatest opportunity for removing NO_X emissions can be found by combining low-NO_X burners with SCR controls.

The cost of reducing NO_X emissions (in $/ton) will vary depending upon the extent that a unit operates. Figure A.2 presents the NO_X control costs for three control technology options, for a typical coal plant at various levels of plant operation. The control costs increase with lower levels of plant operation. The low-NO_X burner represents the least-cost control option available, while the combination of low-NO_X burners and SCR controls provides the greatest level of NO_X removal.

In our economic analysis we have levelized the capital costs over thirty years using a fixed charge factor of 12 percent, in order to present total control costs in annual terms. All costs presented in this study are in 1995 dollars. We do not account for increases or decreases in NO_X control costs beyond inflation.

The general approach in our economic analysis is to identify the NO_X control technologies that would likely be adopted on a plant-by-plant basis to meet various levels of NO_X standards in the Northeast and East-central regions. We begin with a snapshot of control technologies that are in place today. We then look at increasingly stringent levels of NO_X standards, and identify the least-cost control technologies that would be installed and the costs that would be incurred in meeting them. This allows us to develop curves indicating the average and marginal costs of NO_X controls in the two regions.

Table A.1 NO_X Control Technology Costs and Removal Rates for Fossil-Fired Power Plants.

Technology	Applicable Boiler Type	Capital Cost ($/kW)	Capital Scaling[B] Base	Capital Scaling[B] Factor	Fixed O&M ($/kW-yr)	Variable O&M (mills/kWh)	Removal Rate[C] (percent)
Coal Units: Post-Combustion Controls:							
Selective Catalytic Reduction -- Low NO_X Rate		67	200	0.350	5.88	0.23	70
Selective Catalytic Reduction – High NO_X Rate		69	200	0.350	6.13	0.38	80
Selective Non-Catalytic Reduction -- Low NO_X Rate		16	200	0.577	0.23	0.79	40
Coal Units: Combustion Controls:							
Low NO_X Burner Without Overfire Air	Dry Bottom Wall-Fired	14	300	0.691	0.21	0.04	67
Low NO_X Burner With Overfire Air	Dry Bottom Wall-Fired	19	300	0.691	0.29	0.06	67
LNC 1 Close-Coupled Overfire Air[A]	Tangentially-Fired	27	300	0.624	0.41	0.00	47
LNC 2 Separated Overfire Air	Tangentially-Fired	29	300	0.624	0.44	0.00	52
LNC 3 Close-Coupled and Separated Overfire Air	Tangentially-Fired	39	300	0.624	0.59	0.02	57
NO_X Plug-In Controls	Cell Burners	19	300	0.315	0.28	0.06	60
Coal Reburning	Cyclone	59	300	0.388	0.89	0.21	50
NO_X Combustion Controls	Wet Bottom	8	300	0.553	0.12	0.04	50
NO_X Combustion Controls	Vertically Fired	9	300	0.553	0.14	0.04	40
Oil and Gas Units:							
Gas Reburn -- Combustion Control		19	200	0.350	0.29	0.03	50
Selective Catalytic Reduction		27	200	0.350	0.84	0.10	80
Selective Non-Catalytic Reduction		9	200	0.557	0.14	0.42	50

Source: EPA, July 1996, *Analyzing Electric Power Generation Under the CAAA*, Appendix No. 5. All costs are in 1995 dollars.

A. LNC 1, 2, and 3 all have low NO_X coal-and-air nozzles.

B. The capital cost scaling factors represent economies of scale, where the cost for a particular unit is equal to the base size divided by the actual unit size, with the scaling factor as the exponent. For example, for the SCR – Low NO_X Rate at a 240 MW unit, the capital scaling factor cost would be 0.94, calculated as (200 MW/240 MW)^0.35 = 0.94. The size scaling for post-combustion controls can only be applied to units less than or equal to 500 MW in size.

C. Each unit can have both post-combustion controls and combustion controls. The combined removal with the two types of NO_X controls is multiplicative.

Figure A-1 NO_X Removal Rate and Cost for a 300 MW Coal Unit at 50% Capacity Factor.

