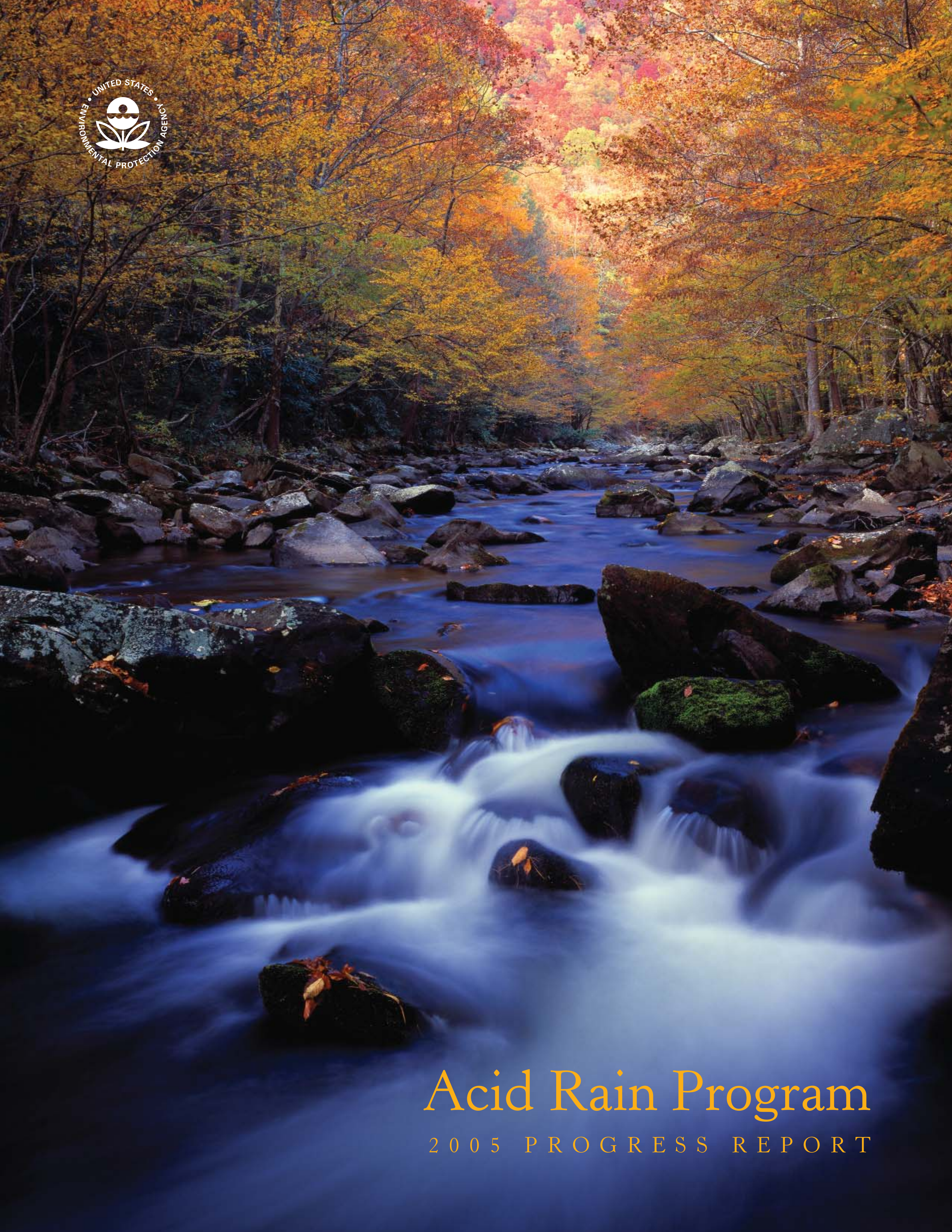
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY



Acid Rain Program

2005 PROGRESS REPORT

Acid Rain Program
2005 Progress Report

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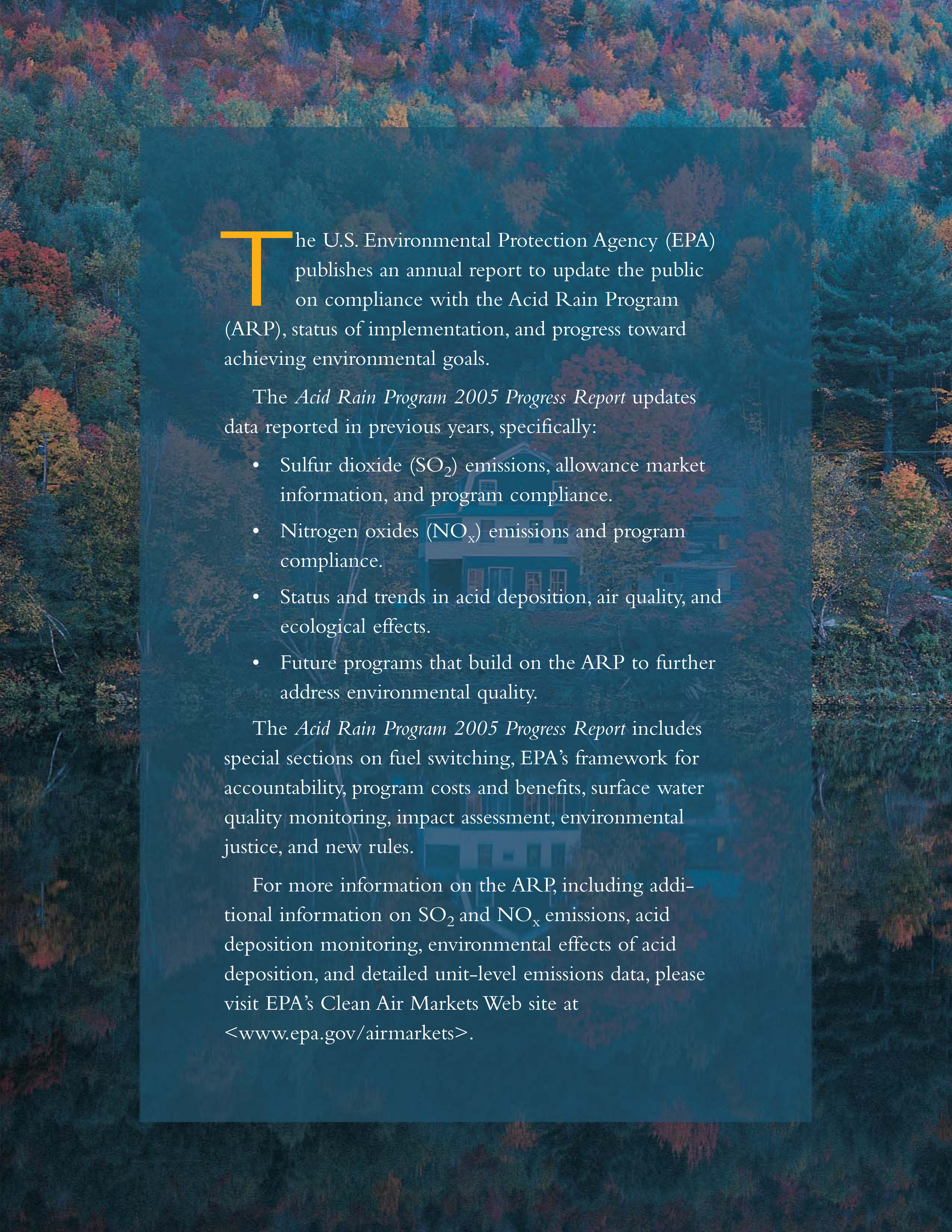
EPA-430-R-06-015
Clean Air Markets Division
Office of Air and Radiation
U.S. Environmental Protection Agency
October 2006



The U.S. Environmental Protection Agency (EPA) publishes an annual report to update the public on compliance with the Acid Rain Program (ARP), status of implementation, and progress toward achieving environmental goals.

The *Acid Rain Program 2005 Progress Report* updates data reported in previous years, specifically:

- Sulfur dioxide (SO_2) emissions, allowance market information, and program compliance.
- Nitrogen oxides (NO_x) emissions and program compliance.
- Status and trends in acid deposition, air quality, and ecological effects.
- Future programs that build on the ARP to further address environmental quality.

The *Acid Rain Program 2005 Progress Report* includes special sections on fuel switching, EPA's framework for accountability, program costs and benefits, surface water quality monitoring, impact assessment, environmental justice, and new rules.

For more information on the ARP, including additional information on SO_2 and NO_x emissions, acid deposition monitoring, environmental effects of acid deposition, and detailed unit-level emissions data, please visit EPA's Clean Air Markets Web site at <www.epa.gov/airmarkets>.

Summary

Sulfur dioxide (SO_2) and nitrogen oxides (NO_x) are the key pollutants in the formation of acid rain. These pollutants also contribute to the formation of fine particles (sulfates and nitrates) that are associated with significant human health effects and regional haze. Nitrates are transported and deposited at levels harmful to sensitive ecosystems in many areas of the country. Additionally, NO_x combines with volatile organic compounds (VOCs) to form ground-level ozone (smog). The U.S. electric power industry accounts for approximately 67 percent of total U.S. SO_2 emissions and 22 percent of total U.S. NO_x emissions from man-made sources.[1]

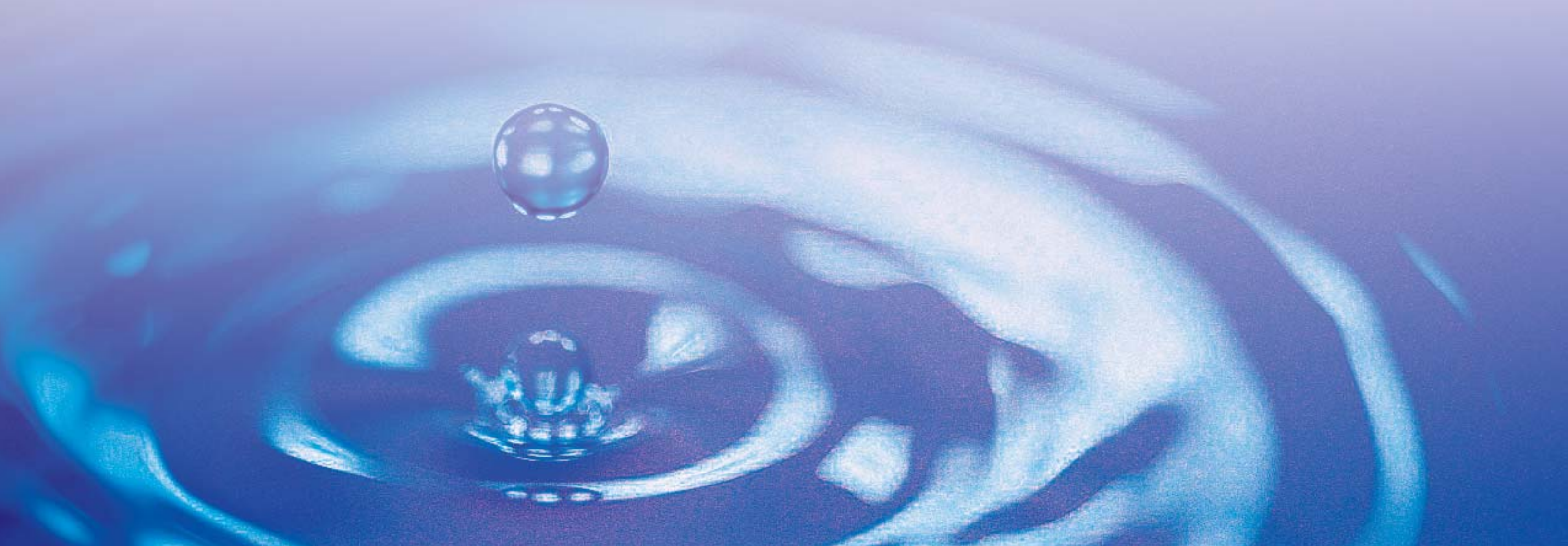
The Acid Rain Program (ARP) was created under Title IV of the 1990 Clean Air Act Amendments to reduce the adverse effects of acid deposition through reductions in annual emissions of SO_2 and NO_x. The act calls for SO_2 reductions of 10 million tons from 1980 emission levels, largely achieved through a market-based cap and trade program, which utilizes emission caps to permanently limit the level of SO_2 emissions from power plants. NO_x reductions are achieved through a program closer to a more traditional, rate-based regulatory system. The NO_x program is designed to achieve a 2 million ton reduction from what NO_x emission levels were projected to be in the year 2000 without implementation of Title IV.

Since the start of the ARP in 1995, reductions in SO_2 and NO_x emissions from the power sector have contributed to significant air quality and environmental and human health improvements.

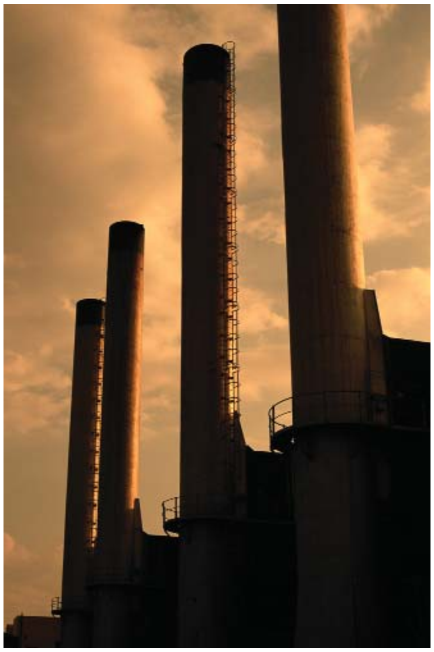
The SO_2 program affected 3,456 operating electric generating units in 2005 (with most emissions produced by about 1,100 coal-fired units). The NO_x program applied to a subset of 982 operating coal-fired units in 2005.

The 2005 compliance year marked the eleventh year of the program. During this period, the ARP has:

- Reduced SO_2 emissions by more than 5.5 million tons from 1990 levels, or about 35 percent of total power sector emissions. Compared to 1980 levels, SO_2 emissions from power plants have dropped by more than 7 million tons, or about 41 percent.
- Cut NO_x emissions by about 3 million tons from 1990 levels, so that emissions in 2005 were less than half the level anticipated without the program. Other efforts, such as the NO_x Budget Trading Program in the eastern United States, also contributed significantly to this reduction.



