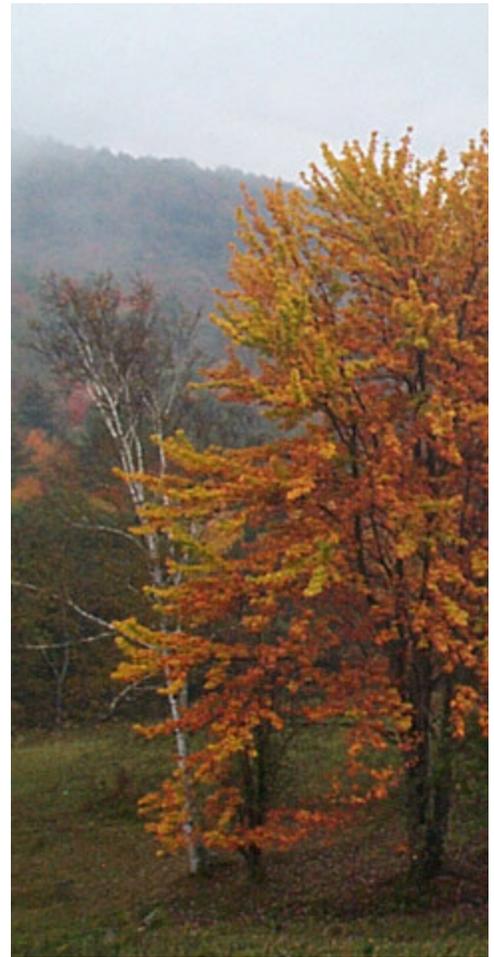
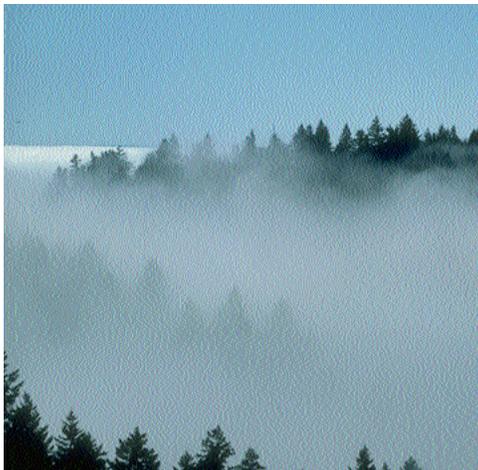


EPA ACID RAIN PROGRAM



2001 PROGRESS REPORT



November 2002



This Progress Report replaces the Compliance Report and the Emissions Scorecard used in previous years to report on the results of the Acid Rain Program. All data and results from the Acid Rain Program are now compiled in a single document that reports information on:

- emission levels
- compliance with the SO₂ and NO_x components of the program
- SO₂ allowance prices
- emissions monitoring
- air quality and deposition monitoring
- environmental and human health effects and benefits

This Progress Report will be published annually by EPA to update the public on the status of implementation of the Acid Rain Program and our progress towards achieving our environmental goals. Detailed unit-level emissions data are available on our website at <http://www.epa.gov/air-markets/emissions/index>. Our new query tool that provides access to a variety of EPA emissions data is available at <http://cfpub.epa.gov/gdm>. For more information on the Acid Rain Program, including information on SO₂ and NO_x emissions, acid deposition monitoring, and the environmental effects of acid deposition, you can visit our website at <http://www.epa.gov/airmarkets>.

EPA Acid Rain Program
2001 Progress Report
EPA-430-R-02-009

Clean Air Markets Program
Office of Air and Radiation
U.S. Environmental Protection Agency

November, 2002

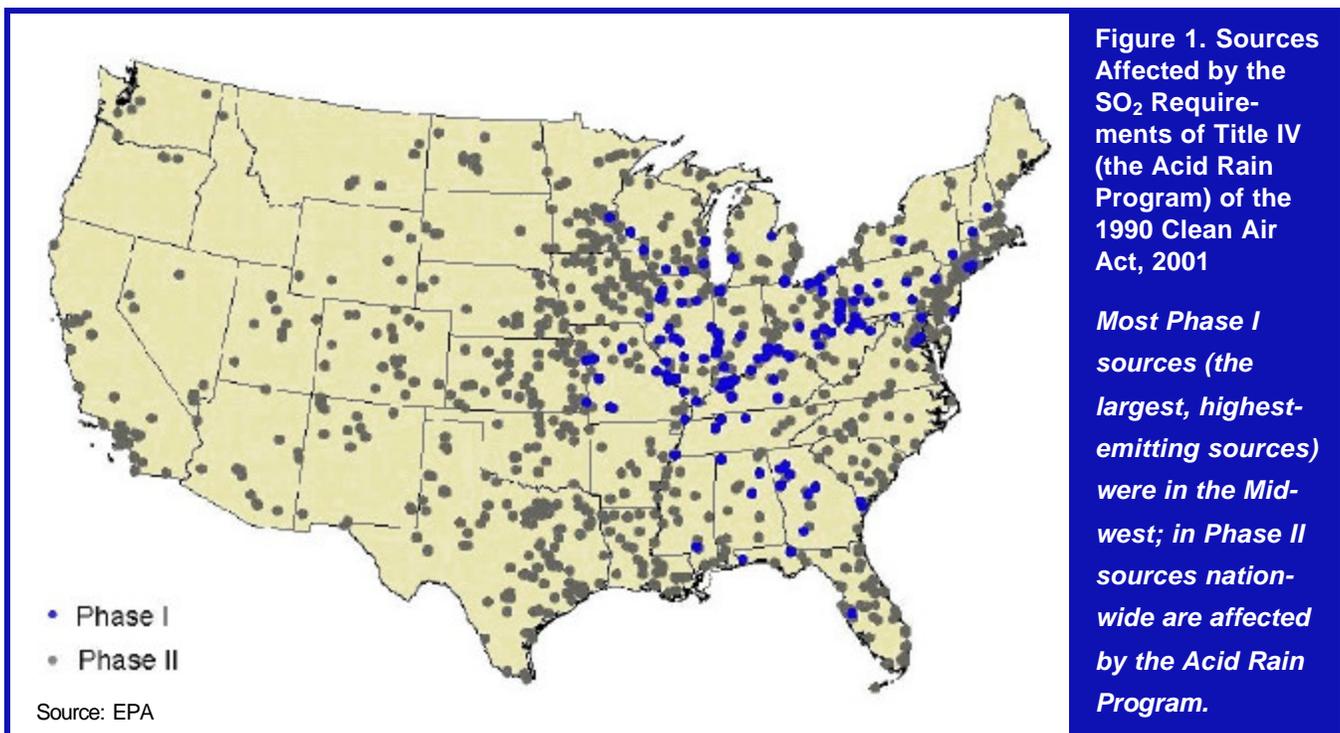


Table of Contents

Introduction.....	1
An Innovative Cap and Trade Program for SO ₂	2
The NO _x Program.....	2
Why Worry about Acid Rain?.....	3
The SO ₂ Program.....	5
Emissions.....	5
Compliance.....	7
Geographic Trends in SO ₂ Emissions.....	9
SO ₂ Allowance Market.....	12
The NO _x Program.....	14
Emissions.....	14
Emission Limits.....	16
Compliance.....	18
Geographic Trends in NO _x Emissions.....	18
Monitoring Results.....	22
Emission Monitoring.....	22
Air Quality and Deposition in 2001.....	23
Clean Air Mapping and Analysis Program (C-MAP).....	27
Freshwater Monitoring.....	27
Environmental Improvement and Trends.....	29
Improved Air Quality and Reduced Acid Deposition.....	29
Visibility.....	34
Human Health Benefits.....	35
Ecological Effects of Reduced Acid Deposition.....	35
Freshwater.....	35
Forests.....	37
Coastal Waters.....	37
Materials and Structures.....	38
Summary.....	39
For Further Information.....	41

Introduction

The Acid Rain Program was established under Title IV of the 1990 Clean Air Act Amendments. The program requires major reductions of sulfur dioxide (SO₂) and nitrogen oxides (NO_x) emissions, the pollutants that cause acid rain. Using an innovative market-based or “cap and trade” approach to environmental protection, the program sets a permanent cap on the total amount of SO₂ that may be emitted by electric power plants nationwide. The cap is set at about one half of the amount of SO₂ emitted in 1980, and the trading component allows flexibility for individual fossil fuel-fired combustion units to select their own methods of compliance. The program also sets NO_x emission limitations (in pounds per million British thermal units or lb/mmBtu) for certain coal-fired electric utility boilers, representing about a 27% reduction from 1990 levels. The Acid Rain Program was implemented in two phases. Phase I applied primarily to the largest coal-fired sources from 1995 through 1999 for SO₂ and from 1996 through 1999 for NO_x. Phase II for both pollutants began in 2000 and applies to thousands of combustion units (see Figure 1). In 2001, there were 2,792 units affected by the SO₂ provisions of the Acid Rain Program. Additionally, 1,046 of these units were required to meet a NO_x emissions limit in 2001 under the Acid Rain Program provisions¹. The Acid Rain Program has significantly reduced emissions of SO₂ and



¹ Sources affected by the Acid Rain Program are tracked for compliance purposes at the unit level. A single source (power plant) may have many units (combustion devices).

NO_x from electric power plants and resulted in substantial environmental and human health benefits.

An Innovative Cap and Trade Program for SO₂

The SO₂ component of the Acid Rain Program represents a dramatic departure from traditional command and control regulatory approaches that establish source-specific emissions limitations. Instead, the program uses an overall emissions cap for SO₂ that ensures emissions reductions are achieved and maintained and a trading system that facilitates lowest-cost emissions reductions. The program features tradeable SO₂ emissions allowances, where one allowance is a limited authorization to emit one ton of SO₂. A fixed number of allowances are issued by the government, and they may be bought, sold, or banked for future use by utilities, brokers, or anyone else interested in holding them. Existing units are allocated allowances for each year; new units do not receive allowances and must buy them. At the end of the year all participants in the program are obliged to surrender to EPA the number of allowances that correspond to their annual SO₂ emissions.

Affected sources must demonstrate compliance with the SO₂ provisions of the Acid Rain Program at the end of each year. Sources are granted a 60-day grace period during which additional SO₂ allowances may be purchased, if necessary, to cover each unit's emissions for the year. At the end of the grace period (the Allowance Transfer Deadline), the allowances a unit holds in its Allowance Tracking System (ATS) account must equal or exceed the unit's annual SO₂ emissions for the previous year. The Acid Rain Program requires affected sources to monitor emissions continuously and to report their emissions regularly. Failure to surrender sufficient allowances results in significant automatic penalties that include fines as well as a reduction in the number of allowances allocated in the following year. Any remaining SO₂ allowances may be sold and/or banked for future use.

The NO_x Program

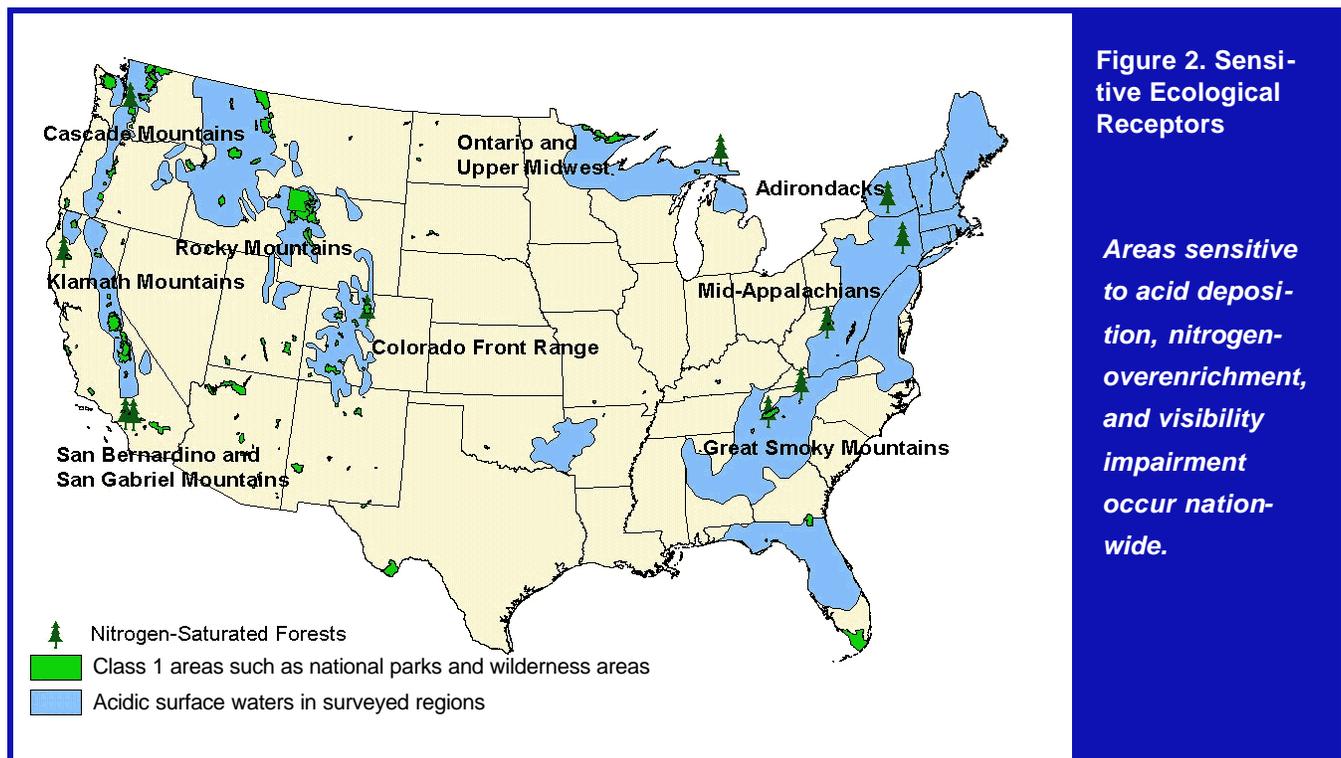
The NO_x component of the Acid Rain Program, using a more traditional regulatory approach, establishes an emission rate limit for certain types of coal-fired boilers. However, sources are provided a degree of flexibility through emissions averaging provisions, whereby a company can meet the standard emission limitations by averaging the emissions rates of two or more boilers. This allows sources to over-control at units where it is technically easier to control emissions, thereby achieving emissions reductions at a lower cost. Additionally, certain Phase II units elected to become subject to Phase I limits beginning in 1997. These early election units are not subject to the more stringent Phase II limits until 2008.

Sources affected by the NO_x portion of the Acid Rain Program must also demonstrate that they have complied with the NO_x provisions at the end of the year. Sources demonstrate compliance with the NO_x program by achieving an annual emission rate at or below mandated levels.

Why Worry about Acid Rain?

Acid deposition, more commonly known as acid rain, occurs when emissions of SO₂ and NO_x react in the atmosphere (with water, oxygen, and oxidants) to form various acidic compounds. These acidic compounds then fall to earth in either a wet form (rain, snow, and fog) or a dry form (gases and particles). Prevailing winds transport the acidic compounds hundreds of miles, often across state and national borders. The acidic compounds (including small particles such as sulfates and nitrates) cause many negative environmental effects. These pollutants impair air quality and damage public health, acidify lakes and streams, harm sensitive forest and coastal ecosystems, degrade visibility, and accelerate the decay of building materials, paints, and cultural artifacts such as buildings, statues, and sculptures nationwide.

Some places and people are more susceptible or sensitive to these impacts than others. Areas where acid deposition damages ecosystems or gases and particles impair visibility are called "sensitive receptors." Sensitive ecological receptors include lakes and streams throughout the Appalachian Mountains; forests in the Appalachian Mountains, the Colorado Front Range, and West Coast coastal mountain ranges; and many East and Gulf coast estuaries and coastal waters. Many national parks and wilderness areas, including Great Smoky National Park, Acadia National Park, and Grand Canyon National Park have impaired visibility due in part to emissions of SO₂ and NO_x from power generation sources. Many people (especially children, the elderly and those with existing respiratory or cardiovascular conditions) are also adversely impacted by fine particles formed from



SO₂ and NO_x emissions and ozone formed from NO_x emissions from power generation sources.

