The Acid Rain Program and Environmental Justice:

Staff Analysis

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

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Executive Summary

This staff paper analyzes the impacts of the Acid Rain Program (ARP) on people of different races, ethnicities, and income levels. Federal agencies are directed by Executive Order 12898 (issued in February 1994) to identify and address, as appropriate, disproportionately high and adverse human health or environmental effects of their programs, policies, and activities on minorities and low income populations.

Congress passed the ARP in 1990 as part of a major overhaul of the entire Clean Air Act. Since then, the program has reduced sulfur dioxide (SO_2) and nitrogen oxide (NO_x) emissions 32% and 37% respectively from the power industry nationwide, reduced acid deposition, and improved air quality in broad swaths of the country. In addition, some acidified lakes and streams in the East are beginning to show signs of recovery. This staff analysis examines how trading of SO_2 emissions under the ARP has affected emissions at various geographical scales (e.g., national, regional, and local) and uses emissions, air quality, and health exposure modeling to estimate the benefits of full implementation of the ARP in 2010 on minority and low income communities.

Analyses of SO_2 emissions trading under the ARP show areas with the highest emissions prior to the program had the largest emission reductions. This occurred at both regional and individual plant-level scales; the largest emission reductions occurred in the Midwest (where emissions were highest) and the sources with the largest emissions before the program tended to reduce emissions the most. Perhaps more importantly, even in areas where emissions increased at some plants, monitoring data suggests that air quality in those areas still improved due to a large overall reduction in regionally-transported air pollution as a result of the ARP. There have been no violations of the SO_2 health-based national ambient air quality standard since at least 2000.

Although the ARP was enacted to reduce acid deposition, it has also benefited public health due to reductions in fine particle concentrations. This is because SO_2 and NO_x emissions react in the atmosphere, often far from their sources, to form fine particle pollution ($PM_{2.5}$). Exposure to $PM_{2.5}$ is known to be associated with many heart and lung illnesses, as well as premature death. It is important that any analysis of the human health impacts of the Acid Rain Program include an analysis of air quality as impacted by sources at both local and regional scales. This report contains air quality modeling analyses using two different methodologies to estimate the changes in exposure of minority and low-income populations to ambient concentrations of $PM_{2.5}$ as a result of the ARP. Both analyses show that, in 2010, each racial, ethnic, and income-level group studied received similar average improvement in $PM_{2.5}$ in the eastern U.S. (where the vast majority of the emission reductions took place) as a result of the ARP. No disproportionately high and adverse human health or environmental effects of the Acid Rain Program were found for any minority, low-income, or other population.

Finally, since air pollution comes from many diverse sources and affects people both close to and far from its sources, EPA uses a number of programs and provisions to protect and improve air quality. The Clean Air Act directs EPA and the States to operate a suite of programs, of which the ARP is only one, to ensure that air quality in all areas protects everyone's health and welfare. The National Ambient Air Quality Standards are in place for all areas of the country to ensure that everyone's air is safe to breathe. In addition, EPA recently promulgated the Clean Air Interstate Rule (CAIR) to further reduce SO_2 and NO_x emissions from ARP sources in the East and the Clean Air Visibility Rule (CAVR) to reduce SO_2 and NO_x emissions in the West. These new programs, several recent mobile source rules, and State actions to bring areas into attainment with the NAAQS, will continue to improve air quality for all people in the future.

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President Bill Clinton issued Executive Order 12898 in February 1994, directing federal agencies to begin:

"...identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations..."[1]

Executive Order 12898 gives federal agencies discretion as to how to conduct environmental justice analyses. EPA's guidance, while defining environmental justice as "fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies,"[2] also leaves analytical discretion to individual offices and programs.