- Led to significant reductions in acid deposition. For example, between the 1989–1991 observation period and the 2003–2005 observation period, wet sulfate deposition decreased 36 percent in the Northeast and 32 percent in the Midwest. These decreases have resulted in positive changes in environmental indicators, including improved water quality in lakes and streams.
- Provided the most complete and accurate emissions data ever developed and made those data available and accessible through comprehensive electronic data reporting and Web-based tools for agencies, researchers, affected sources, and the public.
- Delivered pioneering e-government results, automating administrative processes, reducing paper use, and providing online systems for doing business with EPA.
- Achieved extremely high compliance levels. No units operating in the ARP during 2005 were found out of compliance with the allowance holding requirements.
- Reduced implementation costs by allowing sources to choose cost-effective compliance strategies.



After 11 years of implementation, monitoring, and assessment, the ARP has proven to be an effective and efficient means of meeting emission reduction goals under the Clean Air Act. A 2005 study[2] estimated the program's benefits at $122 billion annually in 2010, while cost estimates are around $3 billion annually (in 2000$). Despite the program's historic and projected benefits, however, EPA analyses of recent studies of human health, data from long-term monitoring networks, and ecological assessments have revealed the need for additional emission reductions to protect human health and continue ecological recovery and protection. EPA recognized the need for further SO_2 and NO_x controls on the power industry to address transport problems many states face in efforts to attain National Ambient Air Quality Standards (NAAQS) for ozone and fine particles. The success of the ARP and NO_x control programs, along with the need for further reductions, provided the impetus for a suite of new rules promulgated in 2005: the Clean Air Interstate Rule (CAIR), the Clean Air Visibility Rule (CAVR), and the Clean Air Mercury Rule (CAMR).

Building on the ARP model, EPA promulgated CAIR in March 2005 to address transport of fine particles and ozone in the eastern United States; CAVR to improve visibility in national parks and wilderness areas; and CAMR to reduce nationwide mercury emissions from coal-fired power plants. Starting in 2009 and 2010, CAIR establishes regional caps on SO_2 and NO_x emissions for affected eastern states. Annual SO_2 emissions are capped at 3.7 million tons in 2010 and 2.6 million tons in 2015. Annual NO_x emissions are capped at 1.5 million tons in 2009 and 1.3 million tons in 2015. CAIR will operate concurrently with the ARP.

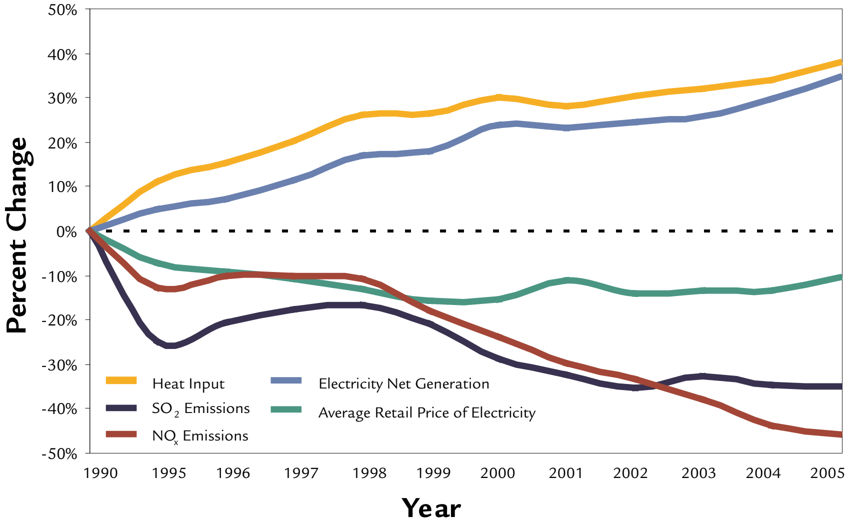
CAVR addresses SO_2 and NO_x emissions from non-CAIR states located in the West and parts of New England. Affected sources under CAVR must reduce SO_2 and NO_x emissions impairing visibility in national parks and wilderness areas. Notably, EPA has proposed to allow power plants and other stationary sources to establish regional cap and trade programs to accomplish these reductions.

CAMR establishes a national cap on mercury emissions beginning in 2010 and utilizes a market-based cap and trade program. Additionally, new and existing coal-fired power plants—the nation's largest sources of mercury emissions—will be required to meet standards of performance that limit mercury emissions. These programs will serve as a key component of strategies to protect human health and the environment across the United States into the next decade.

Origins of the Acid Rain Program

Acid deposition, more commonly known as acid rain, occurs when emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO_x) react with water, oxygen, and oxidants in the atmosphere to form various acidic compounds. Prevailing winds transport these compounds hundreds of miles, often across state and national borders, where they impair air quality and damage public health, acidify lakes and streams, harm sensitive forests and coastal ecosystems, degrade visibility, and accelerate the decay of building materials.

Figure 1: Trends in Electricity Generation,* Fossil Energy Use, Prices, and Emissions from the Electric Power Industry**



* Generation from fossil fuel-fired plants.

** Constant year 2000 dollars adjusted for inflation.

Source: Energy Information Administration, Annual Energy Review, 2005 (electricity generation, retail price); EPA (heat input, emissions), 2005

The Acid Rain Program (ARP), established under Title IV of the 1990 Clean Air Act Amendments, requires major reductions of SO_2 and NO_x emissions from the electric power industry. The SO_2 program sets a permanent cap on the total amount of SO_2 that may be emitted by electric generating units in the contiguous United States. The program is phased in, with the final 2010 SO_2 cap set at 8.95 million tons, a level of about one-half of the emissions from the power sector in 1980.

As seen in Figure 1, emissions of both SO_2 and NO_x have dropped markedly under the ARP while combustion of fossil fuel, measured as "heat input," for electricity generation has increased significantly.

Using a market-based cap and trade mechanism to reduce SO_2 emissions allows flexibility for individual combustion units to select their own methods of compliance. Currently, one allowance provides a regulated unit limited authorization to emit one ton of SO_2. The Clean Air Act allocates allowances to regulated units based on historic fuel consumption and specific emission rates prior to the start of the program. The total allowances allocated for each year equal the SO_2 emission cap. The program encourages early reductions by allowing sources to bank unused allowances in one year and use them in a later year.

The ARP has closer to a traditional approach to achieve NO_x emission reductions. Rate-based limits apply to most of the coal-fired electric utility boilers subject to the ARP.

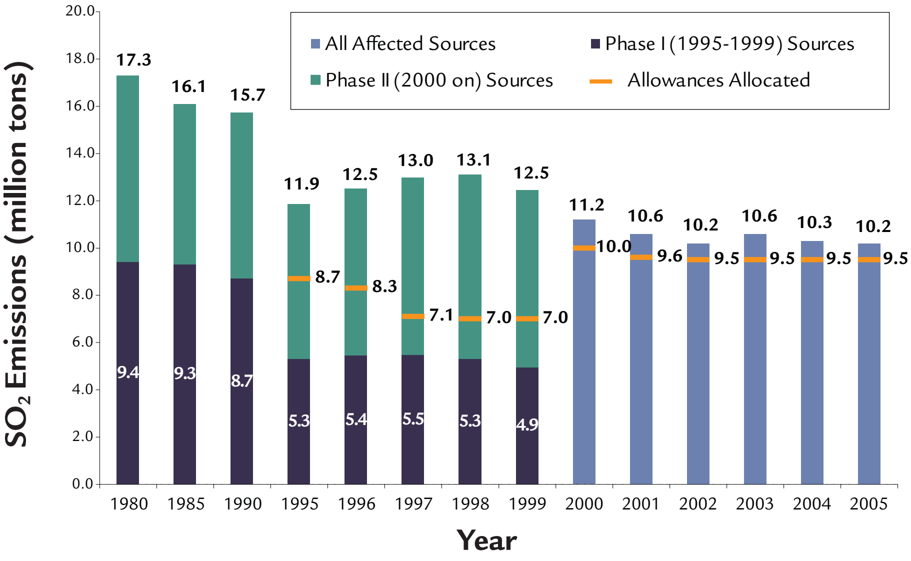
The ARP is composed of two phases for SO_2 and NO_x. Phase I applied primarily to the largest coal-fired electric generation sources from 1995 through 1999 for SO_2 and from 1996 through 1999 for NO_x. Phase II for both pollutants began in 2000. In 2005, the SO_2 Phase II requirements applied to 3,456 operating units; the Phase II NO_x requirements applied to 982 of those operating units that are $\geq$25 megawatts and burned coal between 1990 and 1995.

SO_2 Emission Reductions

Electric power generation is by far the largest single source of SO_2 emissions in the United States, accounting for approximately 67 percent of total SO_2 emissions nationwide.[3]

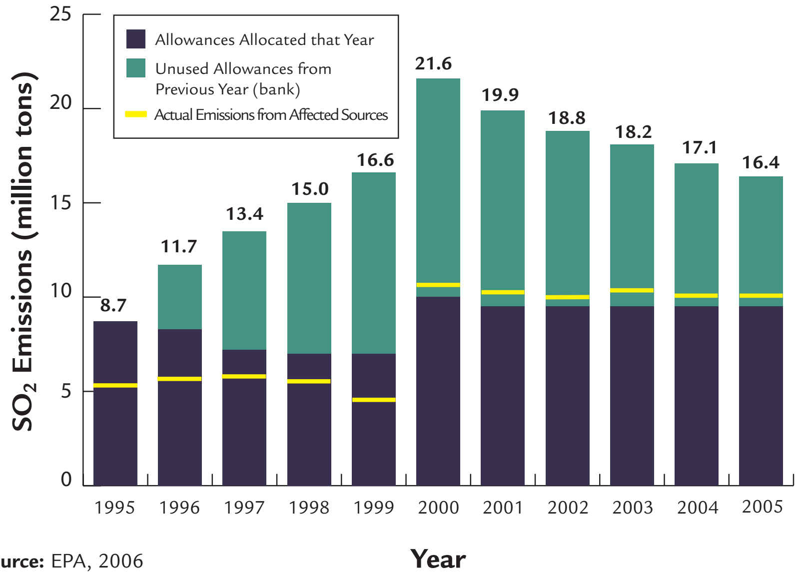
As shown in Figure 2, Acid Rain Program (ARP) sources have reduced annual SO_2 emissions by 41 percent compared to 1980 levels and 35 percent compared to 1990 levels. Reductions in SO_2 emissions from other sources not affected by the ARP (including industrial and commercial boilers and the metals and

Figure 2: SO_2 Emissions from Acid Rain Program Sources



Source: EPA, 2006

Figure 3: SO_2 Emissions and the Allowance Bank, 1995-2005



Source: EPA, 2006

SO_2 Emission Reductions from Acid Rain Program Sources: Cost-Effective Progress

- ✧ In 1995, the first year of implementation, SO_2 emissions decreased by 24 percent—nearly 4 million tons—from 1990 levels.
- ✧ During the past decade, SO_2 emissions dropped an additional 14 percent from 1995 levels despite a 24 percent increase in power generation (based on heat input).
- ✧ In 2005, SO_2 emissions from all ARP units totaled 10.2 million tons, a 35 percent decrease from 1990 levels (15.7 million tons).
- ✧ Until SO_2 allowance prices began to increase in 2004 in anticipation of EPA's 2005 Clean Air Interstate Rule (CAIR), prices generally remained under $200/ton, well below expected control costs for the program.

refining industries) and use of cleaner fuels in residential and commercial burners have contributed to a similar overall decline (42 percent) in annual SO_2 emissions from all sources since 1980. National SO_2 emissions have fallen from 25.9 million tons in 1980 to an estimated 15 million tons in 2005 (see <www.epa.gov/airtrends>).

For 2005, EPA allocated approximately 9.5 million SO_2 allowances under the ARP. Together with more than 6.8 million unused allowances carried over (or banked) from prior years, there were nearly 16.4 million allowances available for use in 2005. Sources emitted 10.2 million tons of SO_2 in 2005, somewhat more than the allowances allocated for the year, but far less than the total allowances available (see Figure 3).[4]

The number of banked allowances dropped from 6.8 million available for 2005 compliance to 6.2 million available for 2006 and future years, a 10 percent reduction of the total bank. In the next several years, industry anticipation of stringent emission requirements under the Clean Air Interstate Rule (CAIR) is expected to encourage sources to pursue additional reductions. While these reductions will result in an increase in banked allowances, tighter retirement ratios under CAIR will lead to depletion of the bank and further emission reductions. In 2010, the total number of Title IV allowances allocated annually drops to 8.95 million (about half of the emissions from the power industry in 1980) and remains statutorily fixed at that annual level permanently. Table 1 explains in more detail the origin of the allowances that were available for use in 2005, and Table 2 on page 7 shows how those allowances were used.