The pollutants that cause acid rain often cause human health and environmental impacts hundreds of miles from where they are emitted. This long-range transport makes it critical to reduce all emissions that cause acid rain, even those that occur far from sensitive receptors or population centers. The Acid Rain Program's ultimate objective is to protect the environment and improve human health by reducing SO₂ and NO_x emissions from power generation sources. These emission reductions benefit the nation by:

- ◆ Improving air quality and protecting public health
- ◆ Restoring acidified lakes and streams so they can once again support fish and other aquatic life
- ◆ Improving visibility, especially at scenic vistas in national parks
- ◆ Reducing the damage to sensitive forests, such as those along the Appalachian Mountains and in the Colorado Front Range
- ◆ Reducing the damage to nitrogen-sensitive coastal waters along the East and Gulf Coasts
- ◆ Protecting our historic buildings and monuments from degradation

The SO₂ Program

There were 2,792 units² used to produce electric power that were subject to the SO₂ provisions of the Acid Rain Program in 2001 (that is, they operated, submitted emissions data for SO₂, and were subject to annual reconciliation of allowable emissions with actual emissions in 2001). Acid Rain Program sources reduced their combined SO₂ emissions in 2001 by 39% from 1980 levels (33% from 1990 levels). All but two of the 2,792 units complied with the requirement to hold sufficient allowances. There were no significant geographic shifts in emissions. The price of an SO₂ allowance ranged from \$135 to \$210/ton in 2001, a price range that is comparable to allowance prices in previous years.

Emissions

In 2001, the second year of Phase II, Acid Rain Program sources achieved a total reduction in SO₂ emissions of about 39% compared to 1980 levels (33% compared to 1990 levels). Compared to 2000 levels, these sources reduced their SO₂ emissions by 5% or 569,000 tons. Figure 3 shows the trend in SO₂ emissions

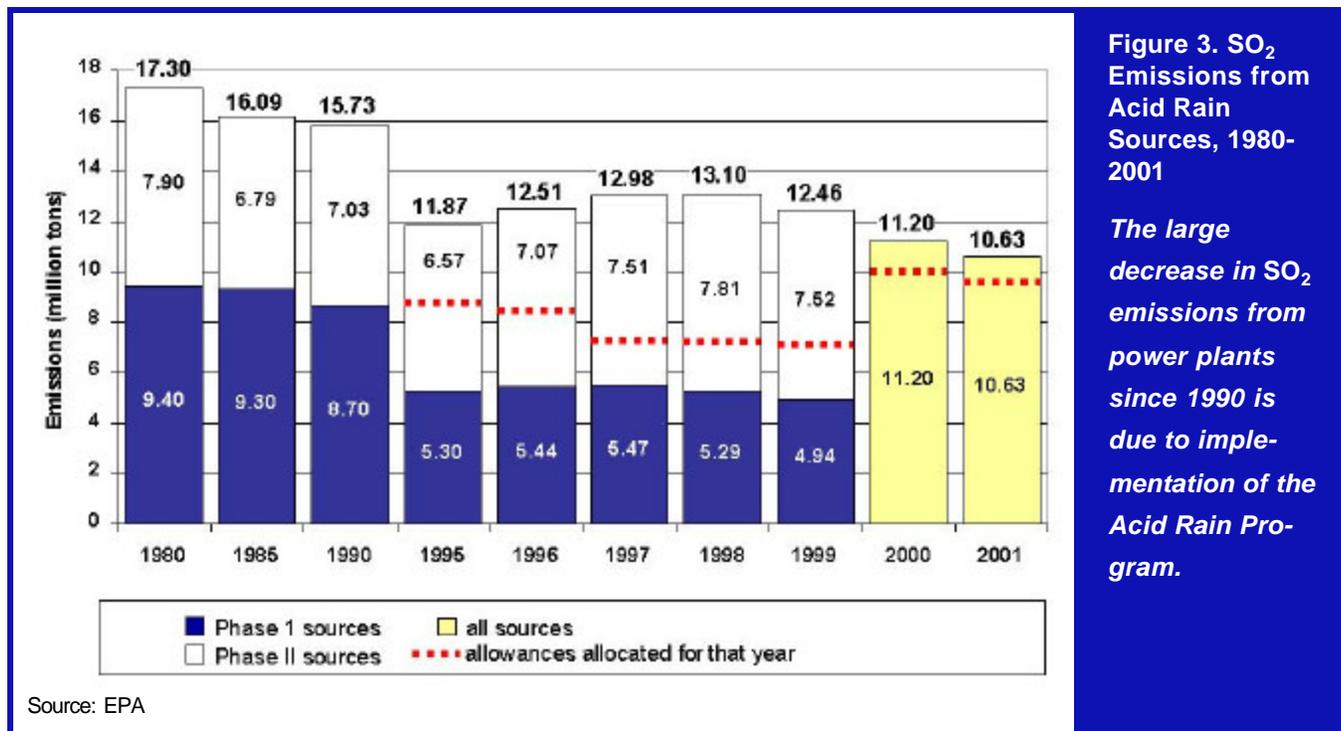


Figure 3. SO₂ Emissions from Acid Rain Sources, 1980-2001

The large decrease in SO₂ emissions from power plants since 1990 is due to implementation of the Acid Rain Program.

² In this report, the term "unit" means a fossil-fuel fired combustor that serves a generator that provides electricity for sale. The vast majority of emissions affected by the program come from coal-fired generation units, but oil and natural gas units are also included in the program.

since 1980 for all affected sources.

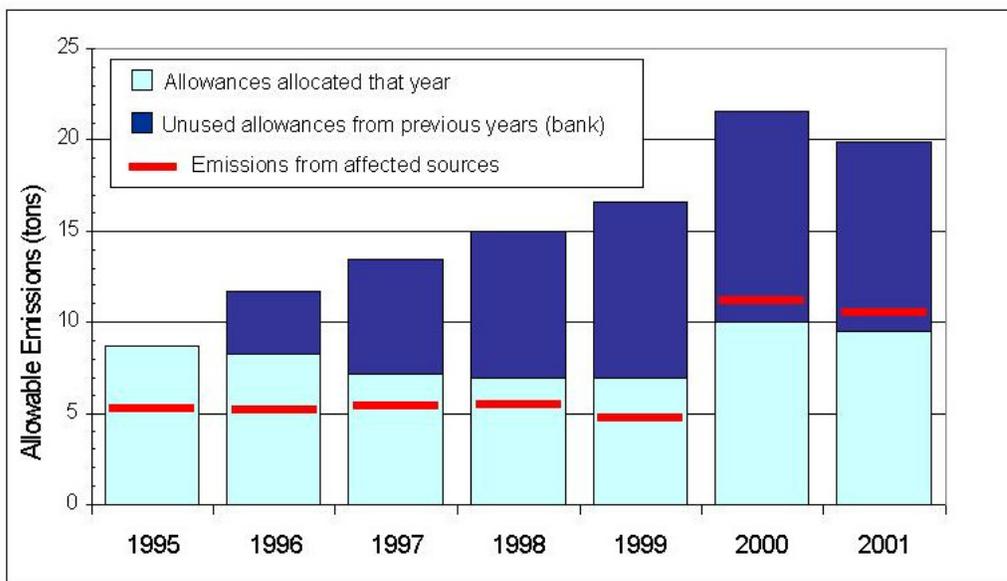
The electric utility industry is by far the largest single source of sulfur dioxide emissions, accounting for approximately 65% of total SO₂ emissions nationwide. In addition to the significant reductions from the electric power generation sector, reductions in SO₂ emissions from other sources, including smelters and sulfuric acid manufacturing plants, and use of cleaner fuels in residential and commercial burners, have also contributed to the 50% decline of SO₂ emissions from all sources since 1980 (National Air Quality and Emissions Trends Report, 1999).

There were 2,792 units that underwent annual reconciliation for SO₂ in 2001. (These units, as well as an additional 273 units which were retired or not yet operating, are listed in Appendix A of this Report. Appendix A is available on our website at www.epa.gov/airmarkets/cmprpt/arp01/index.html).

The allowances (i.e., authorizations to emit SO₂) allocated in a particular year to each source are determined by several provisions of the Clean Air Act. For the year 2001, a total of 9.55 million allowances were granted. Adding these 9.55 million allowances to the unused allowances carried over (or banked) from prior years, a total of 19.93 million allowances were available for use in 2001. Sources emitted 10.63 million tons in 2001, 1.08 million tons more than the allowances granted in 2001 but far less than the allowable level. For the second year in a row the number of allowances in the bank declined. As shown in Figure 4, the bank shrank by 1.08 million allowances in 2001. Over time the bank is expected to continue to be depleted as sources use these banked allowances to comply with the

Figure 4. Allocated, Used, and Banked SO₂ Allowances

The bank was built up during Phase I with early reductions and is now being drawn down under Phase II.



Source: EPA

Type of Allowance Allocation	Number of Allowances	Explanation of Allowance Allocation Type
Initial Allocation	9,190,922 ³	Initial Allocation is the number of allowances granted to units based on the product of their historic utilization and emissions rates (performance standards) specified in the Clean Air Act.
Allowances for Substitution Units	13,547	A lawsuit settlement allowed for a small amount of allowances to be allocated for Substitution Units in 2001 instead of an earlier year during Phase I.
Allowance Auctions	250,000	Allowance Auctions provide allowances to the market that were set aside in a Special Allowance Reserve when the initial allowance allocation was made.
Opt-in Allowances	99,188	Opt-in Allowances are provided to units entering the program voluntarily. There were 11 opt-in units in 2001.
TOTAL 2001 ALLOCATION	9,553,657	
Banked Allowances	10,376,426	Banked Allowances are those held over from 1995 through 2000 which can be used for compliance in 2001 or any future year.
Conservation and Renewable Energy Allowances	3,528	These allowances come from a special reserve set aside when the initial allowance allocation was made. They are awarded to utilities that undertake efficiency and renewable energy measures. These are year 1999 allowances that were allocated in year 2001.
TOTAL 2001 ALLOWABLE	19,933,611	

Figure 5. Origin of 2001 Allowable Emissions Level

There were 9.55 million allowances allocated in 2001; an additional 10.38 million allowances had been banked in previous years and were available for use.

³ The total year 2001 initial allocation was 9,191,897. Fifty-four allowances were deducted as offsets during year 2000 reconciliation, and 921 allowances were surrendered as part of an enforcement action prior to the 2001 reconciliation.

Source: EPA

stringent Phase II requirements. Figure 5 explains in more detail the origin of the allowances available for use in 2001.

Compliance

A total of 10.6 million allowances were deducted from sources' accounts in 2001. Two units were short a total of 11 allowances to cover their emissions for the 2001 compliance year. Eleven year 2002 allowances were taken from these units as

"offsets" and are included in the total number of used allowances for 2001. In addition to the offsets, the operators of these units were assessed an automatic monetary penalty totaling \$30,514.⁴ Figure 6 displays these allowance deductions, as well as the remaining bank of 1995 through 2001 allowances.

During the compliance process, the number of allowances surrendered at an individual unit is equal to the number of tons emitted at the unit, except where the unit shared a common stack with other units. For the purposes of surrendering allowances for emissions at a common stack, the source was allowed to choose the proportion of allowances deducted from each unit sharing the stack, as long as enough allowances were surrendered to cover the total number of tons emitted. If no such apportionment was made, EPA deducted allowances equally among the units sharing the stack to cover total emissions reported by the stack. The deductions for emissions at each unit after the common stack apportionment was made can be found in Appendix A of this Report. Appendix A is available on our website at www.epa.gov/airmarkets/cmprpt/arp01/index.html. Units sharing a common stack are listed directly under the entry for their common stack.

Figure 6. SO₂ Allowance Reconciliation Summary, 2001

Total Allowances Held in Accounts as of 3/1/2002 (1995 through 2001 Vintages)⁵	19,933,611
Unit Accounts	14,749,028
General Accounts ⁶	5,184,583
Allowances Deducted for Emissions (1995 through 2001)	10,633,035
2002 Penalty Allowances Deducted	11
Banked Allowances	9,300,576
Unit Accounts	4,115,993
General Accounts ⁶	5,184,583

⁵ The number of allowances held in the Allowance Tracking System (ATS) accounts equals the number of 2001 allowances allocated (see Figure 5) plus the number of banked allowances. March 1, 2002 represents the Allowance Transfer Deadline, the point in time at which unit accounts are frozen and after which no transfers of 1995 through 2001 allowances will be recorded. The freeze on these accounts is removed when annual reconciliation is complete.

⁶ General accounts can be established in the ATS by any utility, individual or other entity.

Source: EPA

⁴ A source that does not hold enough allowances in its unit account to cover its annual SO₂ emissions has "excess emissions" and must pay a \$2,000 per ton automatic penalty in 1990\$. The \$2,000 penalty is adjusted annually for inflation, so the year 2001 penalty was \$2,774.

Geographic Trends in SO₂ Emissions

Total sulfur dioxide emissions from power generation have decreased significantly since the Acid Rain Program was authorized by Congress in 1990, and they continued to decline in 2001, the second year of Phase II. The geographic distribution of SO₂ emissions did not change significantly between 1990 and 2001. Figure 7 displays bar graphs comparing state SO₂ emission trends from power generation before the Acid Rain Program (1990), during Phase I (1995-1999 average), and in Phase II to date (2000-2001 average).

Several geographic trends are evident:

- The bar graphs on the map in Figure 7 illustrate that the area with the highest emissions--the Midwest--also had the largest reductions;
- SO₂ emission reductions during Phase I occurred predominantly in approximately a dozen states in the Eastern U.S. (Phase I affected the larger, higher emitting utilities in the Eastern half of the country);
- The 24 shaded states represent states where SO₂ emissions in Phase II (2000-2001) were lower than both 1990 levels and the 1995-1999 Phase I average. Unlike the SO₂ emission reductions achieved during Phase I, these Phase II reductions are geographically more widespread, occurring in a larger number of Southeastern and some Western states.

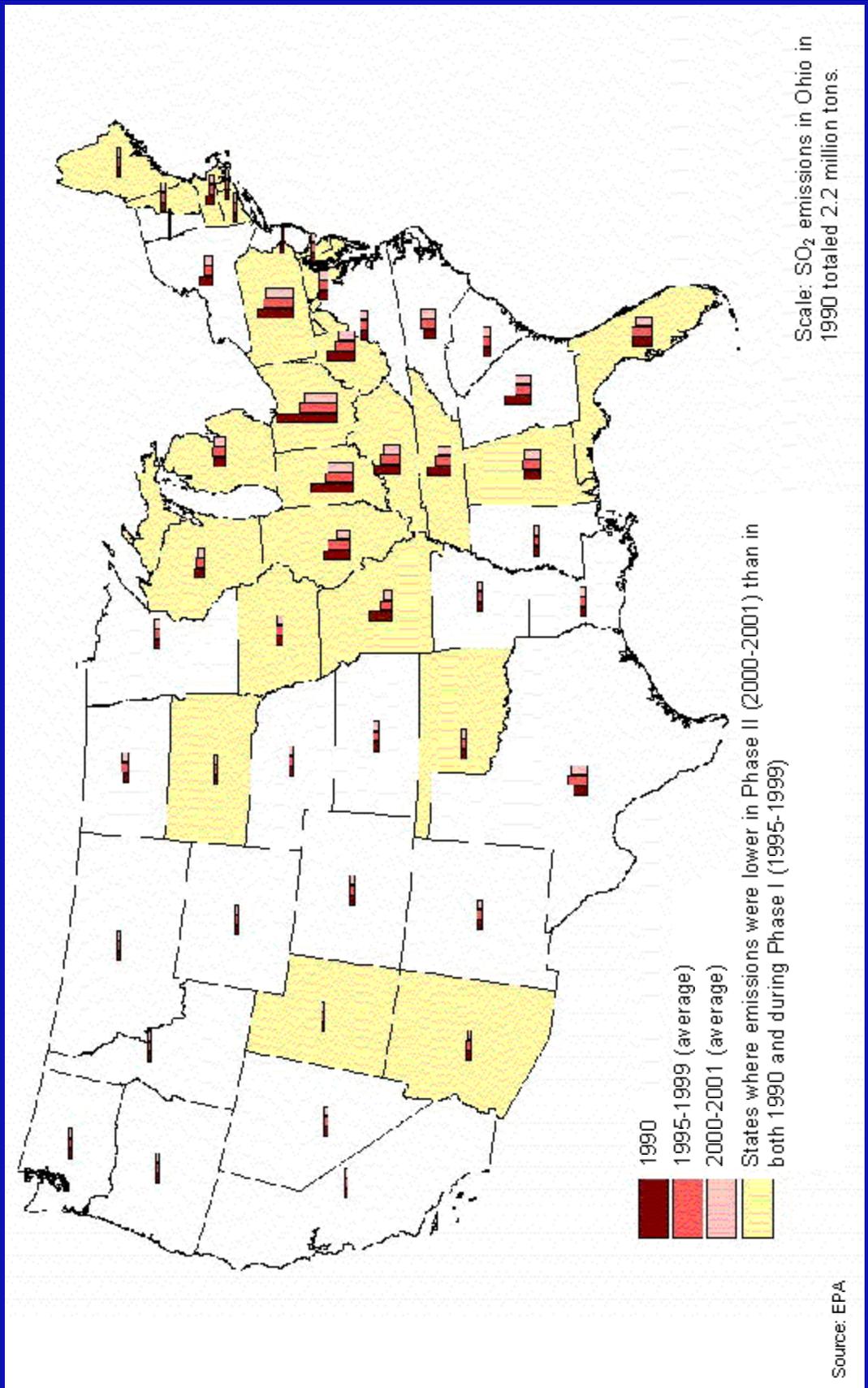
In several states, average SO₂ emissions during Phase 1 were higher than they had been in 1990. This is due to the large number of Phase II sources in these states that were not required to control for SO₂ until 2000. In the 2000-2001 period (Phase II) these emissions declined to levels below what was emitted in 1990. In general, because SO₂ emissions are capped, there will be pressure to continue to reduce SO₂ emissions by installing add-on controls.