This paper explores environmental justice issues related to the Acid Rain Program (ARP), a national program to decrease acid deposition by reducing emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO_x) from power plants. The analysis focuses on the SO_2 portion of the ARP because it is implemented through a cap and trade mechanism that does not require specific emission reductions at any particular source. Instead, it enforces a national cap on emissions (which is significantly lower than emissions at the time) and allows sources to trade amongst themselves as long as aggregate emissions do not exceed the cap. The ARP is analyzed regularly, and all evidence indicates it has been providing widespread air quality improvements to the public at large. Emissions have gone down, acid deposition has been reduced in the most sensitive areas of the country, and there have been no violations of the SO_2 health-based national ambient air quality standard since at least 2000[3]. This indicates that the ARP works in conjunction with other programs and provisions to provide clean air for all people to breathe.

While there is no evidence that this cap and trade mechanism has led to increased human exposure to air pollution, the Clean Air Markets Division (CAMD) has never investigated whether the ARP could cause or contribute to environmental injustices. It is important, therefore, that we assess 1) how trading of SO_2 emissions under the ARP might affect the minority and low-income communities described in Executive Order 12898 and 2) how trading of SO_2 emissions has impacted emissions at both a regional and a local scale. These issues will be especially important as EPA and the states continue to implement new programs that will extend the use of cap and trade to address new problems and to reduce additional pollutants.

This paper concludes that the large emissions reductions required by the emission cap, coupled with the regional nature of fine particle pollution from power plants, have produced large air quality improvements for all people living in the eastern U.S. This conclusion is based on two analyses investigating the change in average air quality for members of racial, ethnic, and income groups as well as a local-scale analysis of the air quality implications of emission increases in one area.

The Acid Rain Program

In the 1990 Clean Air Act Amendments (CAA), Congress required the ARP SO_2 program to reduce emissions to half of 1980 levels, capping them at 8.95 million tons per year by 2010. In 2003, emissions were 10.6 million tons, a 32% reduction in annual emissions from 1990 levels and a 38% reduction from 1980 levels.[4] Emissions in 2003 were higher than the cap, because sources reduced more than required in the early years of the program and built up a bank of available emission allowances. A more detailed explanation of cap and trade and the ARP is below.

Congress did not cap emissions of NO_x from power plants; rather, the NO_x portion of the ARP requires coal-fired power plants to limit their NO_x emissions to specific rates (expressed as pounds of NO_x per million British thermal units (Btu) of heat input). It seeks to achieve a 2 million ton annual reduction in NO_x emissions from what emissions would have been without the program in 2000, a goal it has achieved every year since 2000. Emissions of NO_x were 4.1 million tons in 2003, a 37% reduction from 1990 levels.[4]

These emission reductions of SO_2 and NO_x have led to improved air quality (especially lower concentrations of fine particles) and reduced acid deposition. In addition, some acidified lakes and streams in the East are beginning to show signs of recovery. Although the program affects power plants throughout the U.S., most of the emission reductions, and therefore most of the environmental improvements, have taken place in the eastern half of the U.S. where most of the largest (and highest-emitting) coal-fired power plants are located.[4]

As both the structure of the ARP SO_2 program and how this program fits with other provisions of the Clean Air Act are key to this analysis, it is important to discuss several elements of the ARP and its relationship to the rest of the Clean Air Act before describing the results of the environmental justice analyses.

Cap and Trade under the ARP

The ARP has a permanent annual emission cap on the total amount of SO_2 power plants can emit. Each source is allocated SO_2 "allowances," and each allowance authorizes the source to emit one ton of SO_2. While aggregate national emissions cannot exceed the total number of allocated allowances (the cap), sources can meet their legal obligation under the program by either reducing emissions or purchasing allowances from other sources that reduce emissions below their allocations. At the end of the year, sources with unused allowances may sell them or bank them for future use, while sources needing extra allowances can purchase them through the market. Trading in the ARP is used to increase flexibility and achieve emission reductions at lower cost, but it is the cap, in concert with the National Ambient Air Quality Standards (see below), that ensures the environmental goals of clean air and less acid deposition are met.