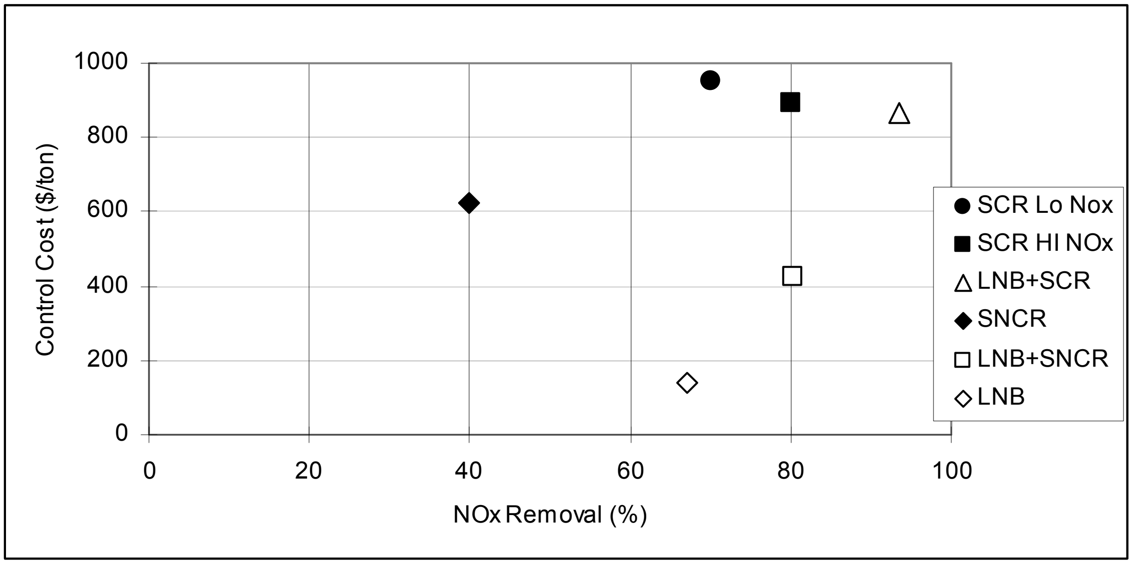
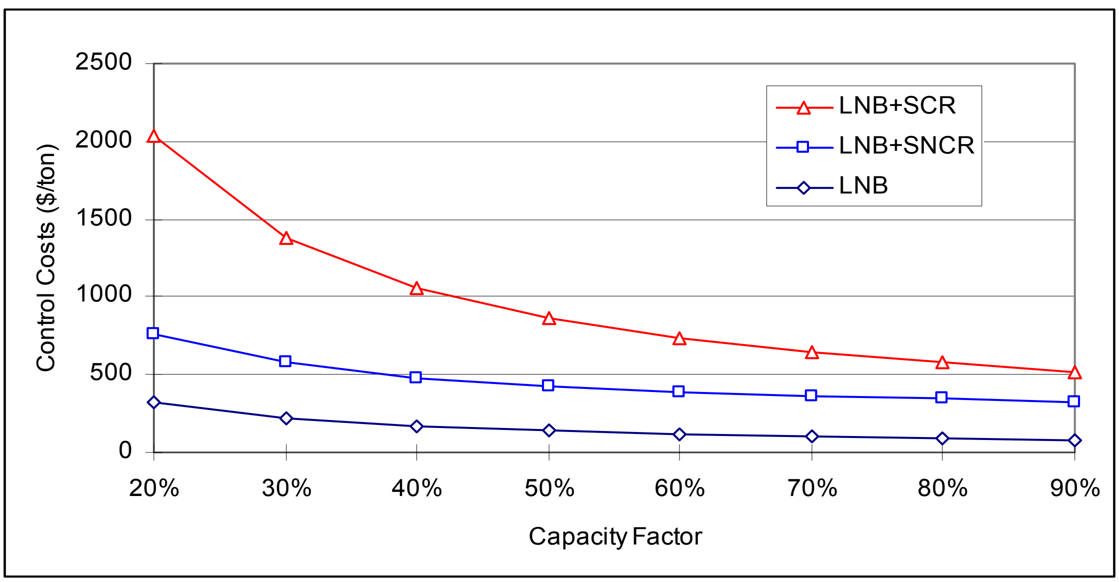


Figure A-2 NO_X Control Costs for a 300 MW Coal Unit at Various Capacity Factors.