Figure 8 illustrates the geographic distribution by state of SO₂ emissions from power generation before implementation of the Acid Rain Program (1990), during Phase I (1995-1999 average), and in Phase II (2000-2001 average).

In 2001, Title IV sources achieved a 33% reduction from 1990 SO₂ levels nationwide. SO₂ emissions in Texas did increase in Phase I; however, SO₂ emissions in the state decreased in Phase II when the Acid Rain Program requirements took effect for Texas sources. Although most SO₂ emissions still occur in the Midwestern U.S., it is important to note that, over time, this same region has also seen the most significant decrease in SO₂ emissions in the country. The highest SO₂ emitting states in 1990 (Ohio, Indiana, and Pennsylvania), reduced emissions 40% in 2001 (49%, 47%, and 22%, respectively) compared to 1990 levels. Other states in the region show similar trends since 1990. SO₂ emissions decreased 59% in Illinois, 41% in Kentucky, 70% in Missouri, 55% in Tennessee, and 49% in West Virginia.

Figure 7. Average SO₂ Emissions from Acid Rain Sources by State, 1990-2001

Emissions in the East, where most Phase I sources are located, decreased during Phase I. Many additional reductions during Phase II are occurring in the Southeast and West.



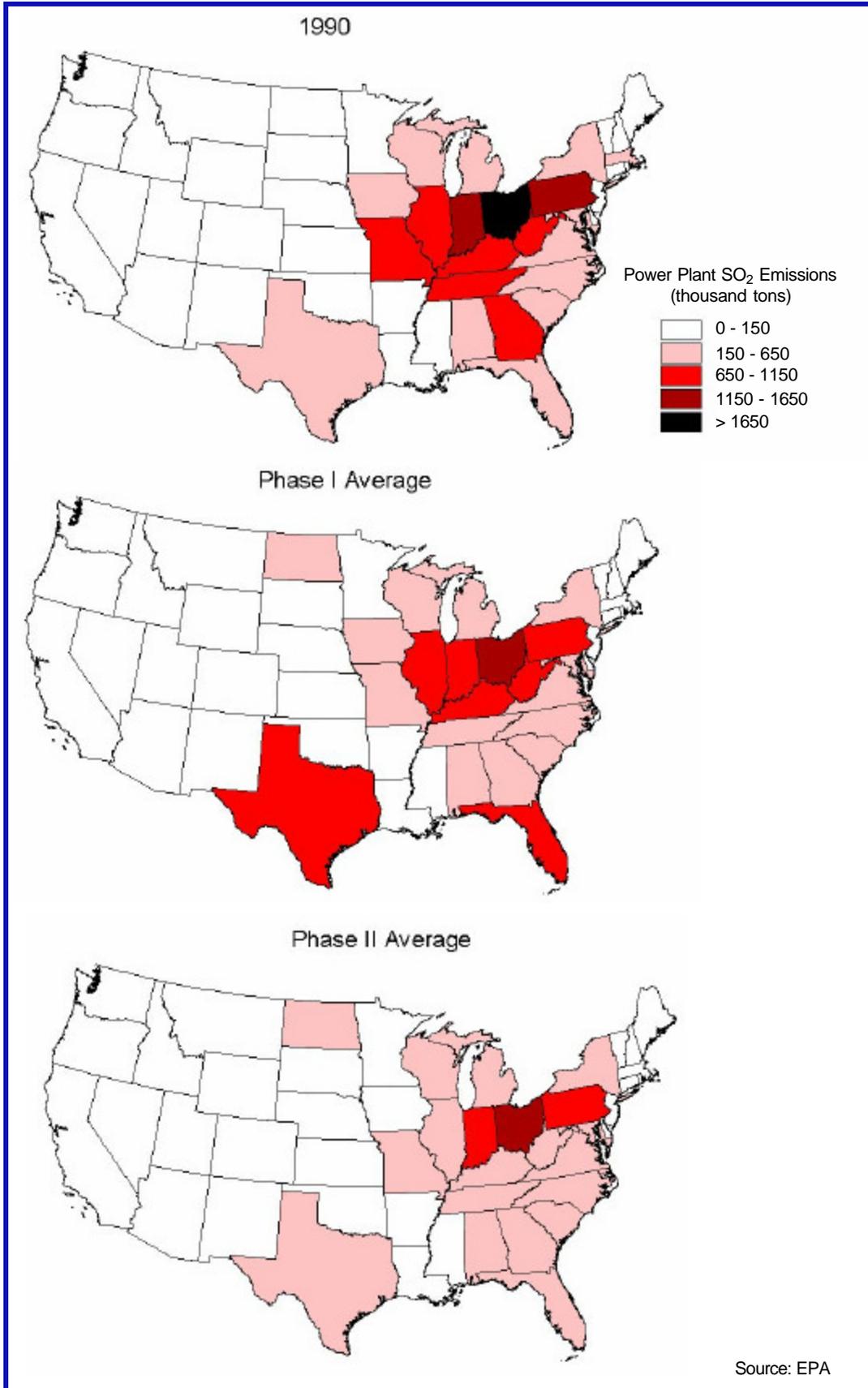


Figure 8. Geographic Distribution of Average SO₂ Emissions from Acid Rain Sources by State, 1990-2001

Since 1990 the most significant emissions reductions have taken place in the highest emitting states. There have been no significant geographic shifts in emissions since 1990.

SO₂ Allowance Market

The flexibility provided by the Acid Rain Program enabled the 2,792 units subject to the SO₂ requirements in 2001 to pursue a variety of compliance options. Sources met their SO₂ reduction obligations by installing scrubbers, switching fuels, changing practices or procedures to improve energy efficiency, and buying allowances. The presence of the allowance market has given some sources the incentive to reduce their SO₂ emissions below the level of their allowance allocation in order to bank their allowances for use in future years. Other sources have been able to postpone or reduce expenditures for control by purchasing allowances from sources that controlled below their allowance allocation level. The flexibility in compliance options is possible because strict monitoring requirements for all affected units ensure one allowance is surrendered for every ton of SO₂ emitted. The program's flexibility significantly reduces the cost of achieving these emissions reductions as compared to the cost of a technological mandate or fixed emission rate.

The marginal cost of compliance--the cost of reducing the next ton of SO₂ emitted from the utility sector--is reflected in the price of an allowance. Emission reductions continue to cost less than anticipated when the Clean Air Act Amendments were enacted and this is reflected in the price of allowances. The cost of an allowance was initially estimated at \$400-1,000/ton in 1990 dollars (\$500-1,200/ton in 2001 dollars). As shown in Figure 9, actual prices have been significantly lower than predicted. During 2001, SO₂ allowances ranged in price from \$135-\$210/ton. At the time of the annual allowance auction in April 2001, allowances were approximately \$170/ton. The price rose through the summer, peaking at \$210/ton in late August/early September. During the last quarter of 2001, prices dropped back to around \$170/ton and then stabilized. Some market observers believe lower-than-expected allowance prices during the first several

Figure 9. SO₂ Allowance Price Index

The cost of allowances in 2001 did not change substantially from the previous few years and remains far lower than estimated in 1990.



Source: Monthly price reports from Cantor Fitzgerald Environmental Brokerage Services

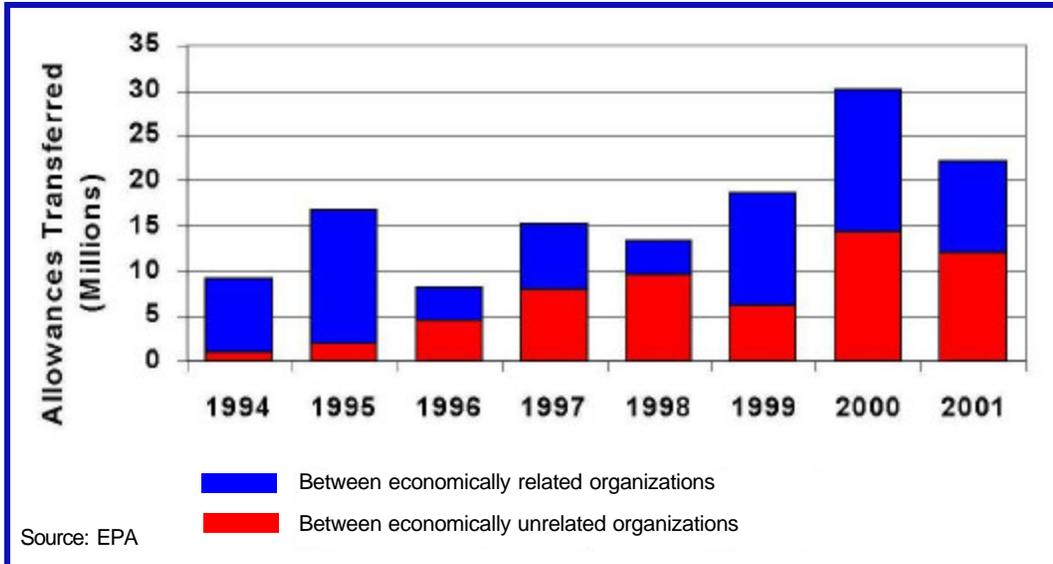


Figure 10. SO₂ Allowances Transferred under the Acid Rain Program

The number of official transfers between economically unrelated organizations has increased since 1994.

years of the program were due primarily to lower than expected compliance costs and larger than expected emissions reductions, which increased the supply of allowances and put downward pressure on prices. Additionally, the more stringent limits in Phase II most likely resulted in higher average prices in 2001 than in 2000 as sources realized they would have to continue to withdraw from the bank and employ further controls to comply in future years.

The level of activity in the allowance market created under the Acid Rain Program increased fairly steadily through 2000 and then dropped off somewhat in 2001, the second year of Phase II. However, the number of official transfers in 2001 was still higher than in any year of Phase I.

In 2001, 4,900 allowance transfers that affected over 22 million allowances (of past, current, and future vintages) were recorded in the Allowance Transfer System, the accounting system developed to track holdings of allowances. Of the allowances transferred, 12.6 million, or 55%, were transferred in economically significant transactions (i.e., between economically unrelated parties). Figure 10 shows the volume of SO₂ allowances transferred under the Acid Rain Program since official recording of transfers began in 1994. The majority of the allowances transferred in economically significant transactions were acquired by utilities. Trades between unrelated organizations accounted for approximately 12 million allowances in 2001. In December 2001, trading parties began to use the On-line Allowance Tracking System (OATS). By the end of 2001, OATS recorded 211 transfers electronically over the internet.

All official allowance transactions, as well as data on account balances and ownership, are posted and updated daily on the Clean Air Markets Division's website (www.epa.gov/airmarkets) in order to better inform trading participants of the status of the market. Cumulative market statistics and analysis are also available.

The NO_x Program

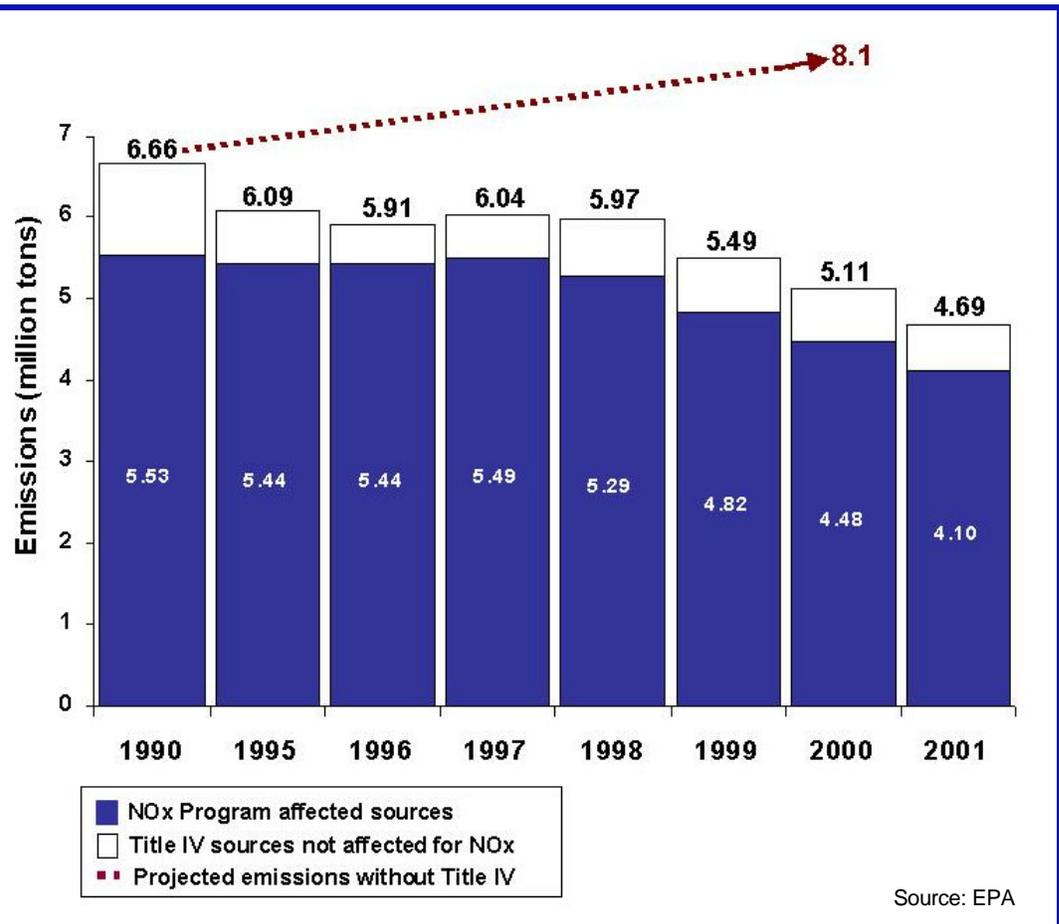
All sources affected by the Acid Rain Program NO_x requirements reduced their combined NO_x emissions by 25% from 1990 levels in 2001. All but one of the 1,046 NO_x program affected units complied with their NO_x emission rate limitation. There were no significant shifts in the geographic distribution of emissions due to use of the emissions averaging compliance option.

Emissions

Title IV of the 1990 Clean Air Act requires the Acid Rain Program NO_x program to achieve a 2 million ton reduction from projected NO_x emissions levels in 2000. Total NO_x emissions from all Acid Rain Program affected units surpassed that goal by 1 million tons in 2000 (see Figure 11). Emissions from those sources in 2001 were even less -- 3.4 million tons (over 40%) below projected 2000 emissions without the Acid Rain Program. For all 2,792 Title IV affected units, total

Figure 11. NO_x Emissions from Acid Rain Sources, 1990-2001

NO_x emissions have decreased since 1990, particularly in preparation for and during Phase II of the Acid Rain Program. Reductions since 1999 are also due in part to implementation of the OTC NO_x Budget Trading Program and the NO_x SIP call.