The states with the highest emitting sources in 1990 have seen the greatest SO_2 reductions during the ARP (see Figure 4). Most of these states are upwind of the areas the ARP was designed to protect, and reductions have resulted in important environmental and health benefits over a large regional scale. In addition, the states that reduced emissions from 1990 to 2005 had total annual reductions of approximately 6 million tons, while the states that increased emissions—largely attributable to growth and not increases in emission rates—had much smaller annual increases of approximately

Table 1: Origin of 2005 Allowances

Type of Allowance Allocation	Number of SO_2 Allowances	Explanation of Allowance Allocation Type
Initial Allocation	9,191,897	Initial allocation is the number of allowances granted to units* based on the product of their historic utilization and emission rates specified in the Clean Air Act.
Allowance Auction	250,000	The allowance auction provides allowances to the market that were set aside in a Special Allowance Reserve when the initial allowance allocation was made.
Opt-in Allowances	97,678	Opt-in allowances are provided to units entering the program voluntarily. There were eight opt-in units in 2005.
Total 2005 Allocation	9,539,575	
Total Banked Allowances**	6,845,477	Banked allowances are those allowances accrued in accounts from previous years, which can be used for compliance in 2005 or any future year.
Total 2005 Allowable Emissions	16,385,052	

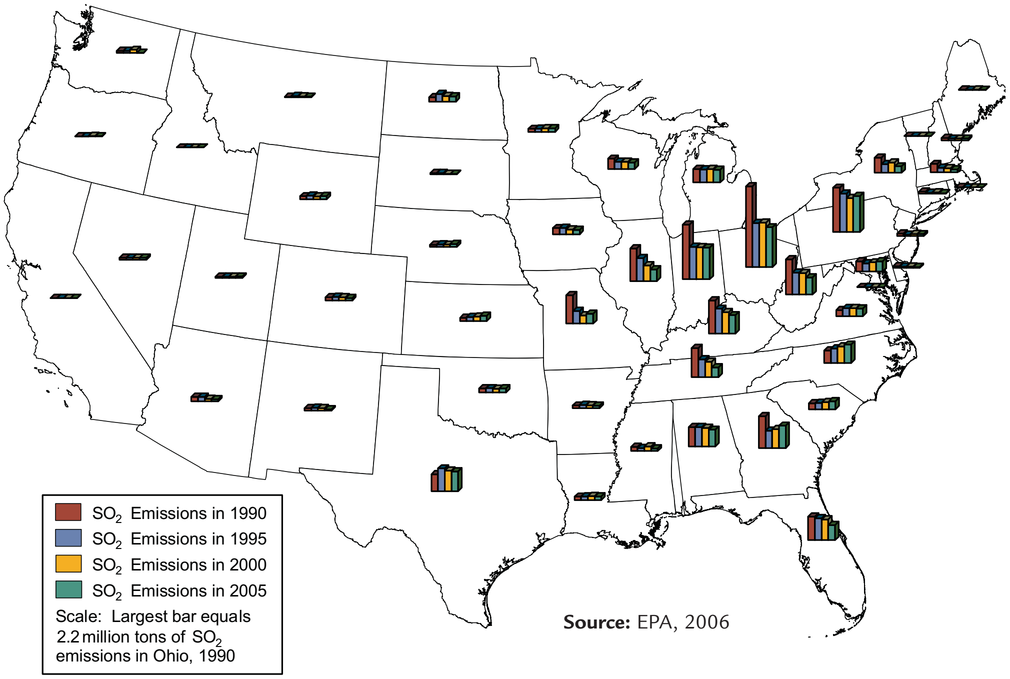
Source: EPA, 2006

*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 SO_2 emissions under the program result from coal-fired generation units, but oil and natural gas units are also included in the program.

**Total banked allowances are adjusted from the 2004 *Progress Report* to account for additional deductions made for electronic data reporting (EDR) resubmissions after 2004 reconciliation was completed.

470,000 tons. For 32 states and the District of Columbia, annual SO_2 emissions in 2005 were lower than 1990 emissions. Among these states, 13 decreased their annual emissions by more than 100,000 tons between 1990 and 2005: Florida, Georgia, Illinois, Indiana, Kentucky, Massachusetts, Missouri, New York, Ohio, Pennsylvania, Tennessee, West Virginia, and Wisconsin. The states with the greatest annual reductions were in the Midwest and include Ohio (1.1 million tons reduced), Illinois, Indiana, Missouri, Tennessee, and West Virginia, each of which reduced over 500,000 tons per year.

Figure 4: State-by-State SO_2 Emission Levels, 1990–2005



Source: EPA, 2006

SO_2 Program Compliance

Approximately 10.2 million allowances were deducted from sources' accounts in 2005 to cover emissions. Table 2 displays these allowance deductions, as well as the remaining banked allowances from 1995 through 2005. In 2005, all Acid Rain Program (ARP) units were in compliance with the allowance holding requirements and no excess emissions penalties were paid.[5] Title IV set a penalty of $2,000 per ton in 1990, which is adjusted annually for inflation. The 2005 penalty level was set at $3,042 per excess ton, but no penalties were levied. The ARP's cap and trade approach offers emission sources the flexibility to comply with regulations using their choice of the most cost-effective strategies available. Since the program's inception, the compliance rate has consistently been extraordinarily high.

Table 2: SO_2 Allowance Reconciliation Summary, 2005

TOTAL HELD ON MARCH 1, 2006*	16,385,052
Unit Accounts Subject to Reconciliation	13,102,070
Other Accounts**	3,282,982
TOTAL DEDUCTIONS	10,222,847
Emissions***	10,222,847
Penalties (2006 Vintage)	0
TOTAL BANKED	6,162,205
Unit Accounts Subject to Reconciliation	2,879,223
Other Accounts	3,282,982

Source: EPA, 2006

* March 1, 2006, is the allowance transfer deadline, the point in time at which unit accounts were frozen and after which no transfers of 1995 through 2005 allowances were recorded. The freeze on these accounts was removed when annual reconciliation was complete.

** Other accounts include general accounts and unit accounts that are not subject to reconciliation. General accounts can be established in the Allowance Tracking System (ATS) by any utility, individual, or other organization.

*** Includes 310 allowances deducted from opt-in sources for reduced utilization.

SO_2 Allowance Market

The allowance trading mechanism enables Acid Rain Program (ARP) sources to pursue a variety of compliance options, while the cap on SO_2 emissions ensures that reductions are achieved and maintained over time. Some sources have opted to reduce their SO_2 emissions below the level of their allowance allocation in order to bank their allowances for use in future years or to sell them. 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 allowance prices ultimately reflect these flexible compliance decisions. Economists refer to this as the marginal cost of compliance—the cost of reducing the next ton of SO_2 emitted from the power sector.

The cost of emission allowances was initially projected to be between \$250 and \$500 per ton during Phase I (1995 to 1999) and \$500 to \$1,000 per ton in Phase II (beyond 2000). As shown in Figure 5, actual allowance prices were in the \$100 to \$200 range, with a low of \$65 in 1996. Even as the more stringent Phase II requirements became effective in 2000, prices were generally below the \$200 per allowance mark until they started to rise at the end of 2003. Market observers believe that the lower than expected prices early in the program were due primarily to reduced compliance costs. The availability of low-cost, low-sulfur coal resulted in larger than expected emission reductions, which increased the supply of allowances and put downward pressure on the market. In addition, technological innovation reduced the expected marginal costs of scrubbers by over 40 percent from original estimates. These cost and emission reductions led to a large bank of allowances from Phase I that were available for compliance in Phase II, contributing to the lower than anticipated prices.

In 2004, the market started to react to the likelihood of future emission reduction requirements that went beyond the existing caps of the ARP. The price of SO_2 allowances continued to rise during 2005, ending the year at about \$1,550 after beginning the year at about \$700. Market observers believe this price run-up occurred due to initial uncertainty as EPA finalized the Clean Air Interstate Rule (CAIR). CAIR requires further SO_2 reductions from sources in many eastern states beginning in 2010. These additional reductions cause an increase in the expected marginal cost of compliance in future years. Because allowances are bankable today for use in future years, estimates of future control costs impact the current market price of allowances. However, an apparent overly conservative reaction by buyers, who wanted assurance that they could cover current and future allowance needs, caused market prices to exceed EPA's estimate of future control costs. In the first half of 2006, however, allowance prices have fallen sharply, and were just over \$600 per ton at the end of June 2006. This price level is more consistent with where EPA has expected allowances to be today, given estimates of the marginal cost of reducing SO_2 emissions under CAIR. EPA has seen temporary run-ups in the allowance markets before, with appropriate downward adjustments as buyers and sellers more completely assess market fundamentals. For instance, at the beginning of compliance with the NO_x Budget Program, EPA observed a similar pattern of market run-up followed by a self-correction.

In fact, current SO_2 allowance market conditions (as of September 2006) track closely with EPA's estimates. The current SO_2 allowance market has factored the costs of compliance with the new suite of regulatory programs into its pricing decisions. As can be seen in Figure 6, EPA has projected that pre-2010 vintage allowances would be worth $721 per allowance in 2010, and that 2010–2014 vintage allowances would be worth approximately $360 per allowance due to the 2:1 retirement ratio that applies to those vintage allowances for sources in the CAIR region.

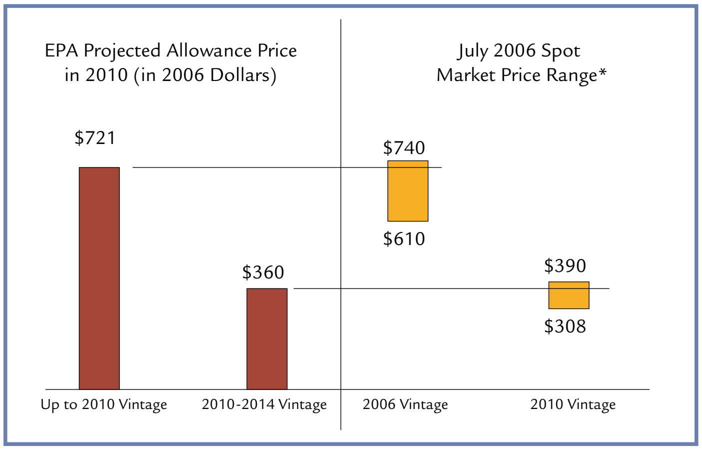
July 2006 spot market prices show that prices for the earlier vintage are trading for $610 to $740 per ton, and the later vintages (2010–2014) are trading for $308 to $390 per ton.

In 2005, nearly 5,700 private allowance transfers (moving roughly 19.9 million allowances of past, current, and future vintages) were recorded in the EPA Allowance Tracking System (ATS). About 10 million (50 percent) were transferred in economically significant transactions (i.e., between economically unrelated parties). Transfers between economically unrelated parties are a better indicator of a vibrant market than are transactions among the various units of a given company. In the majority of these transfers, allowances were acquired by power companies. Figure 7 shows the annual volume of SO_2 allowances transferred under the ARP (excluding allocations, retirements, and other transfers by EPA) since official recording of transfers began in 1994.

Figure 5: SO_2 Allowance Prices for Current Vintage

Source: Cantor Fitzgerald Market Price Index, 2006

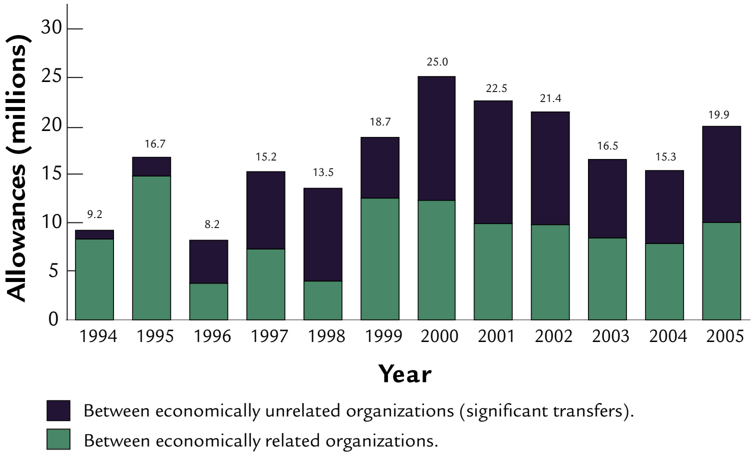
Figure 6: Actual and Forecast Allowance Prices



* EPA analysis suggests that 2006 vintage allowances should be selling for about $600 per allowance and 2010 allowances should be about $300 per allowance.

Source: EPA, 2006, and Evolution Markets, LLC, 2006

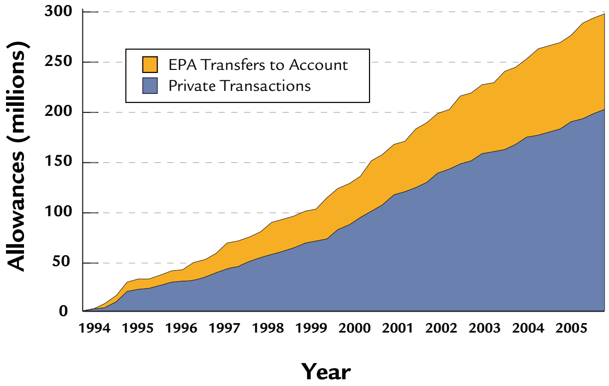
Figure 7: SO_2 Allowances Transferred under the Acid Rain Program



Source: EPA, 2006

Figure 8 shows the cumulative volume of SO_2 allowances transferred under the ARP. The figure differentiates between allowances transferred in private transactions and those annually allocated and transferred to sources' accounts by EPA. Private transactions are indicative of both market interest and use of allowances as a compliance strategy. Of the nearly 300 million allowances transferred since 1994, about 63 percent were traded in private transactions. In December 2001, parties began to use a system developed by EPA to allow online allowance transfers. In 2005, account holders registered about 98 percent of all private allowance transfers through EPA's online transfer system.[6]

Figure 8: Cumulative SO_2 Allowances Transferred through 2005



Source: EPA, 2006.

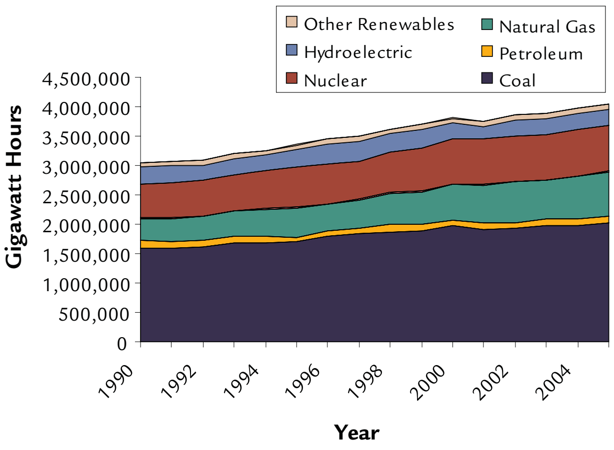
SO_2 Compliance Options

Since 1995, the majority of units affected by the Acid Rain Program (ARP) have chosen to comply with the emission reduction requirements by using or blending low-sulfur coal, installing SO_2 and NO_x controls such as scrubbers and low-NO_x burners, or purchasing allowances from the market or using banked allowances.