Appendix B. NO_X Control Options For Non-Utility Sectors

We rely upon the OTAG information for the primary source of data on NO_X control options for non-utility sectors (Pechan 1997). This information includes inventories of NO_X control costs by sector and by state. The inventories include different groupings of control options, to achieve different degrees of NO_X reductions. These groupings are referred to as Level 1, Level 2 and Level 3, with Level 3 being the most stringent.

We seek to identify those NO_X options that can be applied in the Northeast in the EPA Budget Scenario -- i.e., after the Northeast states have meet the NO_X budgets proposed in the EPA SIP call. To identify the NO_X options available in this scenario, we have relied upon Round 3, Run I of the OTAG modeling.[16] This run is comparable to the NO_X reduction requirements of the NO_X SIP call.

The OTAG runs model the NO_X control options for point sources (both utility and non-utility), area sources and motor vehicles. The results for Round 3, Run I are summarized in Table B.1, and are described below.

Table B.1 NO_X Control Options for Non-Utility Sectors.

	Control Option	Potential Reduction (percent)	Potential Reduction (1000 tons/year)	Average Cost ($/ton)
Point Sources: Industrial	Level 3	44%	56	>5,000
Point Sources: Incinerators	Level 3	44%	7	>5,000
Point Sources: Other Industrial	Level 3	44%	24	>5,000
Area Sources: Industrial	Level 3	44%	67	>5,000
Area Sources: Off-Road Gasoline	Cal RFG II	10%	5	10,000
Area Sources: Off-Road Diesel	55 cetane	3%	6	8,000-23,000
Motor Vehicles	Cal RFG II	55%	235	6,800-11,500
Total Potential Reductions	----	----	400	----

Source: Pechan 1997. All Costs are in 1995 dollars.

Non-Utility Point Sources

From the Run 2, Round 9 OTAG inventory,[17] three general emission sectors are identified.[18] These are industrial and other point sources, incinerators, and other

16 A state-level "Tier 2" emissions inventory description broken down by emission sector is found through OTAG's website http://www.iceis.mcnc.org/OTAGDC/index.html.

17 The Round 3, Run I, NO_X point source inventory was missing from the OTAG website. As a surrogate, the NO_X point source inventory from Round 2, Run 9 was used. In this inventory, NO_X power plant controls were equivalent to Run I. For non-utility point source NO_X emissions, the inventory was equivalent to Run I for boilers >250 MMBtu. The Round 2, Run 9, inventory was more stringent than Run I for boilers <250 MMBtu, but these are not a significant portion of the total NO_X inventory.

18 Costs are based on an OTAG cost matrix that does not exactly correlate with the emission sectors of the Tier 2 OTAG inventories. Therefore, several general, rather than specific, emission sectors are identified, and average reductions across the general sectors are estimated based on the control effectiveness numbers given in the OTAG cost matrix.

industrial processes. These are assumed to be already controlled at OTAG Level 2 under the NO_X SIP call. On average, Level 2 is assumed to be a 55% reduction from the initial OTAG base1c inventory. Going beyond Level 2 to Level 3 is assumed to be an average 75% reduction from the OTAG base1c inventory. Therefore, going beyond the NO_X SIP call (Level 2 controls) to Level 3 will mean an average additional 44% reduction beyond Level 2. The total available reductions in the Northeast from the industrial, incinerators, and other industrial categories are 56, 7, and 24 thousand tons per year beyond the EPA SIP call levels.[19]

Using a cost matrix derived by OTAG, all Level 3 controls are listed as greater than 5,000 dollars/ton for non-utility point sources. Using 5,000 dollars/ton as the lower limit, the total costs of relying upon each of the non-utility point source sectors would require an annual cost of $435 million.