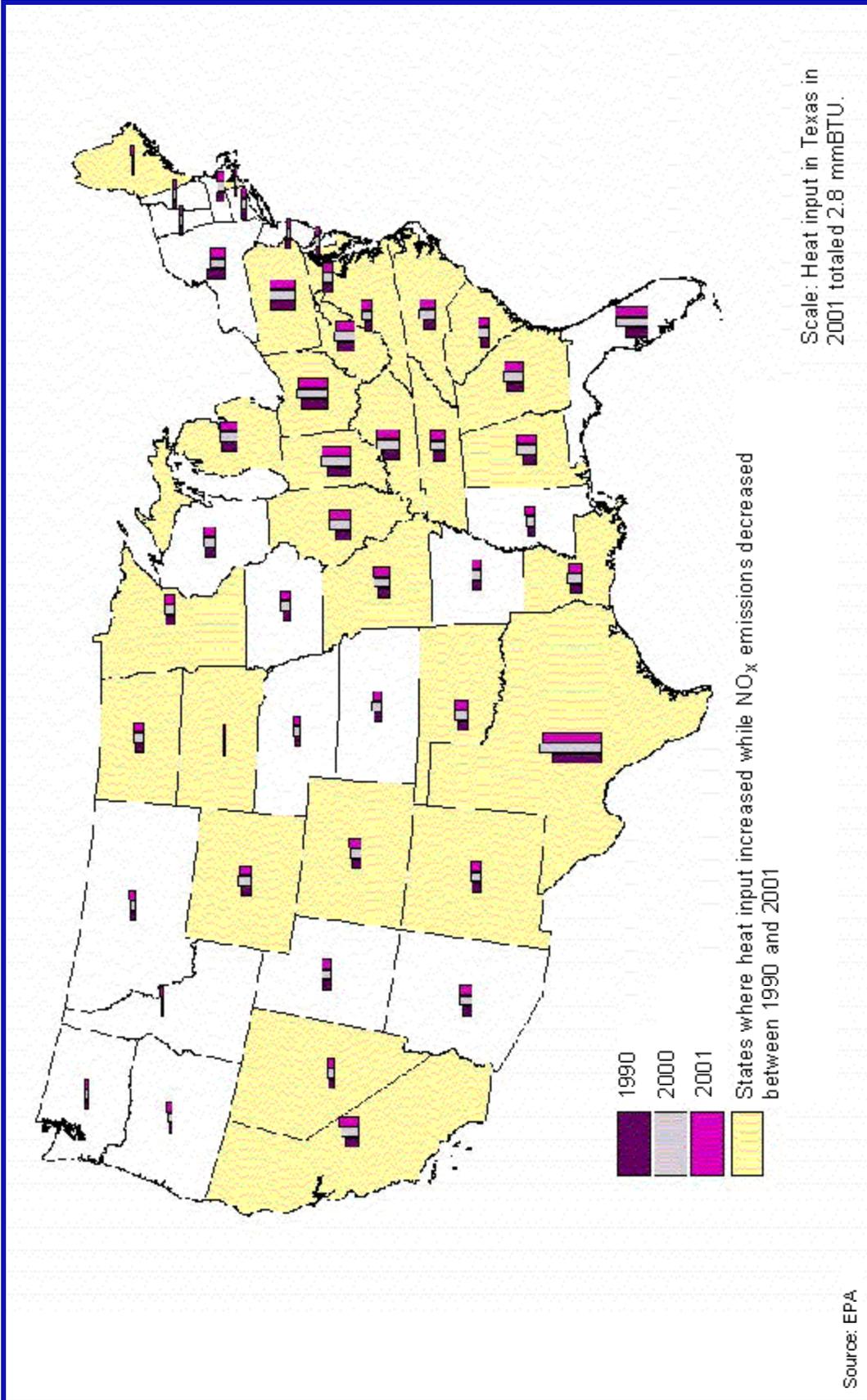


Figure 12. Comparison of Heat Input for Electricity Generation and NO_x Emissions from Acid Rain Sources, by State, 1990-2001

Heat input--a measure of fossil fuel used to generate electricity--increased in almost every state between 1990 and 2001 while nationwide NO_x emissions decreased.

NO_x mass emissions in 2001 were 2 million tons lower than emissions in 1990. Emissions from the 1,046 NO_x program affected sources in 2001 were 1.4 million tons lower than in 1990 and 8% lower than in 2000.

These reductions have been achieved while the amount of fuel burned to produce electricity, as measured by heat input, increased 28% since 1990. As illustrated in Figure 12, many states with increasing electricity production have also decreased total NO_x emissions in 2001, as compared to 1990 levels. Without further reductions in emissions rates or institution of a cap on NO_x emissions, however, NO_x emissions from power plants would have been expected to rise with increased use of fossil fuels in most areas of the country.

NO_x emissions come from a wide variety of sources including those affected by the Acid Rain Program. NO_x emissions from electric utilities account for approximately 20% of NO_x emissions from all sources. NO_x emissions from transportation sources are 55% of NO_x emissions from all sources. Nationally, NO_x emissions have increased 5% between 1990 and 1999. This is primarily due to an increase of 17% in NO_x emissions from transportation sources, particularly heavy duty vehicles, since 1990. That increase has been offset to some extent by the emissions decreases from electric utilities and other fuel combustion sources due to a variety of federal and state emission reduction programs (including the Acid Rain Program, the Ozone Trading Commission NO_x Budget Trading Program, and anticipation of the NO_x SIP call) and federal enforcement actions (National Air Quality and Emissions Trends Report, 1999).

Emission Limits

Instead of using allowance trading to facilitate NO_x emissions reductions, the Acid Rain Program establishes NO_x emission limitations (lb/mmBtu NO_x) for coal-fired electric generation units.

The Acid Rain Program NO_x regulation (40 CFR part 76), establishes NO_x limits for Group 1 boilers (dry bottom wall-fired and tangentially fired boilers), as well as Group 2 boilers (cell burner, cyclone, vertically-fired, and wet bottom boilers). Figure 13 shows the number of NO_x affected units by boiler type and the emissions limit for each boiler type.

There were 1,046 units subject to NO_x emissions limitations in 2001. The owners and operators of a NO_x affected unit must choose at least one NO_x compliance plan (described below) to indicate how the unit will comply with its NO_x limit:

- ◆ **Standard Limitation.** A unit with a standard limit simply meets the applicable individual NO_x limit prescribed for its boiler type under 40 CFR 76.5, 76.6, or 76.7.
- ◆ **Early Election.** Under this compliance option, a Phase II Group 1 NO_x

affected unit met a less stringent Phase I NO_x limit beginning in 1997, three years before it would normally be subject to an Acid Rain NO_x limit. In return for accepting a NO_x limit three years earlier than would normally be required, an early election unit does not become subject to the more stringent Phase II NO_x limit until 2008.

- ◆ **Emissions Averaging.** A company can meet its NO_x emissions reduction requirements by choosing to make a group of NO_x affected boilers subject to a group NO_x limit, rather than meeting individual NO_x limits for each unit. The group limit is established at the end of each calendar year, and the group rate for the units must be less than or equal to the Btu-weighted rate at which the units would have been limited had each been subject to an individual NO_x limit.
- ◆ **Alternative Emission Limitation (AEL).** A utility can petition for a less stringent AEL if it properly installs and operates the NO_x emissions reduction technology prescribed for that boiler but is unable to meet its standard limit. EPA determines whether an AEL is warranted based on analyses of emissions data and information about the NO_x control equipment.

Coal-Fired Boiler Type ⁷	Standard Emission Limit (lb/mmBtu)	Number of Units
Phase I Group1 Tangentially-fired	0.45	135
Phase I Group1 Dry Bottom Wall-fired	0.50	130
Phase II Group 1 Tangentially-fired	0.40	304
Phase II Group 1 Dry Bottom Wall-fired	0.46	312
Cell Burners	0.68	37
Cyclones > 155 MW	0.86	56
Wet Bottom > 65 MW	0.84	31
Vertically-fired	0.80	41
Total		1,046

Figure 13. Number of NO_x Affected Units by Boiler Type

⁷ All coverage for boilers > 25 MW unless otherwise noted.

Source: EPA

Figure 14. Compliance Actions in the NO_x Program, 2001

The primary method of compliance with the NO_x program was emissions averaging.

Compliance Option	Number of Units
Standard Emission Limitation	140
Early Election	274
Emissions Averaging	638
Alternative Emission Limitation	27
TOTAL	1,079⁸

⁸ The total does not equal 1,046 because 28 units have both early election and emissions averaging compliance plans, and 5 units have both AELs and emissions averaging plans.

Source: EPA

Compliance

In 2001, 1,045 NO_x units met their NO_x emissions limits through compliance with their respective NO_x compliance plans. Only one unit failed to meet its NO_x emissions limit in 2001. That unit had excess NO_x emissions of 60 tons and was assessed a monetary penalty of \$166,440 (60 tons x \$2,774 per ton penalty). Detailed compliance information by unit can be found in Appendices B1 and B2. These appendices are available on our website at www.epa.gov/airmarkets/cmprpt/arp01/index. Figure 14 summarizes the compliance options chosen for NO_x affected units in 2001. Averaging was the most widely chosen compliance option; 54 averaging plans involving 638 units were in place in 2001.

Geographic Trends in NO_x Emissions

Total nitrogen oxide emissions from all NO_x affected Acid Rain Program sources have decreased 25% since 1990. Figure 15 displays bar graphs illustrating relative state NO_x emission trends from power generation sources affected by the NO_x program before the Acid Rain Program (1990), during Phase I (1996-1999 average), and in Phase II (2000-2001 average). NO_x emissions reductions since 1999 are due in part to implementation of the OTC NO_x Budget Trading Program, the NO_x SIP call, and several state reduction programs as well as the Acid Rain Program.

Several geographic trends are evident:

- The bar graphs illustrate that NO_x emissions were lower in 35 states in 2001 compared to 1990 levels, with the greatest reduction occurring in the Eastern United States;
- The shaded states had lower NO_x emissions in 2001 compared to both 1990 levels and the 1996-1999 Phase I average. NO_x reductions

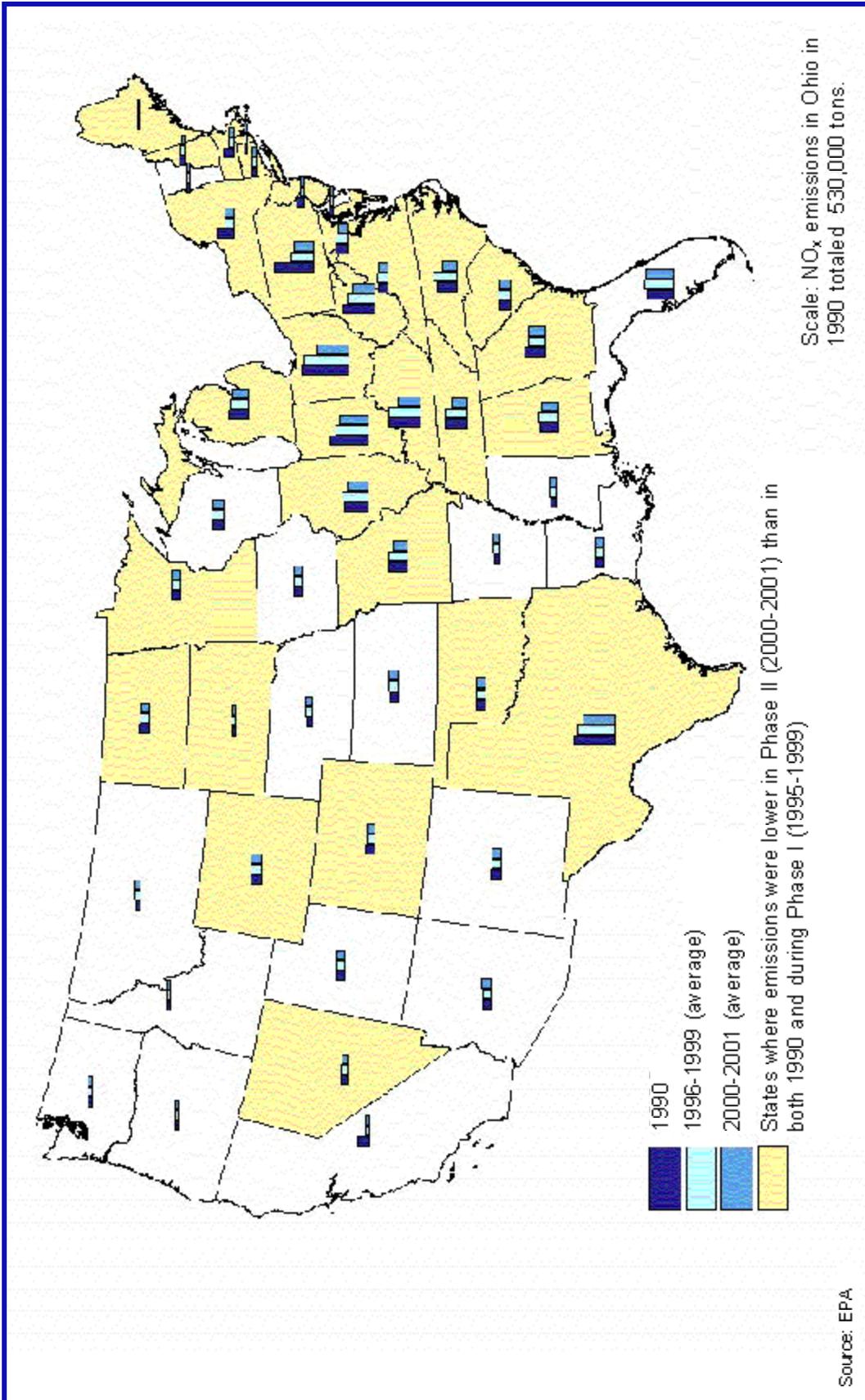
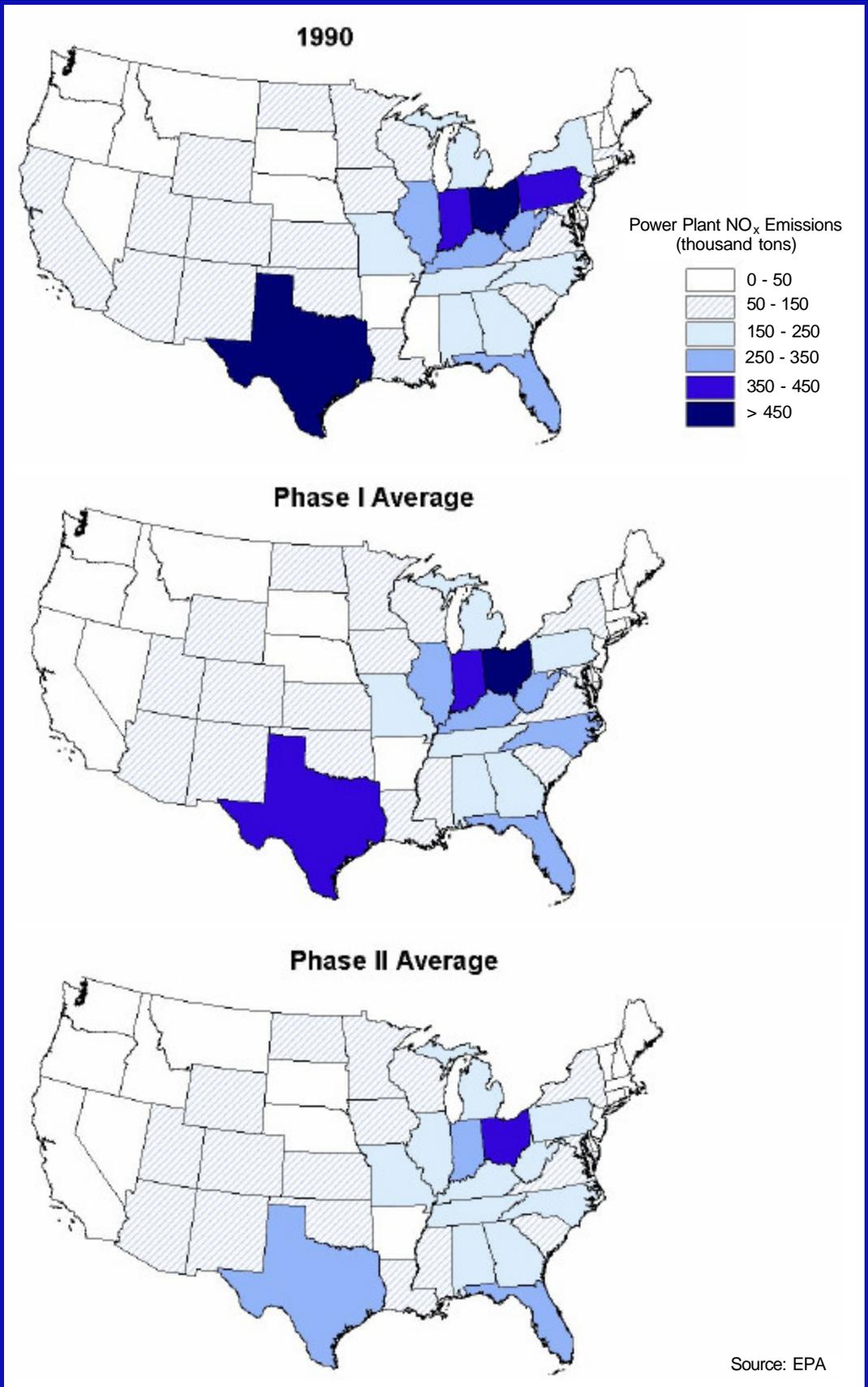


Figure 15. Average NO_x Emissions from Acid Rain Sources by State, 1990-2001

NO_x emissions in Phase II (2000 and 2001) continue to decrease in most states, especially among the highest emitting states.