According to the Energy Information Administration, the 1987 repeal of the Power Plant and Industrial Fuel Use Act prohibiting the use of natural gas by new electric generating units led to a large increase in natural gas generating capacity through 2000.[7] Additional factors contributing to this increase were low natural gas prices through the 1990s, the availability of increasingly efficient natural gas technology in the form of advanced combined cycle units, the short construction-to-operation time to build new combined cycle units, and the attractiveness of natural gas as a trace SO_2-emitting fuel source.

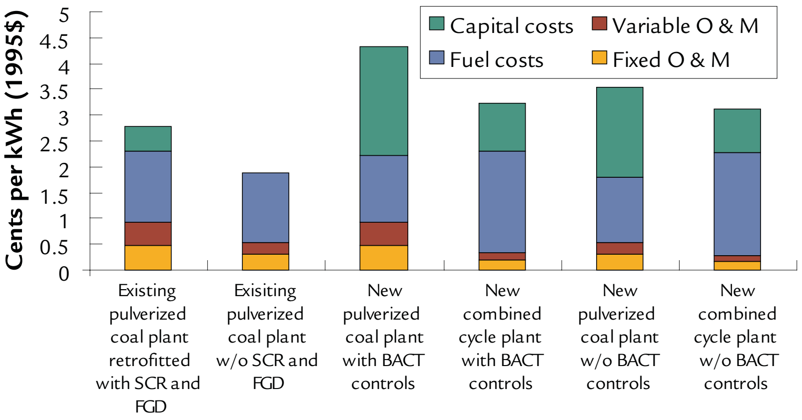
However, coal-fired generation grew from 1990 to 2004, taking advantage of the excess capacity available at existing plants. Today, coal remains the largest single fuel used for generating electricity in the United States, at 50 percent of net generation in 2005 (see Figure 9).

Figure 9: Net Electric Generation by Energy Source



Source: EPA, 2006

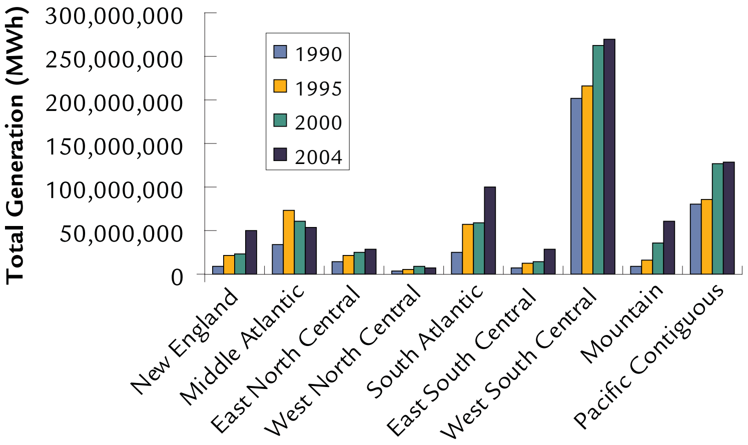
Figure 10: Comparison of Electric Generation Costs in 1995 of Base Load Coal-fired and Gas-fired Electric Generation Units*



*Unit sizes used in this analysis are around 325 megawatts.

Source: EPA, 2006

Figure 11: Distribution of Natural Gas Generation, 1990–2004



Source: Energy Information Administration, 2006

These factors contributed to an economic situation where it became more economical in many regions of the country to retrofit existing baseload coal plants with scrubbers than to build new coal-fired capacity to enhance existing load or to build new coal-fired capacity where excess coal capacity was available at existing plants. Where excess coal-fired capacity was not an alternative, building new combined cycle units was the cheapest alternative to meet new load requirements (see Figure 10).

Finally, most of the new natural gas capacity built in the last 15 years has been in three particular Census regions: West South Central (Arkansas, Louisiana, Oklahoma, Texas); Pacific Contiguous (California, Oregon, Washington); and South Atlantic (Washington DC, Delaware, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia). For the most part, these areas have been, and continue to be, comparatively high users of natural gas and oil and have the infrastructure to support natural gas-fired electric generation. In particular, the West South Central and Pacific Contiguous regions, which contribute over half of the electricity generated by natural gas in the United States, have a long history of oil and gas generation that precedes the implementation of the ARP in 1995 (see Figure 11). Additionally, the West South Central and Pacific Contiguous regions have not traditionally been heavily affected by the requirements of the ARP.

NO_x Emission Reductions and Compliance

Title IV of the 1990 Clean Air Act Amendments requires NO_x emission reductions for certain coal-fired electric generating units. Unlike the SO_2 program, Congress applied rate-based emission limits based on a unit's boiler type to achieve NO_x reductions (see Table 3). The NO_x emission limit is expressed as pounds of NO_x per unit of heat input (lbs/million British thermal units [mmBtu]) for each boiler subject to a NO_x limit. Owners can meet the NO_x limits for each individual unit or meet group NO_x limits through averaging plans for groups of units that share a common owner and designated

Table 3: Number of NO_x-Affected Title IV Units by Boiler Type and NO_x Emission Limit

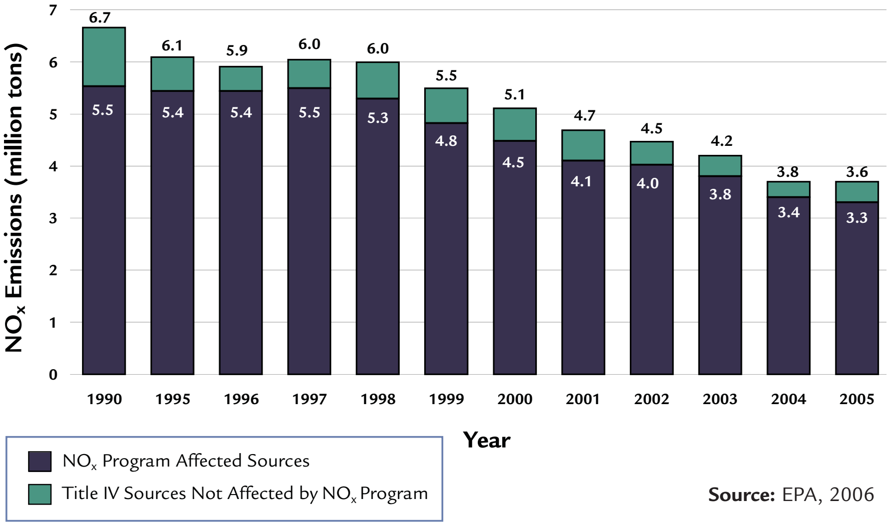
Coal-Fired Boiler Type	Title IV Standard Emission Limits (lb/mmBtu)	Number of Units
Phase I Group 1 Tangentially Fired	0.45	132
Phase I Group 1 Dry Bottom, Wall-fired	0.50	113
Phase II Group 1 Tangentially Fired	0.40	301
Phase II Group 1 Dry Bottom, Wall-fired	0.46	295
Cell Burners	0.68	37
Cyclones >155 MW	0.86	54
Wet Bottom >65 MW	0.84	24
Vertically Fired	0.80	26
Total	n/a	982

Source: EPA, 2006

representative. In 2005, all sources met their emission limit requirements under the Acid Rain NO_x program.

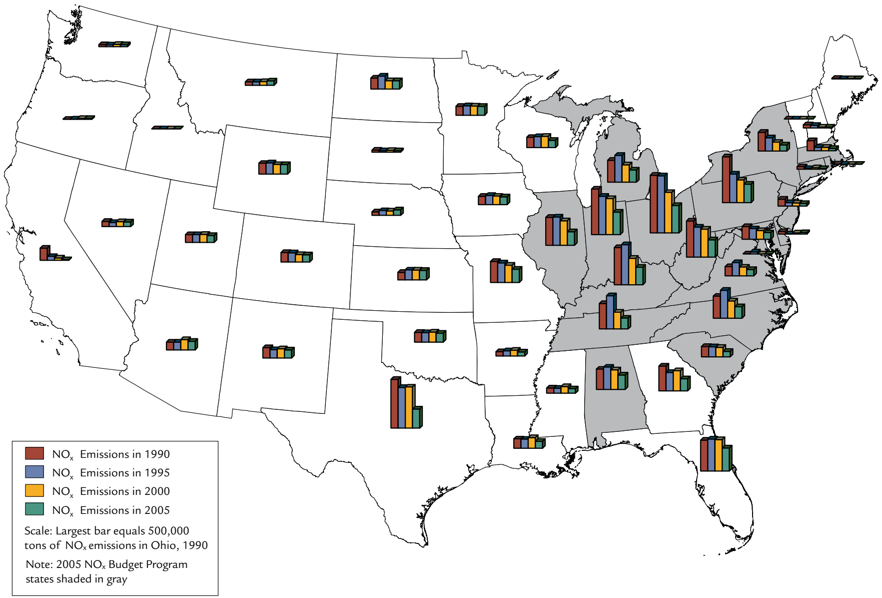
The NO_x program seeks to attain a 2 million ton annual reduction from all Acid Rain Program (ARP) sources relative to the NO_x emission levels that were projected to occur in 2000 absent the ARP (8.1 million tons). This goal was first achieved in 2000 and has been met every year thereafter, including 2005. Figure 12 shows that NO_x emissions from all ARP sources were 3.6 million tons in 2005. This level is 4.5 million tons less than the projected level in 2000 without the ARP, or more than double the Title IV NO_x emission reduction objective. These reductions have been achieved while the amount of fuel burned to produce electricity at all ARP units in 2005, as measured by heat input, has increased 38 percent since 1990. While the ARP was responsible for a large portion of these annual NO_x reductions, other programs (such as the Ozone Transport Commission's NO_x Budget Program, EPA's NO_x State Implementation Plan (SIP) Call, and regional NO_x emission control programs) also contributed significantly to the NO_x reductions achieved by sources in 2005.

Figure 12: NO_x Emission Trends for Acid Rain Program Units, 1990–2005[8]



Source: EPA, 2006

Figure 13: State-by-State NO_x Emission Levels for Acid Rain Program Sources, 1990–2005



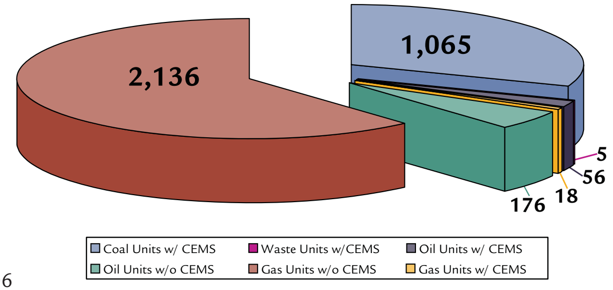
Source: EPA, 2006

As with SO_2, the states with the highest NO_x-emitting sources in 1990 tended to see the greatest power plant NO_x emission reductions (see Figure 13). The sum of reductions in the 39 states and the District of Columbia that had lower annual NO_x emissions in 2005 than in 1990 was approximately 2.8 million tons, while the sum of increases in the nine states that had higher annual NO_x emissions in 2005 than in 1990 was much smaller, about 61,000 tons. Eight of the 11 states with NO_x emission decreases of more than 100,000 tons were in the Ohio River Basin.

Emission Monitoring and Reporting

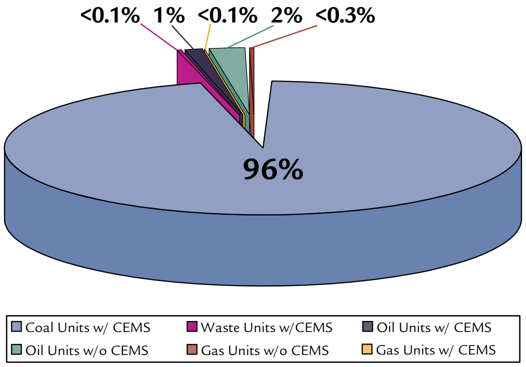
The Acid Rain Program (ARP) requires program participants to measure, record, and report emissions using continuous emission monitoring systems (CEMS) or an approved alternative measurement method. The vast majority of emissions are monitored with CEMS while the alternatives provide an efficient means of monitoring emissions from the large universe of units with lower overall mass emission levels (see Figures 14 and 15).

Figure 14: Monitoring Methodology for the Acid Rain Program, Number of Units



Source: EPA, 2006

Figure 15: Monitoring Methodology for the Acid Rain Program, Total SO_2 Mass



Source: EPA, 2006

Since the program's inception in 1995, emissions have been continuously monitored and reported, verified, and recorded by EPA, and provided to the public through EPA's Web site. Hourly emissions data are reported for all affected sources in quarterly electronic reports, and EPA conducts automated software audits that perform rigorous checks to ensure the completeness, quality, and integrity of the emissions data. CEMS and approved alternatives are a cornerstone of the ARP's accountability and transparency. All emissions data are available to the public at EPA's Clean Air Markets Data and Maps Web site at <http://cfpub.epa.gov/gdm/>. The site also provides access to a variety of other data associated with emission trading programs, including reports, queries, maps, charts, and file downloads covering source information, emissions, allowances, program compliance, and air quality.

The emission monitoring requirements for the ARP are found in 40 CFR Part 75. These provisions are also required for participation in the NO$_x$ Budget Trading Program, a NO$_x$ summer season trading program implemented by many eastern states in response to EPA's 1998 NO$_x$ SIP Call. The Part 75 requirements will also be used in the future to implement the Clean Air Interstate Rule (CAIR) and the Clean Air Mercury Rule (CAMR).

Status and Trends in Air Quality, Acid Deposition, and Ecological Effects

The emission reductions achieved under the Acid Rain Program (ARP) 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 from acidification in fresh water lakes and streams, improvements in visibility, and reduced risk to forests, materials, and structures. Table 4 shows the regional changes in key air quality and atmospheric deposition measurements linked to the ARP's SO_2 and NO_x emission reductions.