Area Sources

NO_X area emissions are split into three general categories – industrial and other combustion sources, off-road diesel, and off-road gasoline. For industrial and other combustion area sources, the same approximation to estimate additional NO_X reductions is used as for the non-utility point sources (i.e. 44% beyond Level 2 controls used in Run I). For off-road diesel, the control measure is going from 50 cetane diesel to 55 cetane diesel.[20] This will result in a 3% NO_X reduction based on figures from Ethyl Corporation. For off-road gasoline, more uncertainty is involved. The presumed control measure is California reformulated gas (RFG) II. This is an average 40 ppm sulfur gasoline. If the impact of Cal RFG II on off-road gasoline vehicles is comparable to older conventional cars (Tier 0), then the impact might be a 10% reduction in NO_X, based on an EPA staff report (EPA 5/1998). The total available reductions in the Northeast from the area industrial, off-road diesel and off-road gasoline are 67, 6, and 5 thousand tons per year beyond the EPA SIP call levels.

Level 3 costs for industrial and other combustion area sources are listed in the OTAG cost matrix as greater than 5,000 dollars/ton. For off-road diesel using 55 cetane fuel, the OTAG cost matrix gives a range of 8,000-23,000 dollars/ton. This range is used to set a low and high cost estimate range. For off-road gasoline, an estimate of 10,000 dollars/ton is used. This estimate is taken from the calculation described below for

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19 The OTAG model runs provide the NO_X emissions and reductions in terms of tons per Summer day. Throughout this study, we use an approximate scaling factor of 300 to translate these into tons per year. The scaling factor is less than 365 because the emissions tend to be highest on Summer days.

20 Additional strategies exist to achieve NO_X reductions from off-road diesels, but were not explicitly included in the OTAG cost estimates. One option is to accelerate the introduction of proposed non-road diesel engine emissions standards between 2000 and 2008. The proposed emissions standards for off-road diesels will result in large NO_X reductions over the next two decades. Nationally, between one to two million tons of NO_X a year (beginning in 2010) will be reduced as a result of introduction of the standards at a cost of less than $1,000 per ton.

In addition, the use of some types of electrically powered off road equipment can reduce NO_X in a cost effective manner. Use of natural gas fuel can also greatly reduce off-road vehicle NO_X emissions. Cost estimates prepared for natural gas highway vehicles suggest that NO_X reductions can be also be achieved in a cost effective manner from off-road vehicles.

mobile source costs. It basically is chosen as a cost that falls within the range described below. While this is a rough estimate, the potential reduction of 5 thousand tons per year from this sector make the overall Northeast cost estimate relatively insensitive to this particular emissions sector.

Motor Vehicles

The control measure assumed for motor vehicles is going from federal RFG (150 ppm sulfur) to Cal RFG II (40 ppm sulfur). Run I assumes national low emission vehicles (NLEV) in the Northeast. Based on an EPA staff report for 40 ppm sulfur gasoline, an average reduction in NO_X of 55% from NLEV could be expected (EPA 5/1990). A reduction of 55% is used in this analysis, but it is an overestimation of available reductions in the Northeast because it does not take into account non-LEV vehicles in the Northeast in 2007. Therefore, 235 thousand tons per year represents a generous estimate of available NO_X reductions from mobile sources in the Northeast beyond the NO_X SIP call.

The cost of Cal RFG II in the Northeast is estimated as follows. Based on EPA's staff report on sulfur in gasoline, an NLEV car will emit 0.50 g/mile at 100,000 miles when using fuel with 150 ppm sulfur. A vehicle fleet average of 25 miles/gal in 2007 is assumed (this is optimistic and ignores sport utility vehicles and heavy duty trucks). From this, the NO_X tons/gal can be calculated. From this value, a 55% NO_X reduction is estimated by going from 150 ppm sulfur gasoline to 40 ppm sulfur fuel. An EPA staff report gives costs of 40 ppm sulfur (Cal RFG II) gasoline in a range of 5.2-8.7 cents/gal. From this we calculate a low cost estimate of $6,845/ton, and a high cost estimate of $11,452/ton.