Figure 16. Geographic Distribution of Average NO_x Emissions from Acid Rain Sources by State, 1990-2001

Emissions reductions in Phase I took place primarily in the Northeast; in the first two years of Phase II additional emissions reductions took place in the South and Midwest. There have been no significant geographic shifts in emissions since 1990.



Source: EPA

occurred predominantly in the Northeastern U.S. during Phase I; in Phase II, NO_x reductions are geographically more extensive and occur in a larger number of Southern and Midwestern states.

In several states, average NO_x emissions during Phase I were higher than they had been in 1990. This is due to the large number of Phase II sources in these states that were not required to control NO_x emissions until 2000. In the 2000-2001 period (Phase II) emissions in these states have declined to levels below what was emitted in 1990. There are also several states where average Phase II NO_x emissions were higher than emissions in 1990 and/or the Phase I average. This is because while the Acid Rain Program limits the rate at which coal-fired power plants may emit NO_x, it does not limit total emissions of NO_x the way total emissions of SO₂ are limited. Since heat input (or fuel use) increased in those states, overall NO_x emissions also increased.

As illustrated in Figure 16, in 1990, the highest NO_x emissions occurred in the Midwestern and Southern regions of the U.S. By 2001, emissions in many of these states had been significantly reduced from 1990 levels. The states with the highest emissions in 1990 (Ohio, Texas, and Pennsylvania), achieved an average reduction of 40% (38%, 31%, and 52%, respectively) in 2001. Other states in the region are showing similar trends since 1990. NO_x emissions decreased 27% in Indiana, 33% in Kentucky, 34% in Tennessee, and 39% in West Virginia.

Monitoring Results

The Acid Rain Program relies on several types of monitoring to implement and assess the effectiveness of Title IV. Each affected source is required to install and maintain Continuous Emissions Monitoring Systems (CEMS) or approved compatible alternatives to accurately measure the amount of SO₂ and NO_x emitted. The Acid Rain Program also assesses the results of the emissions reductions by collaborating with other organizations to measure acid deposition nationwide. Wet acid deposition is monitored by the National Atmospheric Deposition Program (NADP). Dry deposition is monitored by the Clean Air Status and Trends Network (CASTNet). The impacts of acid deposition on lakes and streams are monitored by the Long-Term Monitoring (LTM) and Temporally-Integrated Monitoring of Ecosystems (TIME) ecological monitoring programs.

Emissions Monitoring

Emissions monitoring is necessary in order to verify the reductions of SO₂ and NO_x emissions mandated under the Act and to support the SO₂ allowance trading program. A fundamental objective of the Acid Rain Program is to ensure consistent and accurate accounting of emissions from all affected boilers and turbines. To implement this objective, concentrations and mass emissions of SO₂ and NO_x from each affected unit are measured and recorded using Continuous Emissions Monitoring Systems (CEMS) or an approved alternate measurement method and reported to EPA on a quarterly basis. Daily, quarterly, and annual quality assurance (QA) tests must be performed by each source to ensure that its monitors continuously meet the high accuracy standards of the Acid Rain Program.

SO₂ mass emissions are determined using CEMS to measure SO₂ concentration and stack gas flow rate. NO_x mass emissions are determined by coupling NO_x concentration data with flow, diluent (i.e., CO₂ or O₂) concentrations, or fuel feed rates. Whatever method is selected, all monitors are required to meet strict initial and on-going performance standards to demonstrate the accuracy, precision, and timeliness of their measurement capabilities. The monitors used in the Acid Rain Program have achieved an unparalleled level of performance with respect to all of these criteria.

One measure of the accuracy of a CEMS is the relative accuracy test audit (RATA), which is required for initial certification of a CEMS and on at least an annual basis thereafter. The RATA ensures that the installed monitor measures the "true" value of a pollutant by comparing the monitor to a reference method which simultaneously measures the stack gas pollutant. All monitoring systems

must meet a relative accuracy standard allowing no more than ten percent deviation from the true value in order to continue to be used for emissions reporting. Further, if the CEMS is biased low compared to the true value, a bias adjustment factor must be applied to all future data from that monitoring system to ensure there is no underreporting. This "self correcting" provision, coupled with daily quality assurance testing requirements, creates a strong disincentive to allowing any deterioration in monitor performance.

In 2001, data submitted on monitoring systems indicate that over 96% of the SO₂ concentration monitors and 99% of all flow monitors met this relative accuracy standard. In fact, most sources achieved much better results as the median relative accuracies for all of these monitors were 3% and 2.5%, respectively.

Air Quality and Deposition in 2001

The Acid Rain Program also works with many partners to monitor the effects of emissions changes on air quality, deposition of pollutants, and water quality. The National Atmospheric Deposition Program (NADP) is a nationwide network of precipitation monitoring sites designed to measure regional levels of atmospheric deposition. The network is a consortium of many different groups, including universities, state, local and federal government agencies, and other interested partners. The NADP National Trends Network (NADP-NTN) measures wet acid deposition (deposition that occurs in rain, snow, or sleet) weekly at about 250 monitoring stations throughout the U.S. The data are subject to strict quality assurance

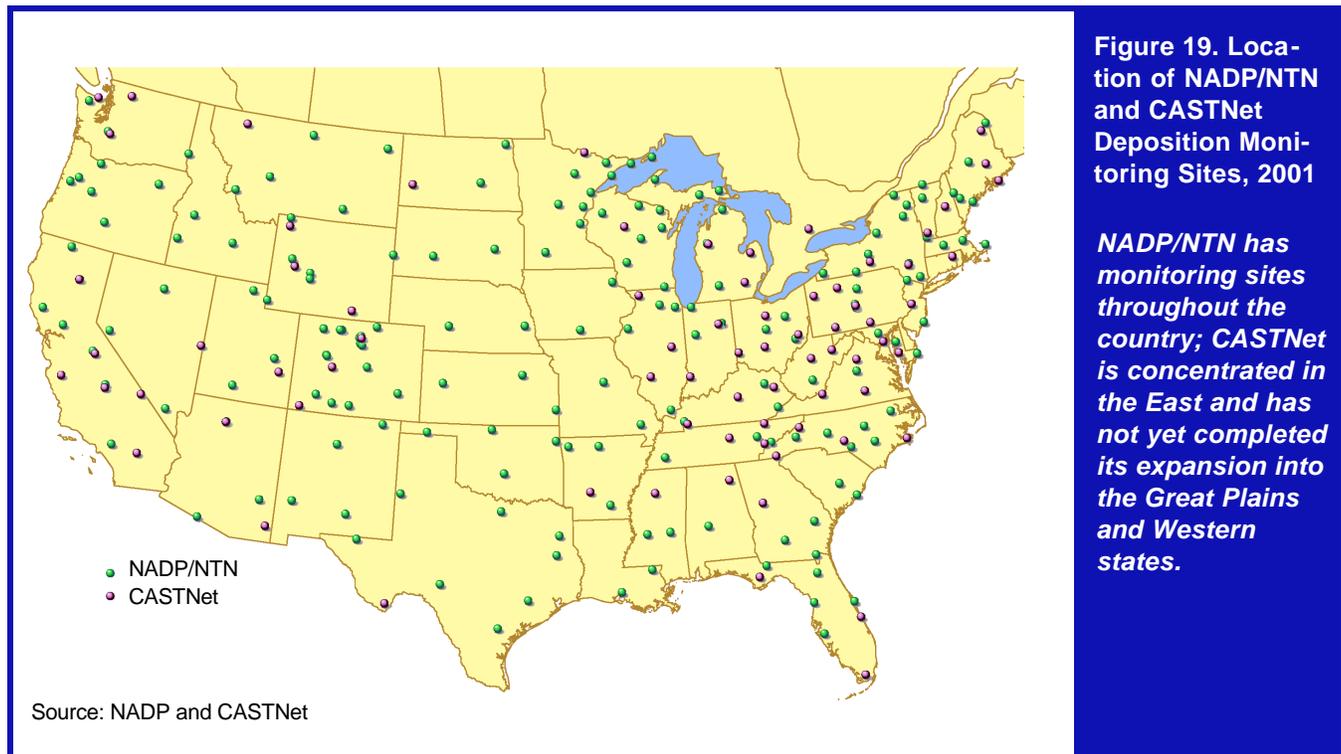


Figure 19. Location of NADP/NTN and CASTNet Deposition Monitoring Sites, 2001

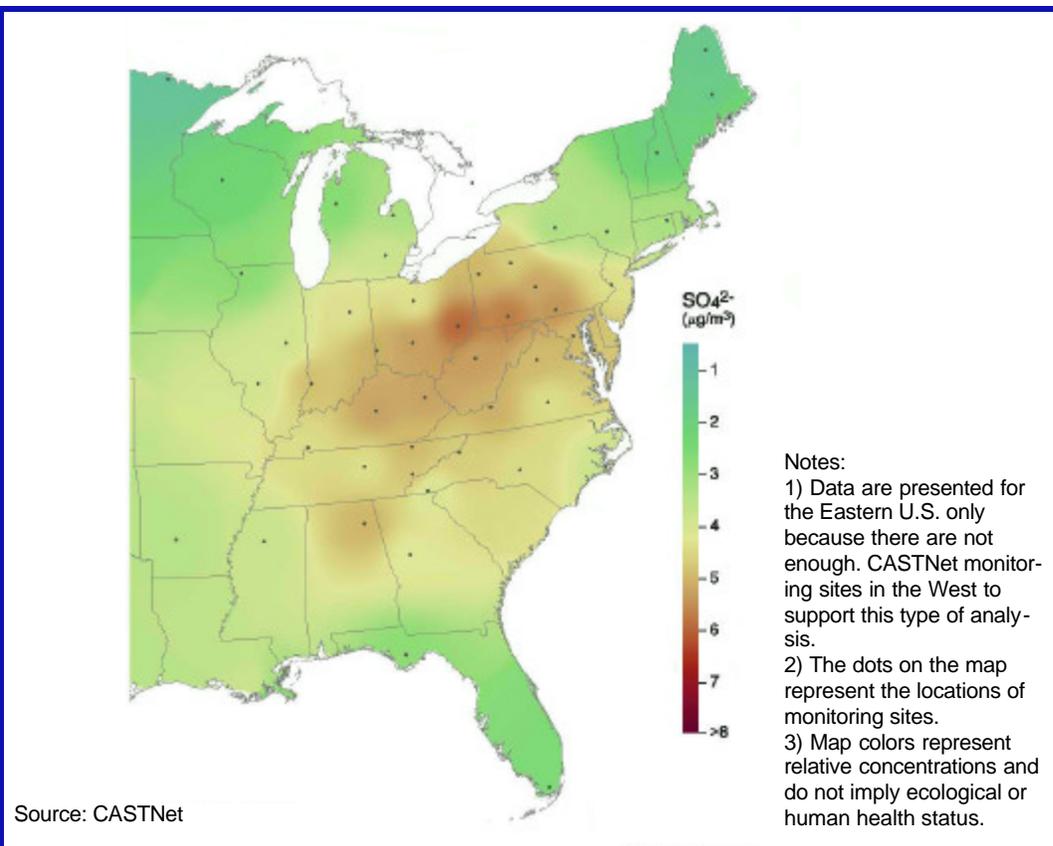
NADP/NTN has monitoring sites throughout the country; CASTNet is concentrated in the East and has not yet completed its expansion into the Great Plains and Western states.

and completeness screening in the field, in the laboratory, and during analysis. All NADP data can be accessed online from the NADP website at <http://nadp.sws.uiuc.edu/>. The Clean Air Status and Trends Network (CASTNet) is a nationwide network of over 70 sites that measures ambient air concentrations of pollutants, including ozone. CASTNet also measures dry deposition (the process through which particles and gases are deposited in the absence of precipitation) of acidic compounds. CASTNet data are also subject to strict quality assurance and completeness criteria. Figure 19 displays a map of the NADP-NTN and CASTNet deposition monitoring sites (the dots on the maps in Figures 20, 21, and 22 also indicate the location of monitoring sites). All CASTNet data can be accessed online from the CASTNet website at <http://www.epa.gov/castnet>.

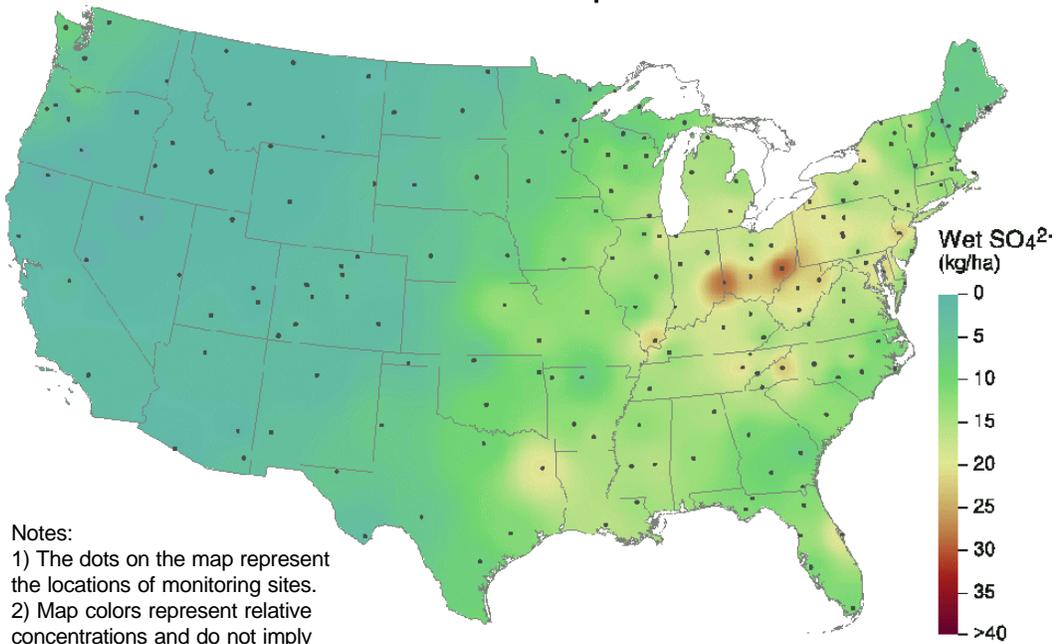
Figure 20 shows the sulfate (SO_4^{2-}) concentrations (a primary component of fine particles in the Eastern U.S.) in the atmosphere. Concentrations are highest in the Midwest, mid-Atlantic, and parts of the South. Figure 21 shows the wet sulfate and total (wet and dry) sulfur deposition in the continental U.S. during 2001. Wet sulfate deposition is highest in the Midwest. Total sulfur deposition is highest in the Eastern U.S. Most sites in the Eastern U.S. have a dry/wet ratio of about 1:1, meaning that wet and dry deposition make up roughly equal portions of the total deposition amount. In general, dry deposition is a larger percentage of total deposition in those areas nearest to SO_2 emission sources.