Accountability

Access to information about pollution is considered critical to environmental justice and to meeting the requirements of Executive Order 12898. The ARP has also considered it crucial to its programs from the very beginning and has collected and reported emissions data from affected sources since the program's inception. In order to know whether any cap and trade emission reduction program is successful, emissions must be measured accurately and credibly. In the cap and trade program, SO_2 emission allowances are a commodity that can be bought and sold, making accurate and credible emissions measurement an important foundation for the allowance market. Emissions are measured hourly by each source and reported quarterly to EPA, where they can be accessed on the EPA website at *www.epa.gov/airmarkets*. The penalties for not monitoring emissions accurately are both automatic and stringent, providing a strong incentive for sources to comply while protecting the integrity of the cap. In addition to the raw data available on the web, EPA reports emission levels, air quality, and environmental changes related to the ARP and reports progress to the public regularly.[4] This information collection and dissemination reflects the important environmental justice value of making reliable information about environmental matters more readily available.

Part of the Clean Air Act

The CAA is a suite of programs designed to ensure that all areas meet health-based air quality goals by regulating emissions from multiple sources using a variety of mechanisms. These include such programs as:

- National Ambient Air Quality Standards (NAAQS), which set standards for six criteria pollutants, including SO_2 and $PM_{2.5}$
- State Implementation Programs (SIPs), which describe how a state will meet the NAAQS
- New Source Review and New Source Performance Standards, which ensure that new or significantly modified power plants and other stationary sources or air pollution will be cleaner than older, retiring sources and will not impede progress toward attaining the NAAQS
- Mobile source controls

The ARP works closely with other aspects of the CAA, particularly the NAAQS program that sets the ambient air quality standards to protect everyone's health. State compliance with the NAAQS will guarantee that no minority, low-income, or any other population will experience disproportionate and adverse human health or environmental effects as a result of programs aimed at lowering criteria pollutant emissions. Although the ARP was not designed to help attain the NAAQS, it has resulted in large reductions in fine particle concentrations throughout the eastern U.S., including in non-attainment areas. Therefore, public health is protected through federal efforts to reduce long-range transport of pollution (such as through the ARP) and state and local efforts to achieve the NAAQS by reducing local sources of pollution (such as through siting and operating permits for sources). Sources covered by the ARP are also subject to the other applicable CAA requirements; for example, the ability of a source to buy allowances under the ARP does not alter the requirement that every area must meet the NAAQS or alter any emission limits set under a SIP.

Analysis of Effects of the ARP on Minority and Low-income Population Exposure to $PM_{2.5}$

By reducing SO_2 and NO_x emissions, the ARP has also reduced the formation and long-range transport of fine particle pollution ($PM_{2.5}$) throughout the East. SO_2 and NO_x react in the atmosphere to form sulfates and nitrates, which are significant components of $PM_{2.5}$. $PM_{2.5}$ is known to cause many different kinds of heart and lung problems, including chronic bronchitis and heart attacks, and can cause premature death. The broad regional reduction in $PM_{2.5}$ is the most important health benefit achieved from implementation of the ARP.

The initial step of this analysis was to develop scenarios of emissions and air quality for two scenarios: with the ARP and without the ARP. We had developed these scenarios for an analysis of the health benefits of the ARP, and we used the emissions and air quality data from that analysis to consider the influence each scenario would have on various population groups.[5]

Emissions of NO_x and SO_2 and $PM_{2.5}$ concentrations in 2010 for the following two scenarios were modeled. The 2002 Integrated Planning Model (IPM)[a] was used for SO_2 and NO_x emissions and the Regulatory Modeling System for Aerosols and Deposition (REMSAD) was used for $PM_{2.5}$ concentrations:[b]

1) *Without the ARP* – This scenario includes all existing and new source emission control standards for SO_2 and NO_x set before 1990. This scenario takes into consideration the retirement of old facilities and NSR requirements for new facilities, a growing demand for electricity in the future, and a less efficient NO_x control technology option for future compliance with the NAAQS. It does not consider the ARP SO_2 emissions cap or NO_x standards. Emissions of both pollutants would be expected to increase between 1990 and 2010 in the absence of the ARP.