Table 4: Regional Changes in Air Quality and Deposition of Sulfur and Nitrogen, 1989–1991 Versus 2003–2005

Measurement	Unit	Region	Average		Percent Change*
			1989–1991	2003–2005	
Wet Sulfate Deposition	kg/ha	Mid-Atlantic	27	20	-24
		Midwest	23	16	-32
		Northeast	23	14	-36
		Southeast	18	15	-19
Wet Sulfate Concentration	mg/L	Mid-Atlantic	2.4	1.6	-33
		Midwest	2.3	1.6	-30
		Northeast	1.9	1.1	-40
		Southeast	1.3	1.1	-21
Ambient Sulfur Dioxide Concentration	$\mu g/m^3$	Mid-Atlantic	13	8.4	-34
		Midwest	10	5.8	-44
		Northeast	6.8	3.1	-54
		Southeast	5.2	3.4	-35
Ambient Sulfate Concentration	$\mu g/m^3$	Mid-Atlantic	6.4	4.5	-30
		Midwest	5.6	3.8	-33
		Northeast	3.9	2.5	-36
		Southeast	5.4	4.1	-24
Wet Inorganic Nitrogen Deposition	kg/ha	Mid-Atlantic	5.9	5.5	-8
		Midwest	6.0	5.5	-8
		Northeast	5.3	4.1	-23
		Southeast	4.3	4.4	+2
Wet Nitrate Concentration	mg/L	Mid-Atlantic	1.5	1.0	-29
		Midwest	1.4	1.2	-14
		Northeast	1.3	0.9	-33
		Southeast	0.8	0.7	-9
Ambient Nitrate Concentration	$\mu g/m^3$	Mid-Atlantic	0.9	1.0	+5
		Midwest	2.1	1.8	-14
		Northeast	0.4	0.5	+20
		Southeast	0.6	0.7	+17
Total Ambient Nitrate Concentration (Nitrate + Nitric acid)	$\mu g/m^3$	Mid-Atlantic	3.5	3.0	-14
		Midwest	4.0	3.5	-12
		Northeast	2.0	1.7	-13
		Southeast	2.2	2.1	-5

Source: Clean Air Status and Trends Network (CASTNET) and the National Atmospheric Deposition Program/National Trends Network (NADP/NTN)

* Percent change is estimated from raw measurement data, not rounded; some of the measurement data used to calculate percentages may be at or below detection limits.

The National Acid Precipitation Assessment Program

The National Acid Precipitation Assessment Program (NAPAP) 2005 Report concluded that Title IV has been quite successful in reducing emissions of SO_2 and NO_x from power generation. These reductions have improved air quality, visibility, and human health at a relatively low cost compared to the benefits generated.

However, the report also noted that several scientific studies indicate that recovery of acid-sensitive ecosystems will require 40 to 80 percent further emission reductions beyond those anticipated with full implementation of Title IV. Power generation currently contributes approximately 67 percent of the SO_2 emissions and 22 percent of the NO_x emissions nationwide. Even if all SO_2 emissions from power plants were eliminated, reductions from other source categories would be needed for full protection of all acid-sensitive ecosystems affected by acid deposition.

To view the report, visit:

<www.al.noaa.gov/AQRS/reports/napapreport05.pdf>

Framework for Accountability

EPA is expanding its capacity to track the effectiveness of programs to protect ecosystems from air pollution and examine the effects of changes in deposition and air concentrations on the health of sensitive receptor species in aquatic and forest ecosystems, human health, and visibility.

This effort stems from the recommendations in the 2004 National Academy of Sciences (NAS) report, *Air Quality Management in the United States*, which recognized the significant reduction in air pollution achieved under the Clean Air Act, and recommended a course of action to achieve further progress. For ecosystem protection, the recommendations include:

- Improving monitoring and tracking of ecosystems and science to support secondary or alternative standards.
- Taking an “airshed” approach.
- Emphasizing results, accountability, and dynamic, data-based program adjustment.

EPA’s Clean Air Act Advisory Committee (CAAAC) expanded on the NAS recommendations with further ecosystem-related recommendations, including the establishment of:

- A framework for accountability
- Benchmarks and measures of the ecological impacts of air pollution
- Effects of multiple pollutants
- Measures of ecosystem response
- Collaborative integrated assessments
- Critical loads and thresholds

Air Quality Management in the United States, National Academies Press: <www.nap.edu/catalog/10728.html>

Understanding the Monitoring Networks

To evaluate the impact of emission reductions on the environment, scientists and policymakers use data collected from long-term national monitoring networks such as the Clean Air Status and Trends Network (CASTNET) and the National Atmospheric Deposition Program/National Trends Network (NADP/NTN). These complementary, long-term monitoring networks provide information on a variety of indicators necessary for tracking temporal and spatial trends in regional air quality and acid deposition (see Table 5).

CASTNET provides atmospheric data on the dry deposition component of total acid deposition, ground-level ozone, and other forms of atmospheric pollution. Established in 1987, CASTNET now consists of nearly 90 sites across the United States. EPA's Office of Air and Radiation operates most of the monitoring stations; the National Park Service (NPS) funds and operates approximately 30 stations in cooperation with EPA. Many CASTNET sites are approaching a continuous 20-year data record, reflecting EPA's commitment to long-term environmental monitoring. Public access to CASTNET data is available at <www.epa.gov/castnet>.

EPA also uses data from other ambient monitoring networks, including the State and Local Ambient Monitoring and National Ambient Monitoring Systems (SLAMS/NAMS). These networks are used to document attainment of National Ambient Air Quality Standards (NAAQS) and show trends in ambient air quality over time.

NADP/NTN is a nationwide, long-term network tracking the chemistry of precipitation. NADP/NTN offers data on hydrogen (acidity measured as pH), sulfate, nitrate, ammonium, chloride, and base cations. The network is a cooperative effort involving many groups, including the State Agricultural Experiment Stations, U.S. Geological Survey, U.S. Department of Agriculture, EPA, NPS, National Oceanic and Atmospheric Administration (NOAA), and other governmental and private entities. NADP/NTN has grown from 22 stations at the end of 1978 to more than 250 sites spanning the continental United States, Alaska, Puerto Rico, and the Virgin Islands.

Table 5: Air Quality and Acid Deposition Measurements

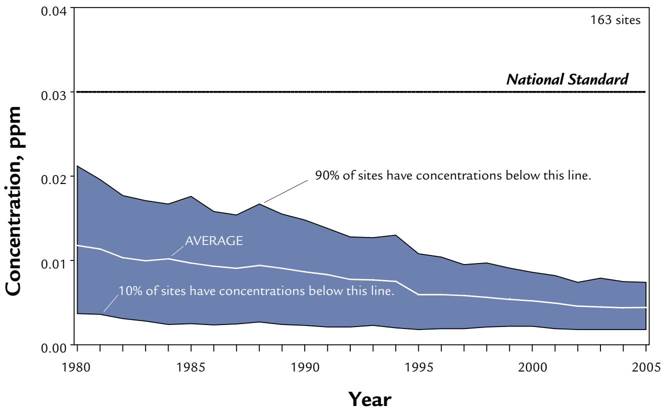
Chemicals	Chemical Species	Measured In		Why are these measured by the networks?
		Ambient Air	Wet Deposition	
SO_2	Sulfur Dioxide	X		Primary precursor of wet and dry acid deposition; primary precursor to fine particles in many regions.
SO_4^{2-}	Sulfate Ion	X	X	Major contributor to wet acid deposition; major component of fine particles in the Midwest and eastern regions; can be transported over large distances; formed from reaction of sulfur dioxide in the atmosphere.
NO_{3-}	Nitrates Ion	X	X	Contributor to acid and nitrogen wet deposition; major component of fine particles in urban areas; formed from reaction of NO_x in the atmosphere.
HNO_3	Nitric Acid	X		Strong acid and major component of dry nitrogen deposition; formed as a secondary product from NO_x in the atmosphere.
NH_4^+	Ammonium Ion	X	X	Contributor to wet and dry nitrogen deposition; major component of fine particles; provides neutralizing role for acidic compounds; formed from ammonia gas in the atmosphere.
H^+	Ionic Hydrogen		X	Indicator of acidity in precipitation; formed from reaction of sulfate and nitrate in water.
Ca_2^+ Mg_2^+ K^+ Na^+	Calcium Magnesium Potassium Sodium	X X X X	X X X X	These base cations neutralize acidic compounds in precipitation and the environment; also play a major role in plant nutrition and soil productivity.

Air Quality

Sulfur Dioxide

Sulfur data collected from the State and Local Air Monitoring Stations (SLAMS) and the National Air Monitoring Stations (NAMS) monitoring networks show that the decline in SO_2 emissions from the power industry has improved air quality. In the entire United States, there has not been a single monitored violation of the SO_2 ambient air quality standard since 2000. Based on EPA's latest air quality trends data located at <www.epa.gov/airtrends>, the national composite average of SO_2 annual mean ambient concentrations decreased 48 percent between 1990 and 2005, as shown in Figure 16. The largest single-year reduction (21 percent) occurred in the first year of the Acid Rain Program (ARP), between 1994 and 1995.

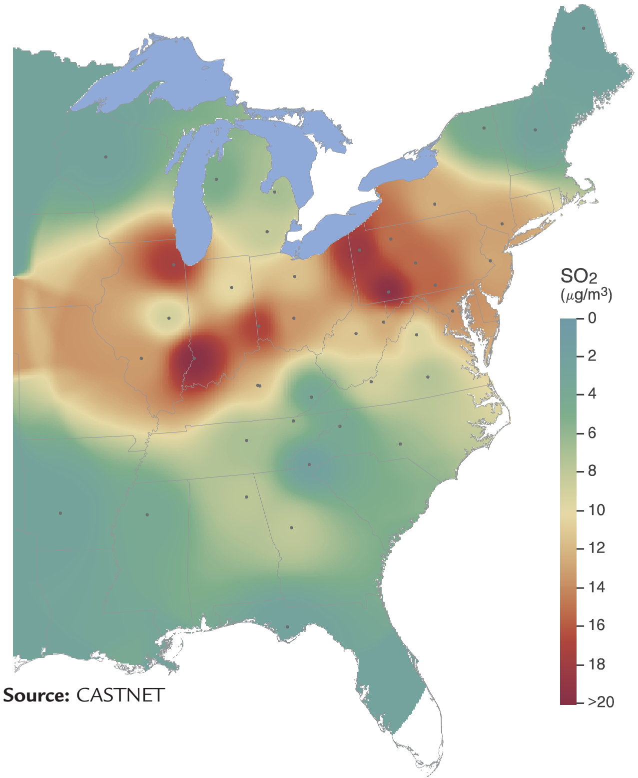
Figure 16: National SO_2 Air Quality, 1980–2005 (Based on Annual Arithmetic Average)



Source: EPA air emission trends, <www.epa.gov/airtrends/sulfur.html>

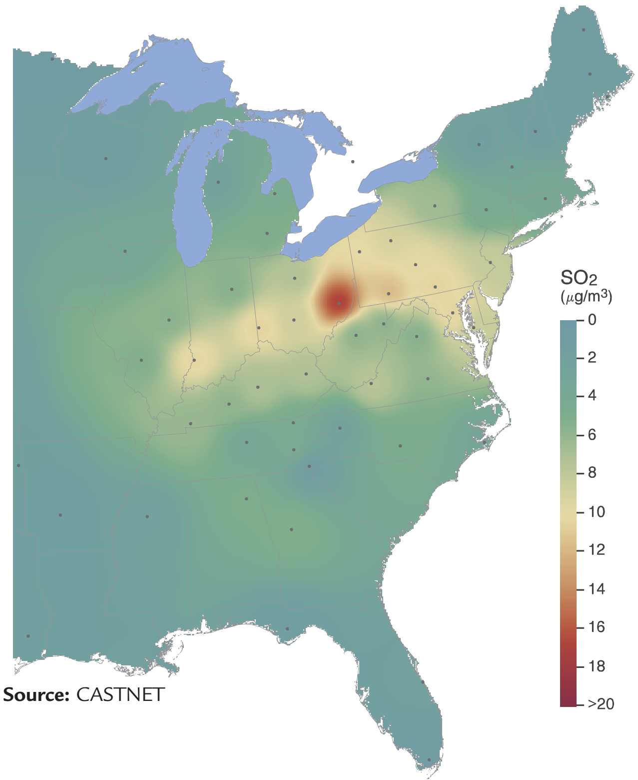
These trends are consistent with the ambient trends observed in Clean Air Status and Trends Network (CASTNET). During the late 1990s, following implementation of Phase I of the ARP, dramatic regional improvements in SO_2 and ambient sulfate concentrations were observed at CASTNET sites throughout the eastern United States due to the large reductions in SO_2 emissions from ARP sources. Three-year mean annual concentrations of SO_2 and sulfate from CASTNET long-term monitoring sites are compared from 1989 through 1991 and 2003 through 2005 in both tabular form (see Table 4 on page 14) and graphically in maps (see Figures 17a through 18b).