Figure 20. Eastern Regional Air Quality, 2001: Sulfate Concentrations

The highest regional concentrations of sulfate (SO_4^{2-}) in the atmosphere are in or downwind of the areas where SO_2 emissions are highest.



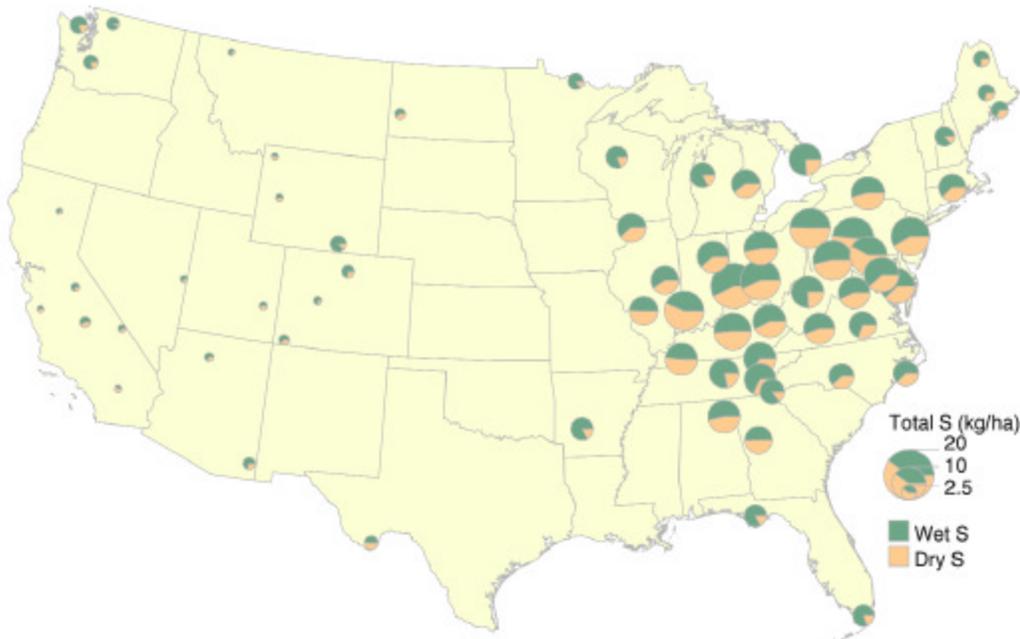
Wet Sulfate Deposition



Notes:
 1) The dots on the map represent the locations of monitoring sites.
 2) Map colors represent relative concentrations and do not imply ecological or human health status.

Source: NADP

Total Sulfur Deposition



Note: The size of the "pies" indicates the total magnitude of deposition; the colors indicate the percentage of wet and dry deposition.

Source: CASTNet

Figure 21. Sulfur Deposition, 2001: Wet Sulfate and Total Sulfur Deposition

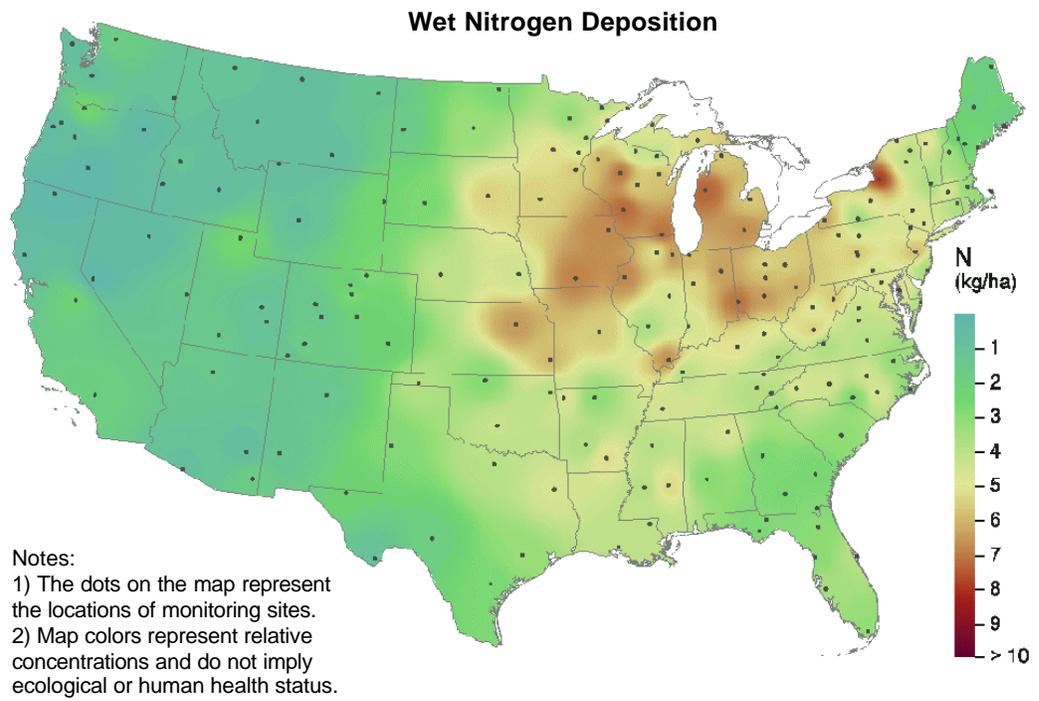
The highest levels of wet sulfate (SO_4^{2-}) deposition are in the areas where emissions are highest and in areas down-wind.

Wet and dry sulfur (S) deposition make up roughly the same percentage of total sulfur deposition in the Midwest; in most other areas wet deposition makes up a greater percentage of the total.

Figure 22. 2001 Nitrogen Deposition: Wet and Total Nitrogen Deposition

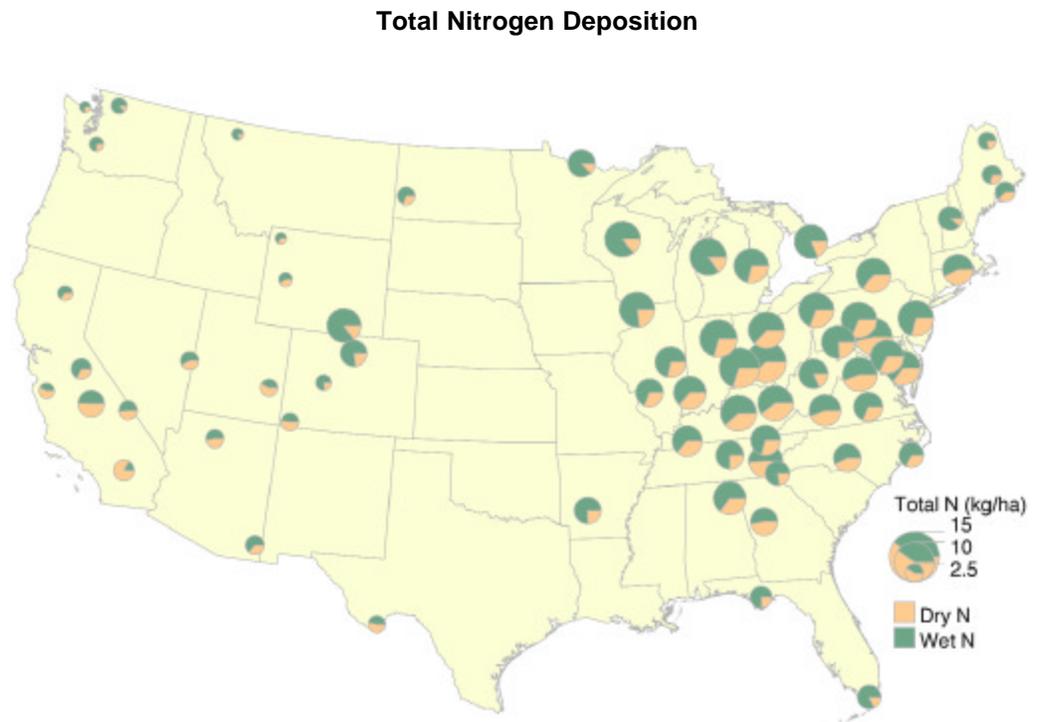
The highest levels of wet nitrogen (N) deposition are in the Midwest and in agricultural areas in the Great Plains.

Wet deposition makes up most of the total deposition load at most of the monitoring sites in the Eastern U.S.; in southern California dry deposition makes up a greater percentage of the total.



Notes:
1) The dots on the map represent the locations of monitoring sites.
2) Map colors represent relative concentrations and do not imply ecological or human health status.

Source: NADP



Note: The size of the "pies" indicates the total magnitude of deposition; the colors indicate the percentage of wet and dry deposition.

Source: CASTNet

Figure 22 shows the wet and total (wet plus dry) nitrogen (N) deposition in the continental U.S. during 2001. Wet nitrogen deposition is highest in the Midwest and in heavily agricultural areas of the Plains. Total nitrogen deposition is highest in the Eastern U.S., although several monitoring stations in the West also show relatively high levels of total nitrogen deposition. As is the case with sulfur, dry deposition of nitrogen makes up a larger part of the total amount of deposition in those areas nearest to the sources of NO_x emissions. In some areas of southern California, for example, the ratio of dry to wet deposition is approximately 4:1.

Clean Air Mapping and Analysis Program (C-MAP)

EPA has developed a mapping and analysis tool that can help users conduct assessments of regional and national environmental changes. C-MAP takes advantage of geographic mapping techniques to assess the environmental benefits of sulfur dioxide and nitrogen oxide emission reduction programs, including the Acid Rain Program. Using a Geographic Information System (GIS), C-MAP allows users to view a series of national and regional maps in the "Map Gallery" section, and then download the data used to generate the maps in the "GIS Data Download" section. The maps display information showing how changes in emissions result in changes in air quality indicators, acid deposition, and sensitive ecosystems. The GIS database provides an extensive inventory of national/regional level emissions, environmental effects, and demographic data available for download, including air quality, surface water quality, acid deposition, forest health, and sensitive ecosystem data. The data behind many of the graphics in this Progress Report, as well as many of the graphics themselves, are available for download and analysis at <http://www.epa.gov/airmarkets/cmap>.

Freshwater Monitoring

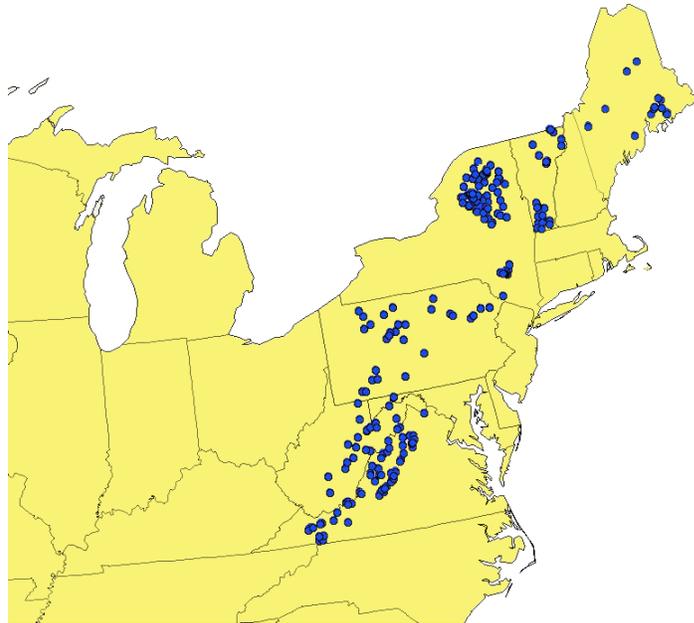
The Temporally Integrated Monitoring of Ecosystems (TIME) and Long-Term Monitoring (LTM) projects were initiated in the early 1990s by EPA's Office of Research and Development to determine whether emissions reductions have had the intended effect of reducing acidity in the environment. Currently all the TIME/LTM sites are in the Northeast and mid-Atlantic (see Figure 23); additional sites in acid sensitive regions of the Southeast and West would make more complete assessments possible. TIME/LTM measures a variety of important chemical characteristics in a regional population of lakes and streams, including acid neutralizing capacity, pH, sulfate, nitrate, several cations (e.g., calcium and magnesium), and aluminum. Its central objectives are to detect trends of these characteristics in regional populations of lakes or streams.

TIME/LTM utilizes a hybrid sampling design. Lakes or streams in the TIME network are measured annually; the results from these sites are used to infer regional changes in chronic acidification. The LTM sites are a non-random group of lakes or streams sampled on a frequent schedule (8-16 times per year) in order to characterize both long-term (over years) and short-term (over weeks) variation in their acid-base chemistry. LTM sites have been chosen to represent the sub-populations of lakes and streams most sensitive to acidic deposition effects.

Researchers use these data to model the episodic behavior of the sites, so that the models can be applied to TIME data. This approach allows the proportion of lakes and streams that undergo episodic acidification (short-term highly acidic pulses) to be estimated as an adjunct to the information on chronic acidification provided by the TIME results. Data collected in this network is used to assess trends in acidification and recovery as shown in Figure 29.

Figure 23. Location of TIME/LTM Surface Water Monitoring Sites

Long-term monitoring sites for acid rain are critical to assess whether lakes and streams are recovering from acidification.



Source: EPA

Environmental Improvement and Trends

The emission reductions achieved under the Acid Rain Program have led to important environmental and public health benefits. These include improvements in air quality with significant benefits to human health, reductions in acid deposition, the beginnings of recovery in surface waters, improvements in visibility, and less damage to forests, coastal waters, and materials and structures.

Improved Air Quality and Reduced Acid Deposition

To evaluate the impact of emissions reductions on the environment, scientists and policymakers use data collected from long-term national monitoring networks such as NADP and CASTNet. Deposition and air quality monitoring data from these and other air quality monitoring networks, such as the Interagency Monitoring of PROtected Visual Environments (IMPROVE) and the State/Local/National Air Monitoring Stations, can be accessed on or through the CASTNet website at <http://www.epa.gov/castnet>.

Data collected from these networks show that the decline in SO₂ emissions from the power industry has decreased acidic deposition and improved air quality. The decline in NO_x emissions has not been as large and the environmental improvements are not as widespread.

Analyses of CASTNet data show that concentrations of SO₂ in the atmosphere have decreased up to 8 micrograms per cubic meter (ug/m³) in the Northeast and mid-Atlantic from 10-20 ug/m³ in 1990 (see Figure 24). These reductions are primarily due to the significant decrease in SO₂ emissions from power plants under the Acid Rain Program.

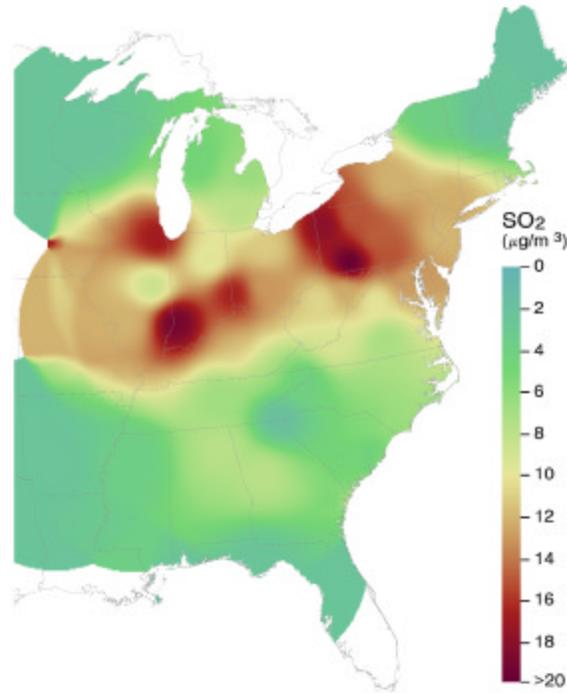
Sulfate concentrations in the atmosphere, a primary component of fine particulate matter in the East, have also decreased significantly since 1990 (see Figure 25). Sulfate concentrations have decreased up to 3 ug/m³ in most of the Eastern U.S. from levels of 5-8 ug/m³ in 1990. These reductions are also primarily due to the significant decrease in SO₂ emissions from power plants under the Acid Rain Program.