2) *With the ARP* – This scenario includes the ARP SO_2 emissions cap with trading and banking and limits on NO_x emissions, as prescribed by the ARP legislation. It also includes several available fuel switching and emission control options, as well as combustion control options available for the ARP NO_x compliance. This scenario is expected to decrease annual SO_2 emissions by 50% and annual NO_x emissions by 30% from what they would have been without the ARP.

Modeling of emissions and air quality enable us to isolate the specific effect of the ARP on atmospheric concentrations of $PM_{2.5}$. Modeling also enables us to look at the projected impact of the ARP in the future (e.g., when it is fully implemented in 2010). EPA, therefore, conducted detailed modeling of the impact of the ARP on minority and low income populations and compared the improvements in $PM_{2.5}$ concentrations that these groups are expected to receive as a result of the ARP to improvements that other groups are expected to receive. These analyses

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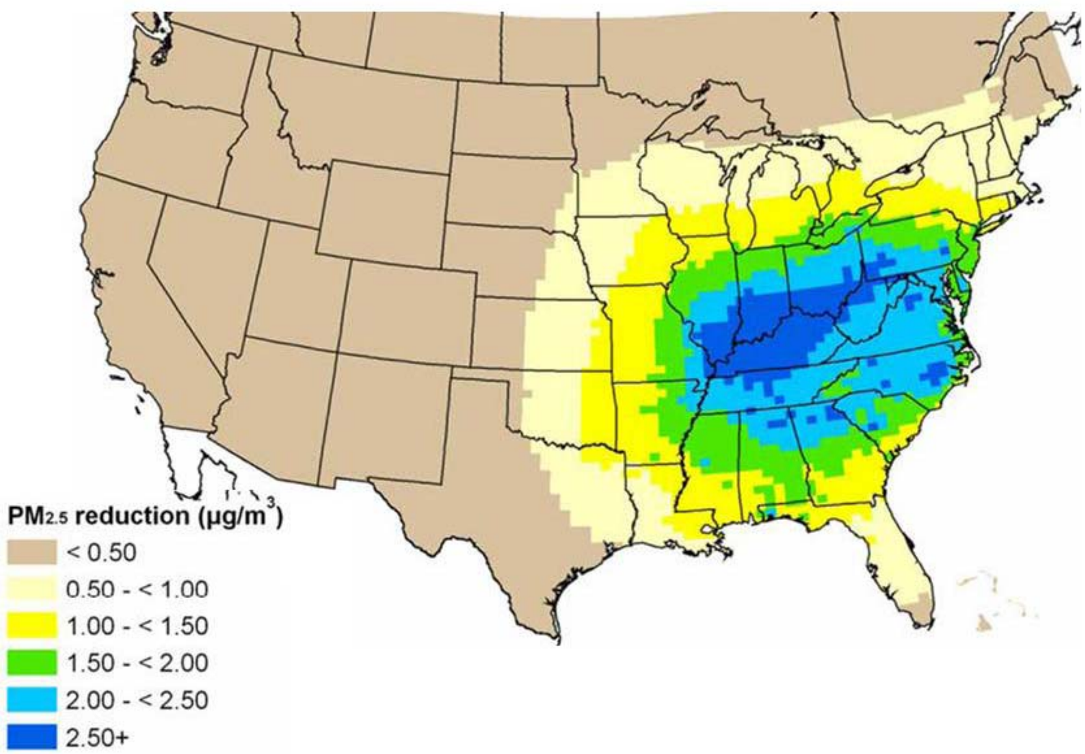
[a] IPM is a multi-regional model of the U.S. power sector that projects emissions and costs. The model has been used extensively to support major rules affecting the power industry and other assessment activities. The model and the assumptions were reviewed by the EPA Science Advisory Board during their review of the Section 812 CAAA Prospective Study. The model also received detailed review in conjunction with the Energy Information Agency's National Energy Modeling System in 2003 by the President's Council of Economic Advisors and was further improved as a result. More information on IPM can be found at *http://www.epa.gov/airmarkets/epa-ipm/*