Figure 17a: Annual Mean Ambient Sulfur Dioxide Concentration, 1989–1991*



Source: CASTNET

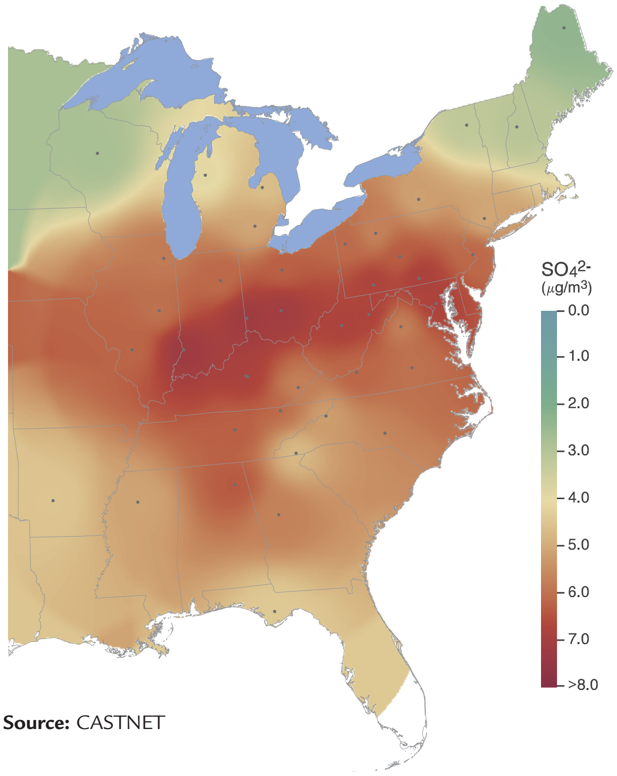
Figure 17b: Annual Mean Ambient Sulfur Dioxide Concentration, 2003–2005



Source: CASTNET

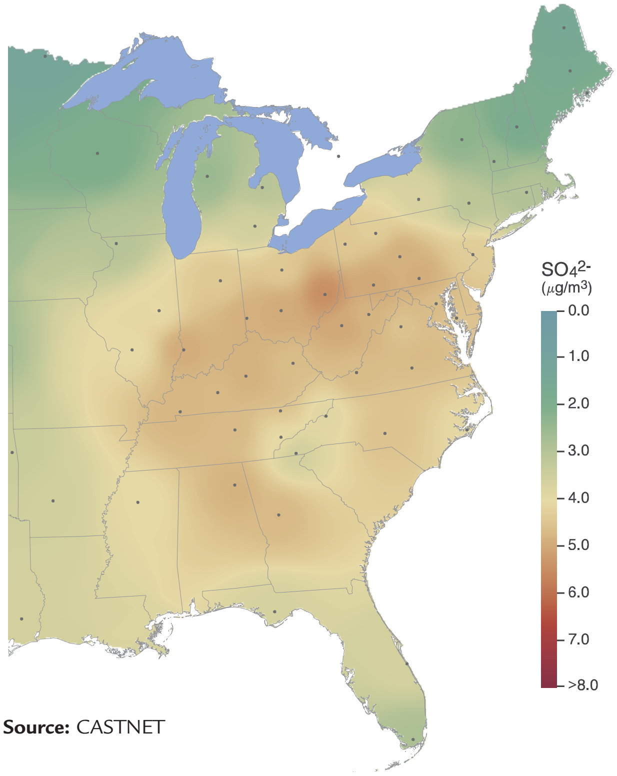
*Dots on all maps represent monitoring sites. Lack of shading for southern Florida on Figures 17a, 18a, and 19a indicates lack of monitoring coverage.

Figure 18a: Annual Mean Ambient Sulfate Concentration, 1989–1991



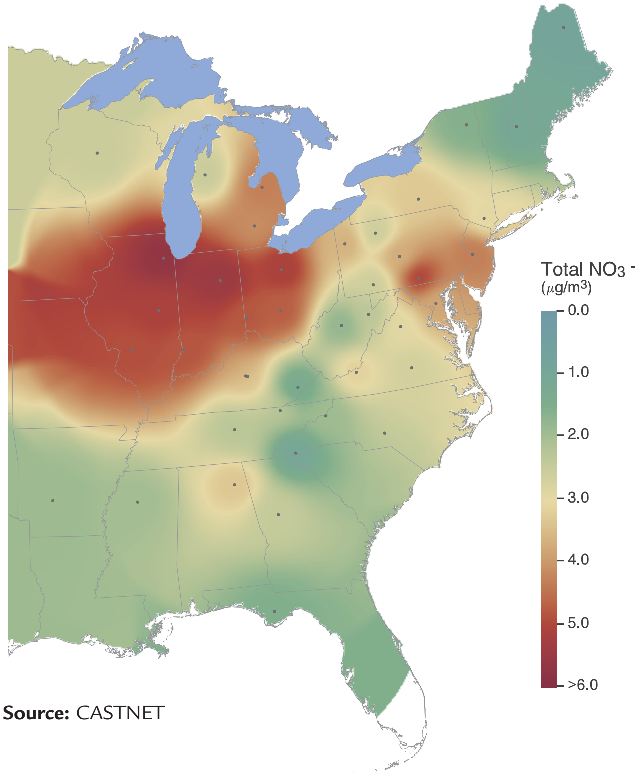
Source: CASTNET

Figure 18b: Annual Mean Ambient Sulfate Concentration, 2003–2005



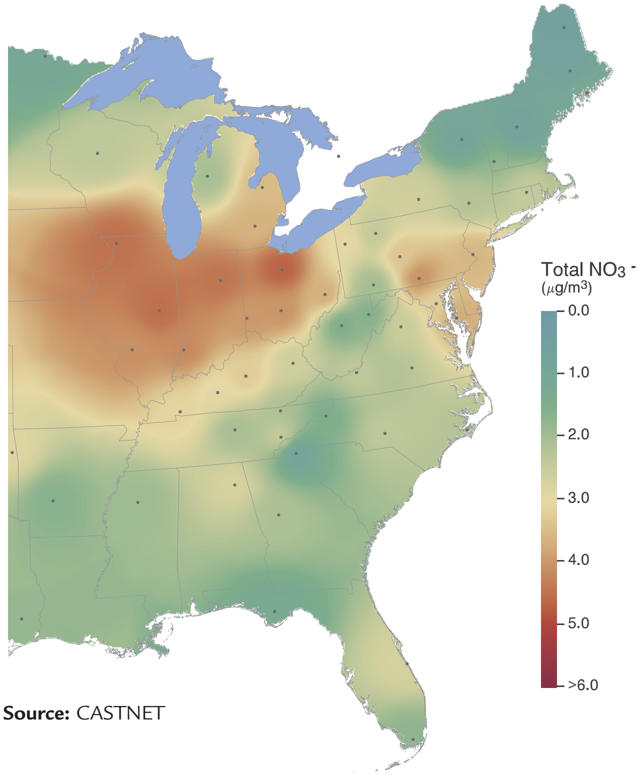
Source: CASTNET

Figure 19a: Annual Mean Total Ambient Nitrate Concentration, 1989–1991



Source: CASTNET

Figure 19b: Annual Mean Total Ambient Nitrate Concentration, 2003–2005



Source: CASTNET

The map in Figure 17a shows that from 1989 through 1991, prior to implementation of Phase I of the ARP, the highest ambient concentrations of SO_2 in the East were observed in western Pennsylvania and along the Ohio River Valley. Figure 17b indicates a significant decline in those concentrations in nearly all affected areas after implementation of the ARP.

Also, in 1989 through 1991, the highest ambient sulfate concentrations, greater than 7 micrograms per cubic meter ($\mu g/m^3$), were also observed in western Pennsylvania, along the Ohio River Valley, and in northern Alabama. Most of the eastern United States experienced annual ambient sulfate concentrations greater than 5 $\mu g/m^3$. Like SO_2 concentrations, ambient sulfate concentrations have decreased since the ARP was implemented, with average concentrations decreasing approximately 30 percent in all regions of the East. Both the size of the affected region and magnitude of the highest concentrations have dramatically declined, with the largest decreases observed along the Ohio River Valley (see Figures 18a and 18b).

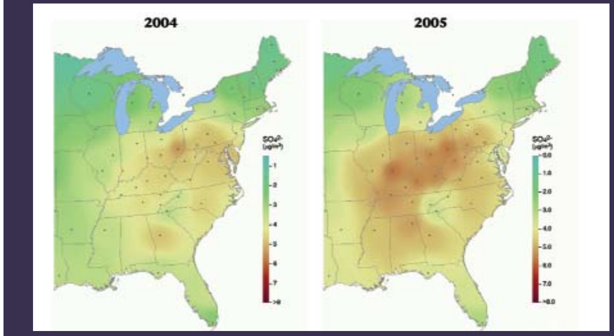
Assessing Recent Monitoring Data—Sulfate

Air quality monitoring networks such as the Clean Air Status and Trends Network (CASTNET), report air concentration data for both primary (sulfur dioxide) and secondary (sulfate) pollutants as an indication of changes in power plant emissions. Continuous emission monitors on fossil fuel-burning power plants at the unit or stack level provide the data for SO_2 emissions, which show a national decrease from 2004 to 2005. Interestingly, ambient monitoring data from CASTNET for 2005 show an increase in sulfate (SO_4^{2}) concentrations—an important constituent of fine particulate matter—across much of the eastern United States. This observed increase does not correlate with the relatively steady or declining emissions data from regional sources and is likely to be the result of year-to-year variations in meteorological conditions or other factors.

Sulfate ion formation is the result of complex chemical and physical processes involving emissions from Acid Rain Program (ARP) sources, non-ARP sources (i.e., industrial processes, agriculture and transportation), meteorological conditions, and other phenomena. EPA employs a range of analytical and assessment protocols to understand these processes, including modeling of source/receptor relationships, source apportionment, and atmospheric transport processes.

Although the ARP has achieved significant reductions in SO_2 from coal-burning power plants—over 35 percent since 1990—sulfate deposition and concentrations vary from year to year. This illustrates the importance of long-term monitoring and accounting for annual variability to determine status and trends over time. Another steep reduction in SO_2 emissions is projected to be achieved by the Clean Air Interstate Rule (CAIR), which will cap eastern SO_2 emissions at 2.6 million tons in 2015, much lower than the ARP's toughest cap that starts in 2010. As with the ARP, this program is expected to result in significant emission reductions. These reductions may be followed by periodic fluctuations in regional and source-specific emissions as sources seek to comply with the cap, as well as fluctuating signals from the air quality and deposition monitoring networks.

Sulfate Concentrations



Source: CASTNET

Nitrogen Oxides

The ARP has met its NO_x reduction targets, and these reductions are correlated with decreases in total ambient nitrate concentrations (the sum of particulate nitrate and nitric acid) at CASTNET sites. The ratio of these two components in the atmosphere is dependent on emissions of NO_x, SO_2, and other pollutants from electric generation and other sectors (such as motor vehicles and agriculture).

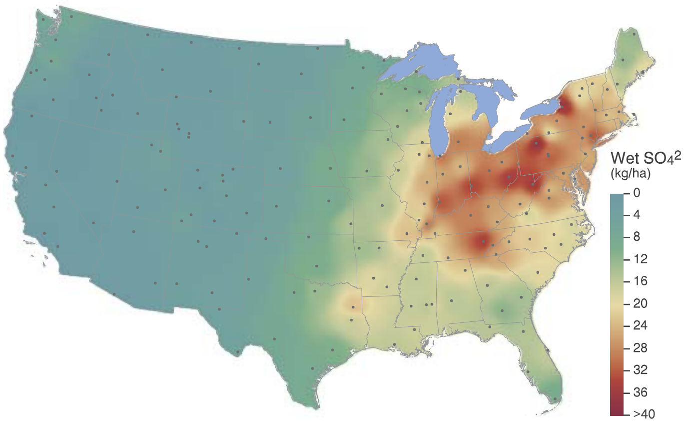
In some areas, NO_x levels can also be affected by emissions transported via air currents over wide regions. From 2003 to 2005, reduced NO_x emissions from power plants under the NO_x Budget Trading Program led to more significant region-specific improvements in some indicators. For instance, mean total annual ambient nitrate concentrations (nitric acid plus particulate nitrate) for 2003 through 2005 decreased in the Midwest by about 12 percent from the annual mean concentration in 1989 through 1991 (see Figures 19a and 19b). While the cause of the reductions has not yet been determined conclusively, these improvements may be partly attributed to added NO_x controls installed for compliance with the NO_x Budget Trading Program.

Acid Deposition

National Atmospheric Deposition Program/National Trends Network (NADP/NTN) monitoring data show significant improvements in most deposition indicators. For example, wet sulfate deposition—sulfate that falls to the earth through rain, snow, and fog—has decreased since the implementation of the Acid Rain Program (ARP), particularly throughout the early 1990s in much of the Ohio River Valley and northeastern United States. Some of the greatest reductions have occurred in the mid-Appalachian region, including Maryland, New York, West Virginia, Virginia, and most of Pennsylvania. Other less dramatic reductions have been observed across much of New England, portions of the southern Appalachian Mountains, and in some areas of the Midwest. Between the 1989–1991 and 2003–2005 observation periods, average decreases in wet deposition of sulfate ranged from 36 percent in the Northeast to 19 percent in the Southeast (see Table 4 on page 14 and Figures 20a and 20b). Along with wet sulfate deposition, wet sulfate concentrations have also decreased significantly. Since 1991, average levels decreased 40 percent in the Northeast, 33 percent in the Mid-Atlantic, and 30 percent in the Midwest. A strong correlation between large-scale SO_2 emission reductions and large reductions in sulfate concentrations in precipitation has been noted in the Northeast, one of the areas most affected by acid deposition.

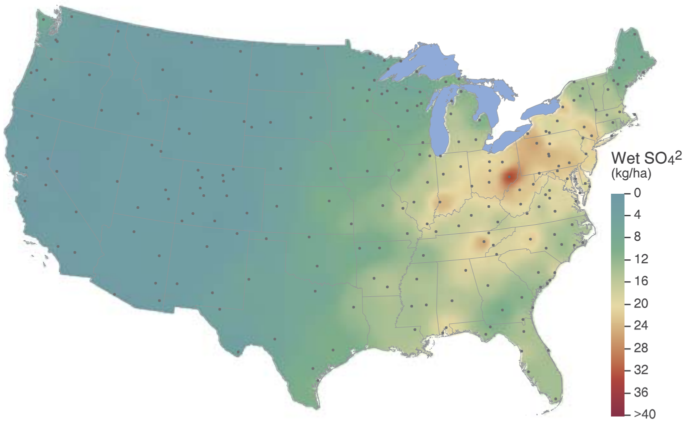
A reduction in the long-range transport of sulfate from emission sources located in the Ohio River Valley is a principal reason for reduced concentrations of sulfate in precipitation in the Northeast. The reductions in sulfate documented in the Northeast, particularly across New England and portions of New York, were also affected by SO_2 emission reductions in eastern Canada. NADP data indicate that similar reductions in precipitation acidity, expressed as hydrogen ion (H^+) concentrations, occurred concurrently with sulfate reductions.