Wet sulfate deposition has decreased more than 8 kilograms/hectare (kg/ha; 1 kg/ha is equivalent to 0.89 pounds/acre) from 30-40 kg/ha/year in 1990 in much

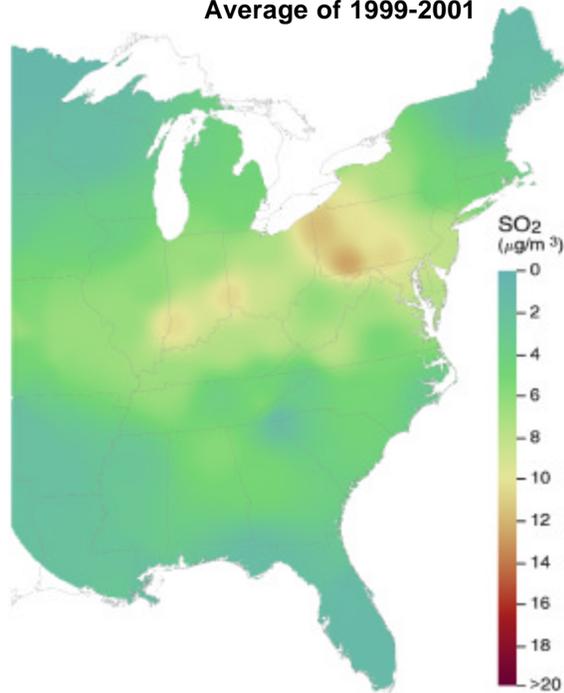
Figure 24.
Trends in Sul-
fur: Average
Yearly Sulfur
Dioxide Concen-
trations, 1989-91
vs. 1999-2001

*Sulfur dioxide
(SO₂) concentra-
tions have
decreased sub-
stantially in
most of the Mid-
west and North-
east since 1989-
1991.*

**Sulfur Dioxide Concentration
Average of 1989-1991**



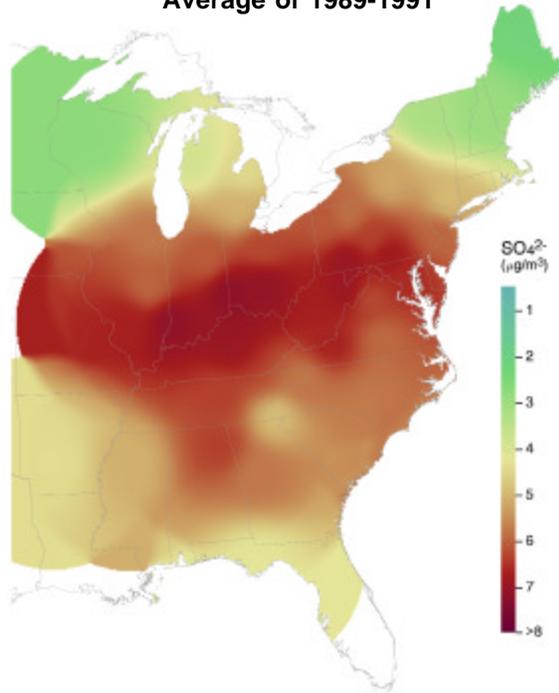
**Sulfur Dioxide Concentration
Average of 1999-2001**



Notes:
1) Data is presented for the Eastern U.S. only because there are not enough CASTNet monitoring sites in the West to support this type of analysis.
2) Map colors represent relative concentrations and do not imply ecological or human health status.

Source: CASTNet

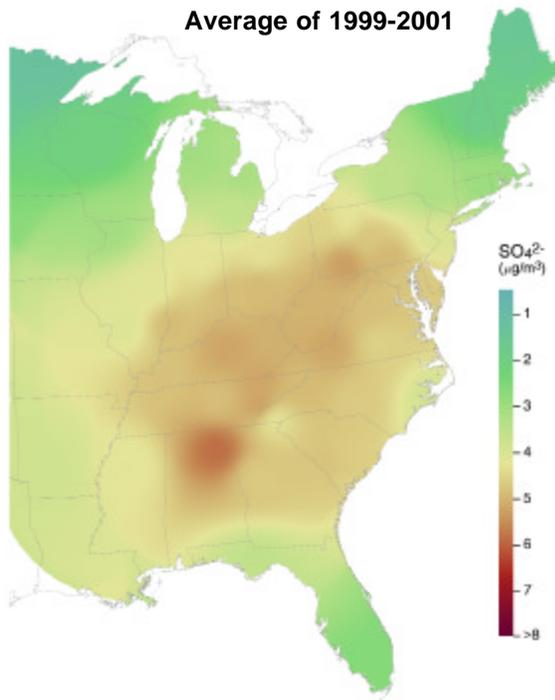
**Sulfate Concentration
Average of 1989-1991**



**Figure 25.
Trends in Sul-
fur: Average
Yearly Sulfate
Concentrations,
1989-91 vs.
1999-2001**

Sulfate (SO_4^{2-}) concentrations in air, a primary component of fine particles in the East, have decreased substantially in most of the East since 1989-1991.

**Sulfate Concentration
Average of 1999-2001**



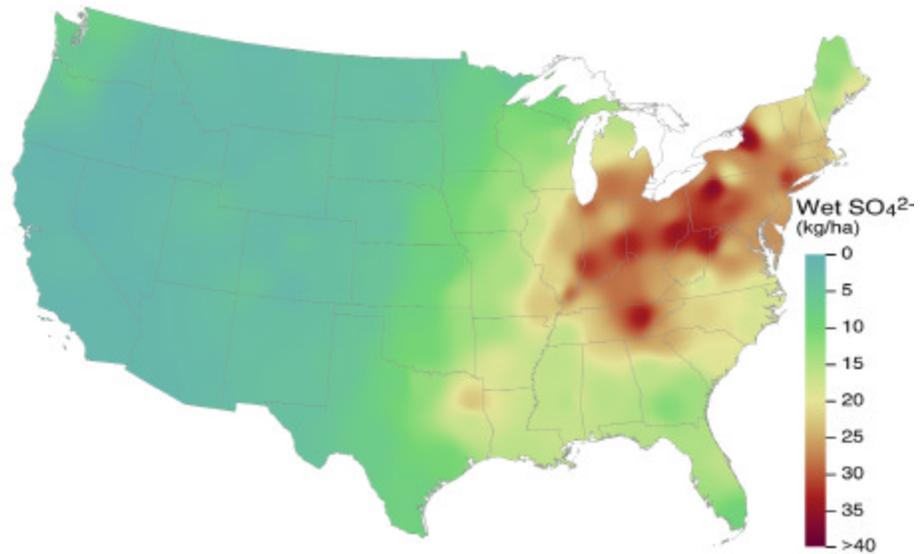
Notes:
1) Data is presented for the Eastern U.S. only because there are not enough CASTNet monitoring sites in the West to support this type of analysis.
2) Map colors represent relative concentrations and do not imply ecological or human health status.

Source: CASTNet

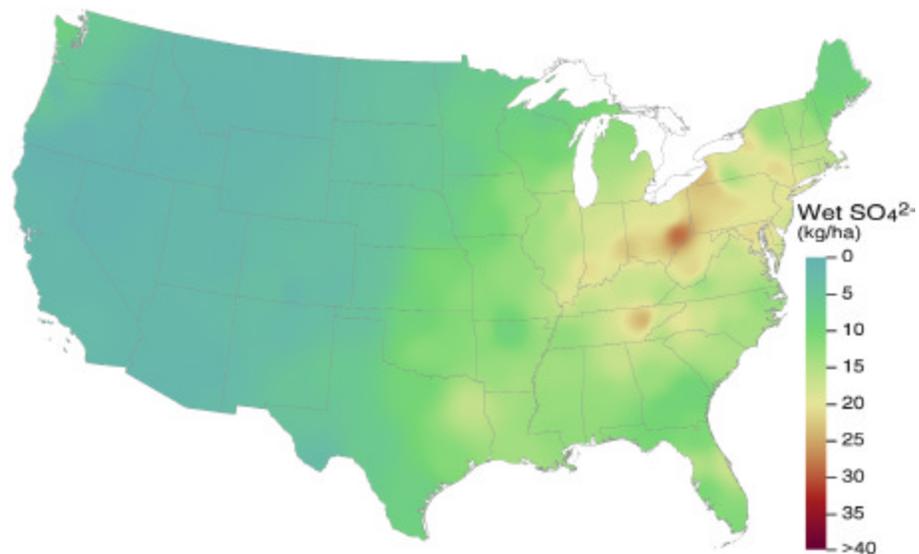
Figure 26.
Trends in Sul-
fur: Average
Yearly Wet Sul-
fate Deposition,
1989-91 vs.
1999-2001

*Wet sulfate
(SO₄²⁻) deposi-
tion has
decreased sub-
stantially
throughout the
Midwest and
Northeast since
1989-1991.*

Wet Sulfate Deposition
Average of 1989-1991



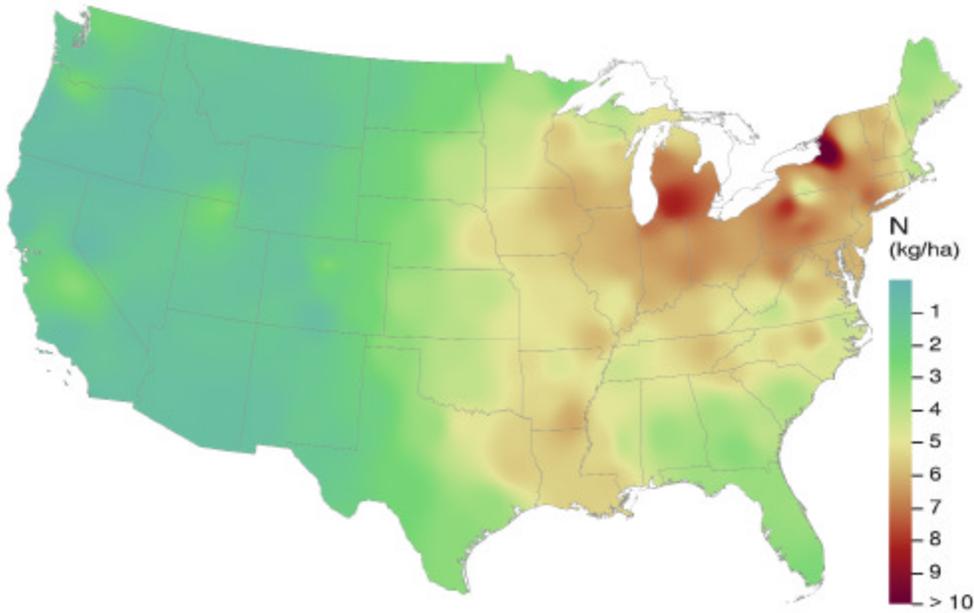
Wet Sulfate Deposition
Average of 1999-2001



Source: NADP

Note: Map colors represent relative concentrations and do not imply ecological or human health status.

**Wet Nitrogen Deposition
Average of 1989-1991**



**Wet Nitrogen Deposition
Average of 1999-2001**

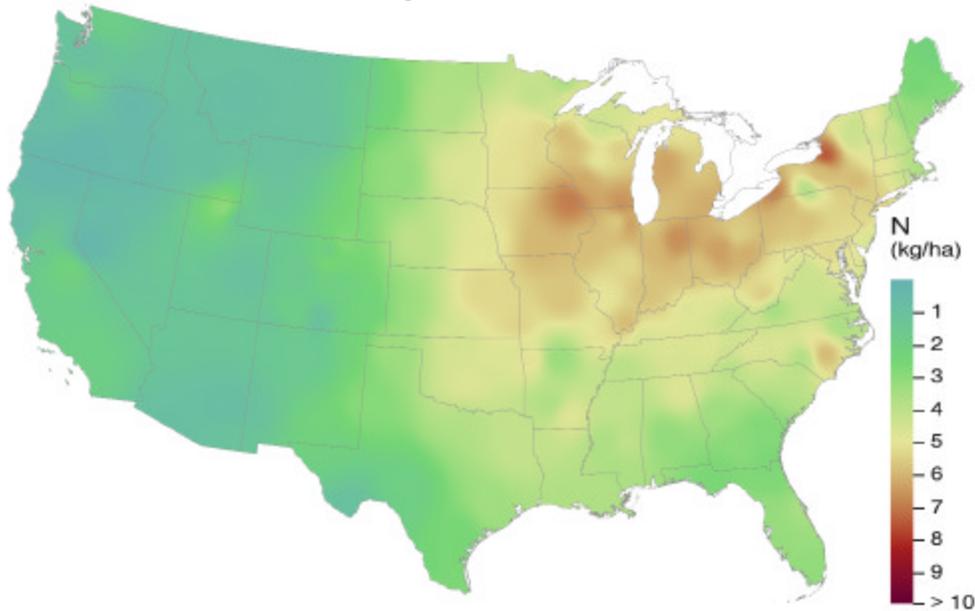


Figure 27.
Trends in Nitrogen: Average Yearly Wet Nitrogen Deposition and Nitric Acid Concentrations, 1989-91 vs. 1999-2001

Nitrogen (N) deposition decreased slightly in areas of the Eastern U.S. since 1990; increases occurred in areas with significant agricultural activity (e.g., the Plains and coastal North Carolina).

Source: NADP

Note: Map colors represent relative concentrations and do not imply ecological or human health status.

of the Ohio River Valley and Northeastern U.S. (see Figure 26). The greatest reductions have occurred in the mid-Appalachian region. Important reductions have also occurred in the Northeast, portions of the southern Appalachians, and the Midwest.

There have been no dramatic regional changes in wet nitrate deposition (see Figure 27). This reflects the fact that total nitrogen emissions from sources other than power plants (e.g., automobiles, trucks, non-road vehicles, and agricultural activities) have increased since 1990. Wet nitrate deposition has in fact increased up to 3 kg/ha in many areas since 1990. These increases occurred in the Plains and eastern North Carolina, where there is significant agricultural activity, and in southern California where motor vehicles are the predominant source of NO_x emissions.

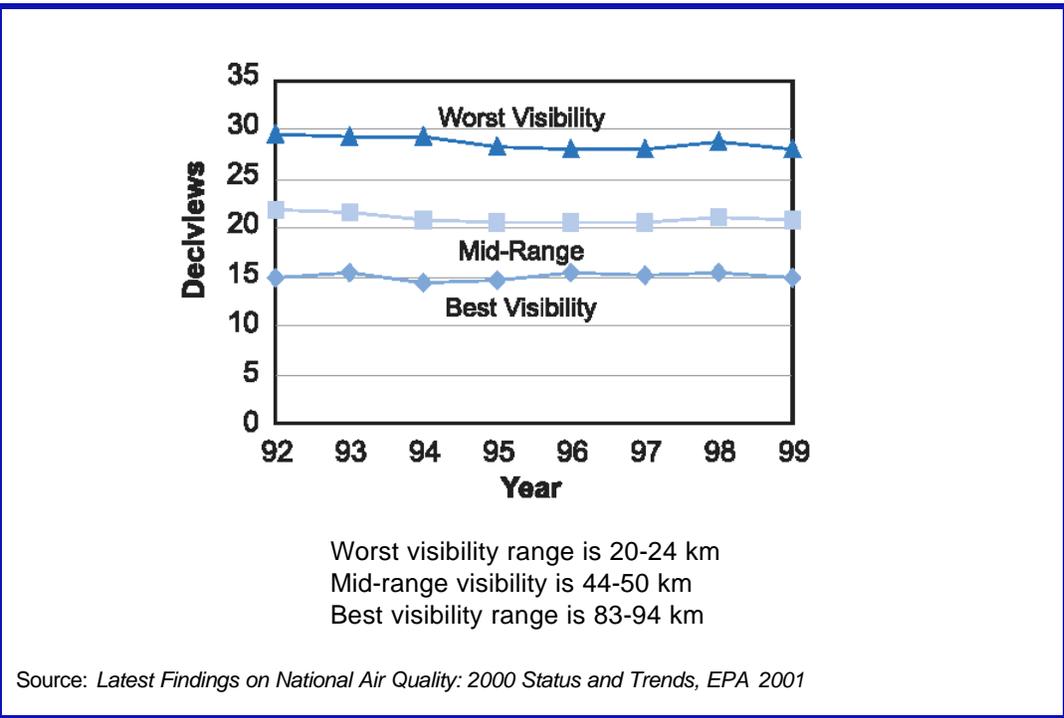
Visibility

In the atmosphere, SO₂ and NO_x gases are transformed into fine particles of sulfates and nitrates. Sulfate and nitrate particles scatter and absorb light, impairing visibility and contributing to haze. In the East, sulfate particles account for more than 50 percent of visibility impairment. The haziest days in the East reduce the visual range to 20-24 km (12-15 miles). The visual range under naturally-occurring conditions is 128-144 km (77-86 miles).

The Interagency Monitoring of PROtected Visual Environments (IMPROVE) network monitors visibility in the nation's national parks and wilderness areas. From 1992-1999, visibility in the ten eastern Class I area trend sites improved 1.5

Figure 28. Trends in Visibility in the Eastern U.S. Class 1 Areas

Although visibility has only improved slightly in the Eastern U.S. since the early 1990s, significant visibility benefits are expected when the Acid Rain Program is fully implemented.



deciviews since 1992 on the haziest days (see Figure 28). A deciview is a measure of human perception of visibility; an improvement of 1 deciview is a perceptible change. On typical days in the East, visibility improved 1 deciview since 1992. Visibility in the East is still significantly impaired in national parks and wilderness areas, especially on the haziest days. Further reductions in fine particle concentrations will be necessary to restore visibility to natural levels.

Human Health Benefits

SO₂ and NO_x emissions react in the atmosphere to form fine particles and ozone. These gases and fine particles are associated with a number of significant health effects in sensitive populations. High SO₂ concentrations can result in temporary breathing impairments in sensitive populations, including asthmatics and those who are active outdoors. A large number of epidemiological studies over the past 10-20 years show an association between ambient fine particle concentrations and health effects, such as increased numbers of hospital admissions and emergency room visits for heart and lung disease, increased incidences of respiratory disease and symptoms (such as asthma), decreased lung function, and even premature death. Children, the elderly, and individuals with existing cardiovascular or lung conditions, such as asthma, are especially vulnerable to the effects of particles. The Acid Rain Program has reduced the amount of fine particles in the air (see Figure 25) by lowering SO₂ and NO_x emissions, achieving significant human health benefits nationwide. It is expected that the Acid Rain Program will achieve further benefits as SO₂ emissions continue to decrease to the level of the cap.

NO_x emissions react with volatile organic compound gases in the atmosphere in the presence of sunlight to form ozone. The scientific literature shows associations between ozone and a number of effects on the respiratory system, including aggravation of asthma, increased susceptibility to respiratory illnesses like pneumonia and bronchitis, and permanent lung damage. Children, the elderly, people with existing respiratory problems, and those exercising or working outside during the ozone season are most vulnerable to the health effects of ozone. Additional health benefits have been achieved under the Acid Rain Program due to NO_x reductions that reduce ozone concentrations.

Ecological Effects of Reduced Acid Deposition

Freshwater

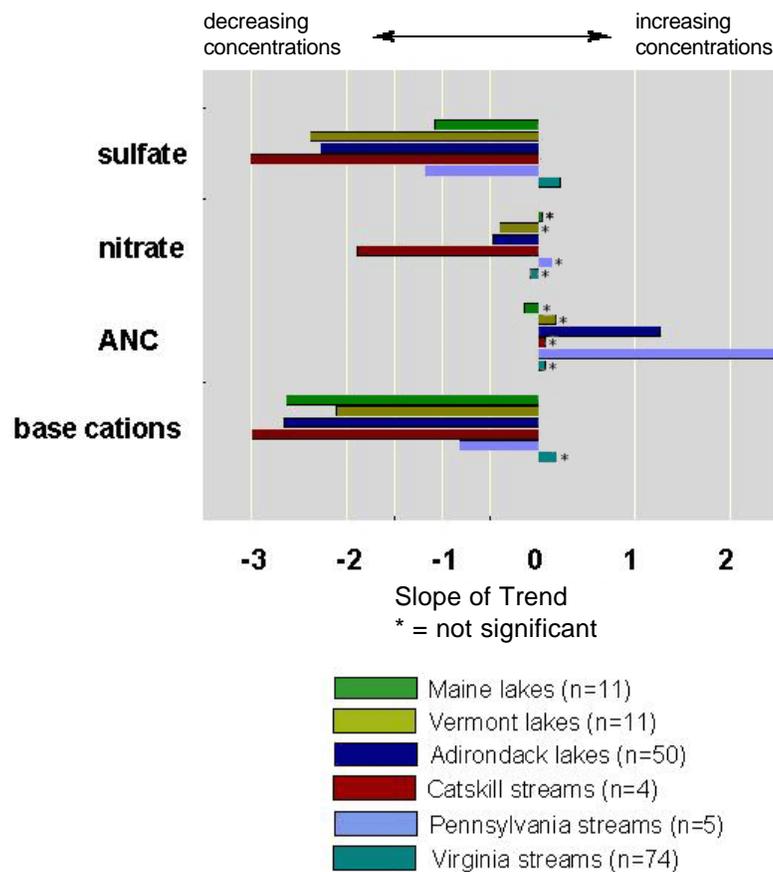
Acid deposition causes acidification of surface waters. In the 1980s, acid rain was found to be the dominant cause of acidification in 75% of the acidic lakes and 50% of acidic streams. Areas especially sensitive to acidification include portions of the Northeast (particularly Maine and the Adirondack and Catskill Mountains) and Southeastern streams. Some high elevation Western lakes, particularly in the Rocky Mountains, have become acidic, especially during snowmelt. However, although many Western lakes and streams are sensitive to acidification, they are not subject to continuously high levels of acid deposition and so have not become chronically acidified.

Whether surface waters can resist acidification depends on the ability of the water and watershed soil to neutralize the acid deposition it receives. This quality, called Acid Neutralizing Capacity (ANC), depends largely on the watershed's physical characteristics such as geology, soils, and size. Waters that are sensitive to acidification tend to be located in small watersheds that have few alkaline minerals and shallow soils. Conversely, watersheds that contain alkaline minerals, such as limestone, tend to have waters with a high ANC.

As acidity increases, aluminum leached from the soil flows into lakes and streams and can be toxic to aquatic species. The lower pH levels and higher aluminum levels that result from acidification can make it difficult for fish and other aquatic species to grow, reproduce, and survive. In some waters, the number of species of fish able to survive has been directly correlated to water acidity. Acidification can also decrease fish population density and individual fish size.

Figure 29 indicates that since the beginning of the Acid Rain Program, sulfate concentrations in lakes and streams have declined significantly in all monitored regions of the Eastern United States, except Virginia. The type of soils present in

Figure 29.
Trends in Acidity of Sensitive Waters, 1990-2000
In Pennsylvania and the Adirondacks, acid neutralizing capacity (ANC) has begun to increase, an indication of the beginning of recovery.



Source: *Recovery of Surface Water Chemistry in the Northern and Eastern U.S.: Effectiveness of the Clean Air Act Amendments of 1990, EPA/620/R-02/004*

Virginia make decreases in sulfate concentrations there unlikely for some time. Nitrate concentrations have decreased significantly in the Catskills, Adirondacks, and Vermont since 1990. Recovery, as shown by increasing Acid Neutralizing Capacity (ANC), is occurring, especially in the Adirondacks and Pennsylvania. In several regions, including the Adirondacks, recovery has begun in the past few years (circa 1995). However, levels of base cations, including calcium, magnesium, and potassium, are not increasing; in fact, they are decreasing. This reduction in base cation levels over the same period is believed to slow the onset of recovery. The sulfate reductions achieved by the Acid Rain Program are projected to spur the recovery of lakes and streams in the East.

In spite of declining sulfate concentrations, some lakes and streams have been slow to recover. Their recovery is slowed by continuing acid deposition, the presence of nitrate in surface waters, the loss of the soil's ability to neutralize excess acidity, the contribution of naturally occurring acid sources, and a lengthy lag time between deposition reduction and ecosystem recovery.

Full recovery of damaged watersheds will be a lengthy process, especially since acidic deposition is still occurring, albeit to a lesser extent. Although conditions would have been worse without the Acid Rain Program, full recovery of some surface waters requires additional reductions in sulfur and nitrogen emissions.

Forests

Acid deposition, especially combined with other pollutants and natural stresses, can also damage forest ecosystems. Sulfates and nitrates from acid deposition leach nutrients from forest soils, reducing the forest's capacity to buffer further acidification and removing elements essential for tree growth. Acidification also leads to the mobilization of naturally-occurring aluminum, which may interfere with the uptake of calcium by roots in forest soils. In addition, exposure to tropospheric ozone (a product of NO_x emissions) has direct toxic effects on plant leaves. The combined effects of depletion of soil nutrients, mobilization of aluminum, and exposure to ozone make trees more susceptible to drought, temperature extremes, and diseases.

There is currently less stress on forest ecosystems compared to what it would have been without the Acid Rain Program. The timeframe for full recovery, however, is uncertain. Leached nutrients must first be restored through weathering of the bedrock and soilwater aluminum concentrations must be reduced. Even after soil chemistry is restored, full recovery of sensitive forests is not expected to occur for decades because of the extensive recovery time of trees and the time required to re-establish forest floor ecosystems (soil biota, microbes, and roots).

Coastal Waters

The nitrogen component of acid deposition is a significant source of nitrogen to many estuaries and coastal waters in the Eastern U.S. Excessive nitrogen loads from a variety of sources, including atmospheric deposition, causes many of

those estuaries and coastal waters to periodically become eutrophic. Eutrophic conditions include algal blooms (some of which may be harmful) and low levels of dissolved oxygen in the water (hypoxia or anoxia) which can stress or kill fish and shellfish.

The Acid Rain Program has reduced nitrogen deposition in some places compared to what it would have been without Title IV (see Figure 27). However, in many sensitive coastal waters there has been little or no reduction in nitrogen deposition since 1990. Additional reductions from the power generation sector, as well as reductions from other atmospheric sources of nitrogen, such as automobiles and trucks, and other land-based sources such as septic systems and urban runoff, may be needed before coastal waters can recover from eutrophication.

Materials and Structures

SO₂, NO_x, and many of the pollutants they form can also corrode materials, particularly those made of limestone or marble. Monuments and historic buildings, outdoor structures such as bridges and buildings, and automotive paints and finishes are all susceptible to damage by acidic pollutants. Studies have shown that air pollution has been responsible for more deterioration of carbonate buildings and statues than other weathering processes. Structures made of limestone and marble are particularly sensitive to acidic deposition. Most damage appears to come from dry deposition. However, in rural areas and in areas where buildings and monuments remain wet for long periods of time, wet deposition can be a significant or primary cause of damage.

Weathering due to acid deposition may harm cultural assets (e.g., statues and monuments) more than purely operational resources (e.g., bridges and buildings). This is because the appearance of cultural resources, where much of their value lies, is particularly vulnerable to damage. There are also historic and emotional values attached to cultural assets, which increase the value of their preservation. The Acid Rain Program has reduced the risk of damage to sensitive buildings and materials by reducing the amount of SO₂ and NO_x emitted into the atmosphere and the amount of dry sulfur deposition reaching sensitive structures. Therefore, on-going monetary costs and cultural losses due to acid gases, particles, and deposition are also expected to be declining under Title IV.

Summary

The Acid Rain Program continued to be successful in substantially reducing emissions of SO₂ and NO_x from electric power plants during the second year of Phase II. Sources continue to close in on the goal of reducing power plant SO₂ emissions from 1980 levels by 50% (8.5 million tons) in 2010 as required by the 1990 Clean Air Act. Sources have also exceeded the goal of a two million ton reduction in NO_x emissions from projected 2000 levels as required by the 1990 Clean Air Act.

Sources in both the more conventional NO_x program and the cap and trade approach for SO₂ have demonstrated a high level of compliance and their efforts have achieved measurable environmental results. The flexibility for sources inherent in the cap and trade approach has been successful at reducing compliance costs and has not resulted in any significant geographic shifts in SO₂ emissions.

The Acid Rain Program has:

Established and maintained a robust infrastructure to ensure compliance with the program and expanded our ability to assess its environmental benefits, including:

- ◆ A sound compliance tracking system;
- ◆ A high quality emissions monitoring system at every source;
- ◆ An expanded national dry deposition monitoring network to complement the nationwide wet deposition monitoring network.

Reduced emissions of SO₂ and NO_x substantially from the power generation sector at a significantly lower cost than expected:

- ◆ In 2001, SO₂ emissions were 10.6 million tons, 33% lower than 1990 emissions and 5% lower than 2000 emissions.
- ◆ In 2001, NO_x emissions were 4.10 million tons, 25% lower than 1990 emissions and 8% lower than 2000 emissions.

Contributed to measurable improvements in air quality, reductions in deposition, and recovery of acid-sensitive waters:

- ◆ SO₂ concentrations in the atmosphere (a precursor to fine particles and acid deposition) have decreased since 1990. In 2001, concentrations in the Northeast and Mid-Atlantic were 8-12 ug/m³, as much as 8 ug/m³ lower than in 1990.
- ◆ Sulfate concentrations in the atmosphere (a major component of fine particles, especially in the East) have decreased since 1990. In 2001, concentrations in most of the East were 2-3 ug/m³, as much as 3 ug/m³ lower than in 1990.

- ◆ Wet sulfate deposition, a major component of acid rain, has also decreased since 1990. In 2001, deposition in the Northeast and Midwest was 20-30 kg/ha/yr, as much as 12 kg/ha/yr lower than it was in 1990.
- ◆ Wet nitrate deposition has not decreased regionally because of the relatively small NO_x reduction from power plants and the large contribution from other sources of NO_x.
- ◆ Visibility has improved in the Eastern U.S.
- ◆ Acid neutralizing capacity, a major indicator of recovery in acidified lakes and streams, is beginning to rise in streams in the Northeast, including the Adirondacks. This is an indicator that recovery from acidification is beginning in those areas.
- ◆ Reductions in fine particles due to reductions in emissions of SO₂ and NO_x are expected to continue to benefit human health by reducing the incidence of respiratory and cardiovascular illnesses.

For more information on the EPA Acid Rain Program, visit our website at <http://www.epa.gov/airmarkets>. For additional detailed emissions data see <http://www.epa.gov/airmarkets/emissions/index>.

For Further Information

The following publications are suggested as a starting point for those who want additional information on any of the topics discussed in this Progress Report. Additional information on emissions, air quality and deposition trends can be found at <http://www.epa.gov/airtrends> and <http://www.epa.gov/castnet>. Additional published scientific literature on emissions trading, acid rain, and benefits assessments can be found at <http://www.epa.gov/airmarkets/articles/index>.

Emissions and Air Quality

A Ten-Year Spatial and Temporal Trend of Sulfate Across the United States, Malm, Schichtel, Ames and Gebhart, *Journal of Geophysical Research-Atmospheres*, *in press*

Latest Findings on National Air Quality: 2000 Status and Trends, EPA 2001
EPA 454/K-02-001

National Air Quality and Emissions Trends Report, 1999
EPA 454/R-01-004

Environmental Effects of Acid Rain

Acidic Deposition in the Northeastern United States, *BioScience* 51(3):180-198, 2001

National Acid Precipitation Assessment Program Biennial Report to Congress: an Integrated Assessment, National Science and Technology Council Committee on Environment and Natural Resources, 1998

Recovery of Surface Water Chemistry in the Northern and Eastern U.S.: Effectiveness of the Clean Air Act Amendments of 1990, Stoddard, J. L., J. S. Kahl, F. A. Deviney, D. R. DeWalle, D. C.T., A. T. Herlihy, J. H. Kellogg, P. S. Murdoch, J. R. Webb, and K. E. Webster, *in press*

Health Benefits Assessment

Reanalysis of the Harvard Six Cities Study and the American Cancer Society Study of Particulate Air Pollution and Mortality; Health Effects Institute, 2000

Air Quality Criteria for Particulate Matter, volumes I-III, EPA 1996
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EPA 430-R-95-010

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