Figure 20a: Annual Mean Wet Sulfate Deposition, 1989–1991



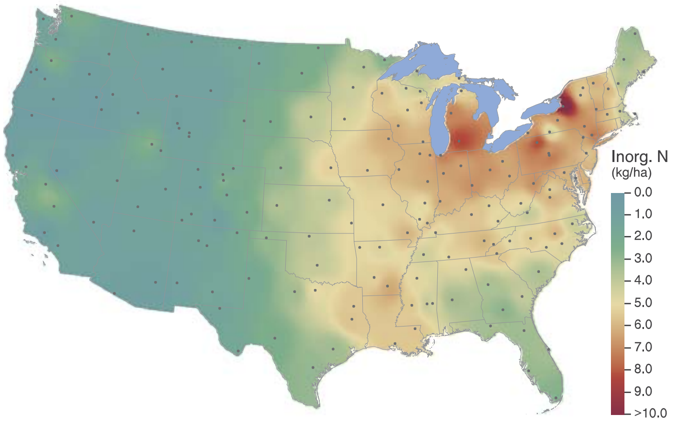
Source: National Atmospheric Deposition Program

Figure 20b: Annual Mean Wet Sulfate Deposition, 2003–2005



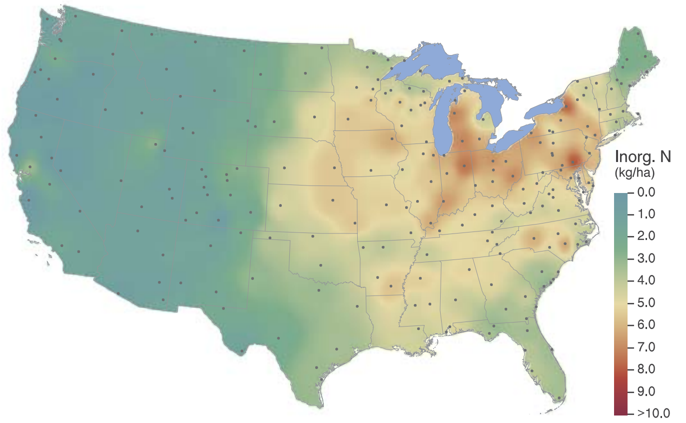
Source: National Atmospheric Deposition Program

Figure 21a: Annual Mean Wet Inorganic Nitrogen Deposition, 1989–1991



Source: National Atmospheric Deposition Program

Figure 21b: Annual Mean Wet Inorganic Nitrogen Deposition, 2003–2005



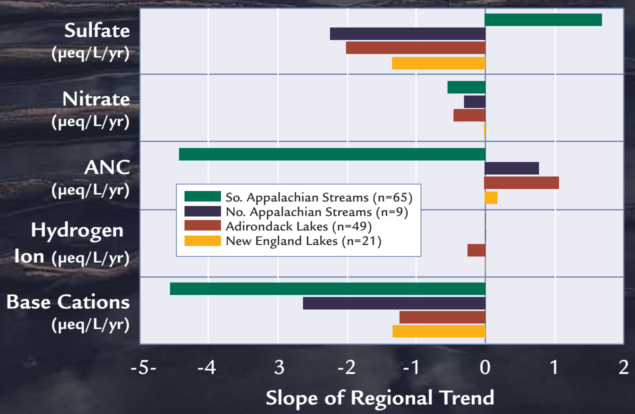
Source: National Atmospheric Deposition Program

Reductions in nitrogen deposition recorded since the early 1990s have been less dramatic than those for sulfur. As noted earlier, emissions from source categories other than ARP sources significantly affect air concentrations and nitrogen deposition. Inorganic nitrogen deposition decreased in the Mid-Atlantic and Midwest (8 percent) and more significantly in the Northeast (23 percent), but remained virtually unchanged in the Southeast (see Figures 21a and 21b).

Improvements in Surface Water

Long-term monitoring networks provide information on the chemistry of lakes and streams, which demonstrates how water bodies are responding to changes in emissions.[9] The data presented in the figure below show regional trends in acidification from 1990 to 2004 in areas of the eastern United States. For each lake or stream in the network, measurements of various indicators of recovery from acidification were taken. These measurements were plotted against time, and trends for the given lake or stream during the 15-year period were then calculated as the change in each of the measurements per year (e.g., change in concentration of sulfate per year). Using the trends calculated for each water body, median regional changes were determined for each recovery measure. A negative value of the "slope of the regional trend" means that the measure has been declining in the region, while a positive value means it has been increasing. The greater the value of the trend, the greater the yearly change in the measurement. Movement toward recovery is indicated by positive trends in acid neutralizing capacity (ANC) and negative trends in sulfate, nitrate, hydrogen ion, and aluminum. Negative trends in base cations and positive trends in organic acids can balance out the decreasing trends in sulfate and nitrate and prevent ANC from increasing. The results of these regional trend analyses are shown in Figure 22 and Table 6.

Figure 22: Regional Trends, Lakes and Streams, 1990–2004



Source: EPA

Increasing ANC was evident in two of the regions studied (Adirondacks and northern Appalachians). One-quarter to one-third of the lakes and streams in these regions previously affected by acid rain are no longer acidic at base-flow conditions, although they are still highly sensitive to future changes in deposition.

Recovery of Acidified Lakes and Streams

Acid rain is only one of many large-scale anthropogenic impacts affecting lakes and streams in the United States. Climate change, forest maturation, biological disturbances (e.g., pest outbreaks), and land use change can have an impact on ecosystems that are also affected by acid deposition. Nevertheless, scientists have demonstrated measurable improvements in some lakes and streams resulting from the Acid Rain Program (ARP). Scientists studied lakes and streams in four regions—New England, the Adirondack Mountains, the northern Appalachians (including the Catskill Mountains), and the southern Appalachians (including the Blue Ridge)—and found signs of recovery in many, but not all, of those areas (see Figure 22).These signs of recovery include reductions in sulfate and aluminum concentrations and decreases in acidity.

The monitoring data show that sulfate concentrations are declining substantially in all but one of the regions. Statistically significant decreases in nitrate concentrations are evident in all of the regions, although the magnitude of these changes is small, especially in New

Table 6: Results of Regional Trend Analyses on Lakes and Streams, 1990–2004

Chemical Variable	New England Lakes (n = 21)	Adirondack Lakes (n = 49)	No. Appalachian Streams (n = 9)	So. Appalachian Streams (n = 65)
Sulfate (μeq/L/yr)	**-1.4**	**-2.0**	**-2.3**	**+1.7**
Nitrate (μeq/L/yr)	**-0.02**	**-0.45**	**-0.31**	**-0.55**
Acid Neutralizing Capacity (μeq/L/yr)	+0.18	**+1.08**	**+0.76**	**-4.44**
Base Cations (μeq/L/yr)	**-1.35**	**-1.24**	**-2.63**	**-4.56**
Hydrogen (μeq/L/yr)	**-0.02**	**-0.26**	-0.01	-0.01
Organic Acids (μeq/L/yr)	+0.02	**+0.15**	-0.03	Insufficient data
Aluminum (μg/L/yr)	Insufficient data	**-4.72**	Insufficient data	Insufficient data

Values show the slope of the regional trend (the median value for the trends in all of the sites in the region). Regional trends that are statistically significant are shown in bold.

Source: EPA, 2004

England. It should be noted, however, that decreasing nitrate concentrations do not appear to be related to the magnitude of changes in emissions or deposition in these areas, but are likely a result of ecosystem factors that are not yet fully understood.

As a result of declining sulfate (and to some extent nitrate) concentrations, the acidity of lake and stream water is decreasing in three of the four regions. In the Adirondacks and northern Appalachians, acid neutralizing capacity (ANC, an indicator of aquatic ecosystem recovery) is increasing. For example, 48 out of 49 monitored Adirondack lakes showed reductions in sulfate concentrations that coincide with reductions in atmospheric concentrations of sulfur. These decreases in sulfate, as well as decreases in nitrate concentrations that do not appear to be due to changes in atmospheric nitrogen deposition, have resulted in increased pH and ANC as well as decreases in the amount of toxic inorganic aluminum in Adirondack lakes. In New England, ANC appears to be increasing only slightly, and is not statistically significant, but hydrogen ion concentrations are declining. Declining hydrogen ion concentrations represent an increase in pH, which also is elevated by statistically significant levels in the Adirondacks. In contrast, increasing sulfate concentrations are evident in the southern Appalachians. This regional increase may be explained in part by the region's soils, which can store large amounts of sulfate delivered by deposition. When large amounts of sulfate have accumulated in the soils over time, stream water sulfate concentrations can also continue increasing over time. Thus, despite decreasing sulfate in atmospheric deposition, an increase in sulfate concentrations in-stream has been observed in that region.

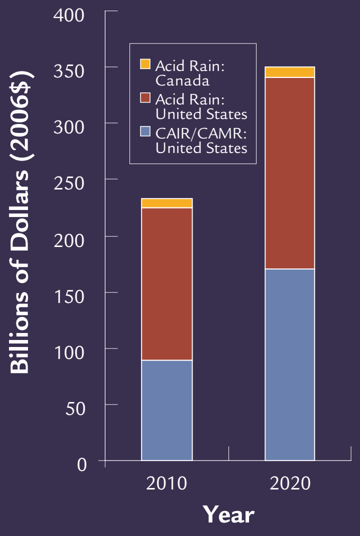
Base cations are important because they buffer the impact of sulfur and nitrogen deposition. Base cation concentrations in lakes and streams are expected to decrease when rates of atmospheric deposition decline, but if they decrease too much, they limit recovery in pH and ANC. While the high rates of base cation decline in the northern Appalachians may be of concern, they do not currently seem to be preventing recovery. However, their behavior in the future will bear watching.

Organic acids are natural forms of acidity. Lakes and streams vary widely in how much natural acidity they have, and increases in organic acids, like declining base cations, over time can limit recovery. Organic acid concentrations are currently increasing in many parts of the world, but the cause is still being debated. Of the regions monitored by EPA, only the Adirondacks are showing significant increases in organic acids, and their increase may be responsible for 10 to 15 percent less recovery (in ANC) than expected. In order to fully understand and assess response and recovery of sensitive ecosystems to emission reduction programs, this area may require further investigation.

Benefits

- Preliminary estimates of annual benefits EPA can monetize are substantial.
- Benefits are driven by:
  - Reduced premature deaths.
  - Lowering aggravation and incidence of heart and lung ailments.
  - Visibility improvements in some parks.
- Many benefits are not included in estimates:
  - Mercury reductions.
  - Acid rain environmental benefits.
  - Remaining visibility benefits from parks and urban areas.
  - Others.
- Benefits from CAIR/CAMR for Canada have not yet been quantified.

Figure 23: Combined Estimated Annual Benefits for ARP, CAIR, and CAMR



Source: EPA, 2006, derived from Chestnut & Mills Analysis, "A fresh look at the benefits and costs of the US acid rain program" (Oct. 1, 2004) and EPA's Multi-pollutant Regulatory Analysis: CAIR, CAVR, CAMR (Oct. 2005). Acid Rain 2020 benefits extrapolated from 2010 estimates. Consumer Price Index-Urban was used to convert 1999 dollars and 2000 dollars to 2006 dollars.

Most of the regions do not have sufficient aluminum data to estimate trends. Aluminum is a critical element because it increases when lakes and streams acidify and is very toxic to fish and other wildlife. The one region where good aluminum data exist (the Adirondacks) is showing strong declines in the most toxic form of aluminum (inorganic monomeric aluminum). As mentioned earlier, the southern Appalachians are unusual in both their physiography and response to changing atmospheric deposition. Because sulfate concentrations in streams are increasing strongly in this region, many of the other chemical variables (e.g., ANC and pH) show trends typical of acidifying conditions, rather than recovery.

Quantifying Costs and Benefits of the Acid Rain Program

A 2005 analysis[10] of the annual benefits and costs of the Acid Rain Program (ARP) updated those of the National Acid Protection Assessment Program (NAPAP) 1990 Integrated Assessment and a 1995 EPA report[11] by integrating scientific knowledge that has emerged since the 1990s. An expanded list of impacts has increased the program's estimated benefits, while newer implementation strategies—unforeseen in 1990—have lowered estimated costs. The estimated value of the program's annual benefits in the year 2010 now totals $122 billion (in 2000$). These benefits result mostly from the prevention of health-related impacts (such as premature deaths, illnesses, and workdays missed due to illness), but also include improved visibility in parks and other recreational areas and ecosystem improvements. These benefits stem from the substantial difference that the ARP is expected to make in many areas meeting the National Ambient Air Quality Standards (NAAQS) by 2010 for fine particles less than 2.5 micrometers in diameter ($PM_{2.5}$) and ozone (see Figure 25). Notably, some significant benefits are not quantified, such as the 20 percent reduction in mercury emissions from coal-fired power plants; improvements to urban visibility, forest health, and surface water quality; and increased longevity and reduced soiling of painted and stone surfaces.

The 2005 study finds that the estimated annual cost of the ARP in 2010 will be $3 billion, with the SO_2 program accounting for about $2 billion. These findings are generally consistent with other recent independent findings and are far less than the original NAPAP estimates.[12] EPA expects NO_x costs to be no more than $1 billion annually, and likely less, from the limited analysis that has been completed in this area. This leads to a more than 40:1 benefit-cost ratio. Among the most important factors in reducing SO_2 program costs were changes in transportation and production of coal, which enabled sources to increase the use of low-sulfur coal. The flexibility offered by the SO_2 program also may have enabled technological innovations that lowered compliance costs. For instance, boiler adaptations and lower than expected installation and operation costs for flue gas desulfurization systems (scrubbers) reduced costs below original estimates.[13] See Figure 23 on page 24 for the combined estimated benefits of the ARP, Clean Air Interstate Rule (CAIR), and Clean Air Mercury Rule (CAMR).

Environmental Justice Analysis

In September 2005, EPA published a staff report evaluating the public health benefits of the ARP, focusing on the changes in exposure of minority and low-income populations to ambient concentrations of $PM_{2.5}$ as a result of the ARP. Analyses of SO_2 and NO_x emissions show that, in general, the areas with highest emissions prior to the program have also experienced the greatest emission reductions. However, since the ARP does not mandate reductions from specific sources, the exact effects of the ARP on specific populations or localities are harder to assess. To explore the potential environmental justice issues related to the ARP, EPA investigated how trading SO_2 emissions under the ARP might affect minority and low-income communities, and how trading SO_2 emissions has impacted air quality at both regional and local levels. In formulating this analysis of the ARP, EPA measured exposure to $PM_{2.5}$ concentrations in relation to regional locations, population size, race, and income levels. This investigation led EPA to the following conclusions:

- There is no evidence that the cap and trade mechanism has led to increased human exposure to air pollution.
- The ARP improved air quality substantially overall.
- The ARP improved air quality substantially for all population groups.
- No disproportionately high and adverse human health or environmental effects were found for minority or low-income groups.

To view the complete report, visit <www.epa.gov/airmarkets/staff_analysis.pdf>.

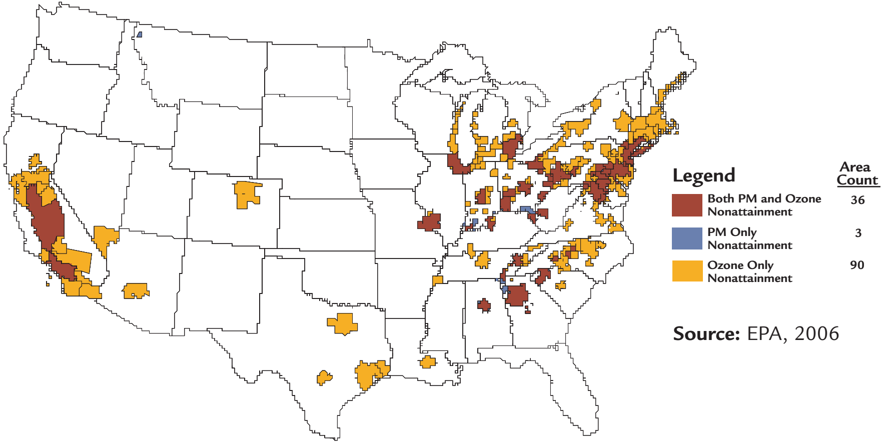
Further National Controls to Protect Human Health and the Environment

A combination of existing programs and future regulations that address the interstate transport of ozone and fine particles and mercury deposition will help ensure further improvements in human health and environmental protection. With the Acid Rain Program (ARP), the NO_x SIP Call in the eastern United States, and mobile source rules covering new cars, trucks, buses, and nonroad equipment, states have critical controls to help achieve ozone and fine particle National Ambient Air Quality Standards (NAAQS).

In the spring of 2005, EPA promulgated a suite of air quality rules designed to achieve additional reductions of SO_2, NO_x, and mercury from power plants. These rules include Clean Air Interstate Rule (CAIR), Clean Air Mercury Rule (CAMR), and Clean Air Visibility Rule (CAVR).[14] See Figure 27 for an implementation timeline.

EPA expects that the air quality impacts of these regulations, coupled with recent rules to reduce fine particles and NO_x from motor vehicles, will be extensive. Figures 24-26 show areas projected to attain the NAAQS in 2010 and 2020 with these regulations, compared to today. Figure 24 shows ozone and $PM_{2.5}$ nonattainment areas primarily occurring in eastern states and California. As the new rules are implemented, nonattainment is expected to decline steadily, with 92 fewer areas by

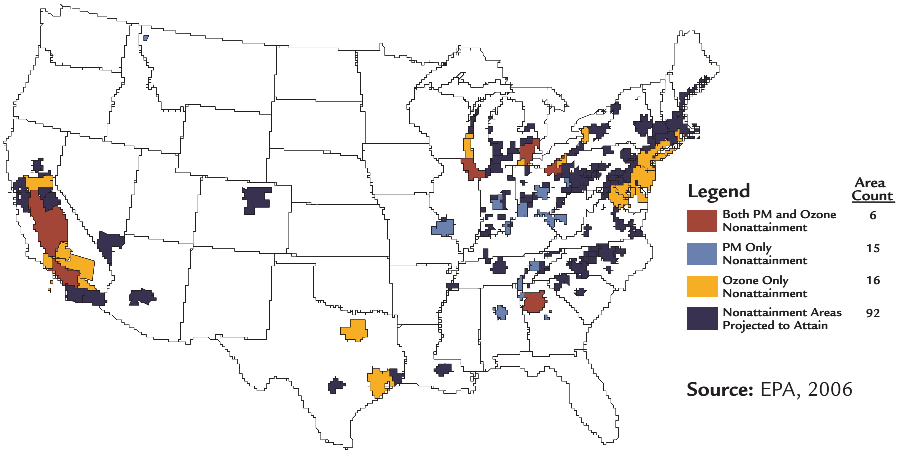
Figure 24: Ozone and Fine Particle Nonattainment Areas, April 2006



Source: EPA, 2006

Note: 129 areas currently designated as nonattainment for $PM_{2.5}$ and/or 8-hour ozone.

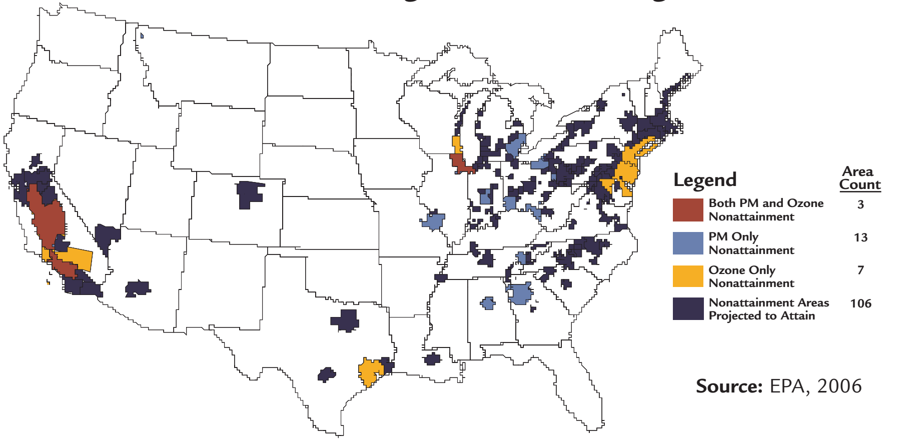
Figure 25: Projected Nonattainment Areas in 2010 After Reductions From CAIR and Existing Clean Air Act Programs



Source: EPA, 2006

Note: Areas forecast to remain in nonattainment may need to adopt additional local or regional controls to attain the standards by dates set pursuant to the Clean Air Act. These additional local or regional measures are not forecast here, and therefore this figure overstates the extent of expected nonattainment.

Figure 26: Projected Nonattainment Areas in 2020 After Reductions From CAIR, CAVR, and Existing Clean Air Act Programs



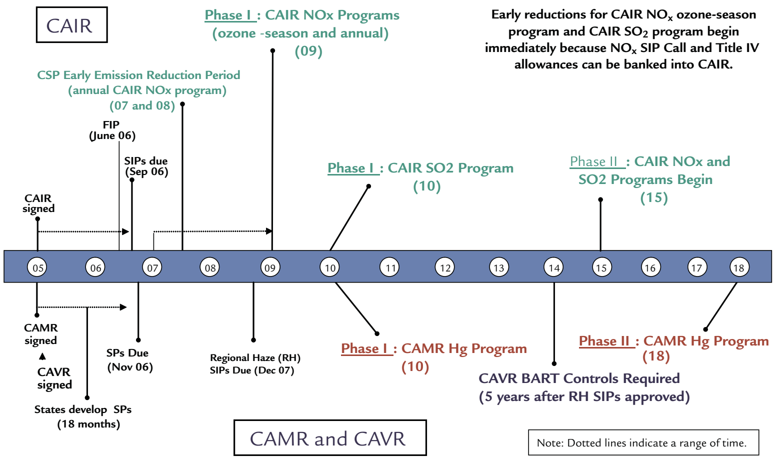
Source: EPA, 2006

Note: Areas forecast to remain in nonattainment may need to adopt additional local or regional controls to attain the standards by dates set pursuant to the Clean Air Act. These additional local or regional measures are not forecast here, and therefore this figure overstates the extent of expected nonattainment.

2010 (see Figure 25), and 106 fewer areas by 2020 (see Figure 26).

As the maps indicate, implementing these three new regulations is an important step toward improving air quality in the United States, protecting human health and the environment, and helping states and local communities meet NAAQS for fine particles and ozone.

Figure 27: CAIR, CAMR, CAVR Implementation Timeline



Source: EPA, 2006

Online Information, Data, and Resources

About the Clean Air Markets Division

The availability and transparency of data, from emission measurement to allowance trading to deposition monitoring, is a cornerstone of effective cap and trade programs. The Clean Air Markets Division in the Office of Air and Radiation's Office of Atmospheric Programs develops and manages programs for collecting these data and assessing the effectiveness of cap and trade programs, including the Acid Rain Program (ARP).

<www.epa.gov/airmarkets>

Regulatory Information

To learn more about how emissions cap and trade programs work, see:

www.epa.gov/airmarkets/arp
Acid Rain Program

www.epa.gov/airmarkets/progsregs/noxview.html
NO_x Budget Trading Program

www.epa.gov/airmarkets/capandtrade/index.html
General Cap and Trade Information

Also, See Recent Related Rulemakings:

www.epa.gov/cair
Clean Air Interstate Rule (CAIR)

www.epa.gov/CAMR/index.htm
Clean Air Mercury Rule (CAMR)

www.epa.gov/visibility
Clean Air Visibility Rule (CAVR)

http://www.epa.gov/airmarkets/cair/analyses/naaqsattainment.pdf
CAIR, CAMR, CAVR and NAAQS Attainment

Progress and Results

Several reports have assessed the progress and results, and projected future impacts of the Acid Rain Program.

www.sciencedirect.com/science/ journal/03014797
Chestnut, L. G., Mills, D. M. (2005, November). *A fresh look at the benefits and costs of the U.S. acid rain program. Journal of Environmental Management, Vol. 77, Issue 3, 252-256.*

www.al.noaa.gov/AQRS/reports/napapreport05.pdf
2005 National Acid Precipitation Assessment Program Report to Congress.

www.epa.gov/airmarkets/articles/adaq.html
U.S. Environmental Protection Agency, Office of Air and Radiation, Clean Air Markets Division. (2005, September). *The Acid Rain Program and Environmental Justice: Staff Analysis.*

www.rff.org/Documents/RFF-RPT-Adirondacks.pdf
Banzhaf, S., Burtraw, D., Evans, D., and Krupnick, A. (2004, September). *Valuation of natural resource improvements in the Adirondacks. Resources for the Future*.

www.adirondacklakessurvey.org
Jenkins, J., Roy, K., Driscoll, C., Beurkett, C. (2005, October). *Acid rain and the Adirondacks: A Research Summary.* Adirondack Lakes Survey Corporation.

Emissions, Allowances, and Environmental Data

For more information on emissions, allowances, and environmental data, see:

cfpub.epa.gov/gdm
EPA Clean Air Markets Data and Maps

www.epa.gov/castnet
Clean Air Status and Trends Network (CASTNET)

www.epa.gov/airmarkets/deposition/2005atlas.pdf
Atmosphere in Motion Results from the National Deposition Monitoring Networks: 2005 Atlas

nadp.sws.uiuc.edu
National Atmospheric Deposition Program/
National Trends Network

Endnotes

1 See: <www.epa.gov/ttn/chief/trends.html> (Based on 2002 National Emissions Inventory).

2 Chestnut, L. G., Mills, D. M. (2005, November). A fresh look at the benefits and costs of the U.S. acid rain program. *Journal of Environmental Management*, *Vol. 77, Issue 3, 252-256.*

3 See: <www.epa.gov/ttn/chief/trends.html>.

4 Detailed emissions data for ARP sources are available on the Data and Maps portion of EPA's Clean Air Markets Web site at <www.epa.gov/airmarkets>. Allowance transfers are posted and updated daily on <www.epa.gov/airmarkets>.

5 During 2005, EPA found that there were two small units at a plant that the Agency believes should have been in the ARP since 2000, and EPA is now working to resolve this legal issue.

6 Allowance transfers are posted and updated daily on <www.epa.gov/airmarkets>.

7 Gruenspecht, Howard. (2006, February 9). Deputy Administrator of the Energy Information Administration, Department of Energy. Statement before the Subcommittee on Clean Air, Climate Change, and Nuclear Safety of the Committee on Environment and Public Works in the United States Senate. p.3.

8 Other programs such as the NO_x SIP Call, the OTC NO_x Budget Program, and state laws also contribute to reductions, especially after 2000.

9 Monitoring data from the Temporally Integrated Monitoring of Ecosystems (TIME) and Long-Term Monitoring network.

10 Chestnut and Mills, 2005.

11 Human Health Benefits from Sulfate Reduction under Title IV of the 1990 Clean Air Act Amendments. EPA-430-R-95-010.

12 See, for example:

Ellerman, D. (2003). *Lessons from Phase 2 compliance with the U.S. Acid Rain Program*. Cambridge, Massachusetts: MIT Center for Energy and Environmental Policy Research.

Carlson, C.P., Burtraw, D., Cropper, M., and Palmer, K. SO_2 control by electric utilities: What are the gains from trade? *Journal of Political Economy, Vol. 108, No. 6: 1292-1326.*

Office of Management and Budget. (2003). *Informing Regulatory Decisions: 2003 Report to Congress on the Costs and Benefits of Federal Regulations and Unfunded Mandates on State, Local, and Tribal Entities.* Office of Information and Regulatory Affairs. <www.whitehouse.gov/omb/inforeg/2003_cost-ben_final_rpt.pdf>.

13 EPA estimates recognize that some switching to lower-sulfur coal (and accompanying emission reductions) would have occurred in the absence of Title IV as railroad deregulation lowered the cost of transporting coal from Wyoming's Powder River Basin electric power plants in the Midwest and as plant operators adapted boilers to different types of coal.

14 CAIR (see <www.epa.gov/cair/index.html>), CAMR (see <www.epa.gov/air/mercuryrule>), CAVR (see <www.epa.gov/oar/visibility/index.html>).

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EPA-430-R-06-015
October 2006

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