[b] REMSAD is an air quality model that estimates the transport and transformation of emissions into ambient $PM_{2.5}$ concentrations. The model uses a 36 by 36 kilometer grid covering the continental United States as well as some areas offshore. This model has been reviewed and used extensively to support major rules affecting the power industry as well as for Total Maximum Daily Load (TMDL) analyses. More information on REMSAD can be found at *http://resmad.saintl.com*.

showed that the ARP did not degrade air quality for *any* population group and that all groups received similar improvements.

Figure 1 displays the change in $PM_{2.5}$ concentrations due to the ARP ("With the ARP" compared to "Without the ARP"). This gives an estimated change in exposure to $PM_{2.5}$, indicating where the main $PM_{2.5}$ improvements occurred. All areas experienced improvements in $PM_{2.5}$ due to the ARP. This map shows that the greatest improvements occurred in the Midwest and radiated out from there across the eastern U.S., with much lower levels of improvement in the West. These modeling results are consistent with the location and magnitude of emission reductions from power plants under the ARP.

Figure 1: Projected Reduction in Annual $PM_{2.5}$ Concentrations in 2010: "With the ARP" Compared to "Without the ARP"



Source: EPA REMSAD Modeling, 2002

Methods for Estimating the Impact on Minority and Low Income Populations

Using the geographic changes in $PM_{2.5}$ concentrations across the U.S. resulting from the ARP in 2010, EPA took two slightly different approaches to analyze the potential impact of the program on $PM_{2.5}$ concentrations for minority and low-income populations in 2010.[6,7] The main differences between the analyses are summarized in Table 1.

Table 1. Methodology Comparison between Environmental Justice Analyses A and B

Analysis A	**Analysis B**
1. Scope: Divided into eastern and western by longitude -98.5	1. **Scope:** 31 eastern states
2. **Census data:** Block data (race), County data (income), 2010 projections (Woods and Poole)	**2. Census data:** Census tract data, 2000 data
3. **Race Variables:** Number of African American, Asian, Caucasian, Native American, and "Other" at the block-level; Number of Hispanic and Non-Hispanic at the block-level	**3. Race Variables:** Percent of the population that is white and percent non-white calculated for each tract and compared to the state average
4. **Income Variables:** Number of people above and below the poverty line at the county level	4. **Income Variables**: Percent above and below the poverty level calculated for each tract and compared to average poverty rate in the eastern states studied
5. Analytical Methods: Estimated average change in exposure to $PM_{2.5}$ for each group	5. **Analytical Methods:** Conducted regression analysis with change in $PM_{2.5}$ as the dependent variable

Scope

Because emissions from power plants in the West are quite low relative to emissions in the East, both analyses isolated the impact in the East. In Analysis A, EPA produced nationwide results and results for the East and West separately.[c] This showed that there was a large difference in air quality improvements between states in the East and West. Analysis B was limited to 31 eastern states, where most of the change took place.[d]

Census Data

The two analyses used census data from different years. Analysis A used 2010 population projections (based on 2000 census data) developed by Woods and Poole, while Analysis B used data from the 2000 census.

The REMSAD air quality grid does not directly match up with the geographical units of census data, so each analysis also had to assign air quality concentrations to census units. For the

[c] In Analysis A, the eastern U.S. is defined as those areas East of -98.5 longitude (a line that runs from roughly central North Dakota south through the Great Plains states to west Texas).

[d] Alabama, Arkansas, Connecticut, Delaware, District of Columbia, Florida, Georgia, Illinois, Indiana, Iowa, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, New Hampshire, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Rhode Island, South Carolina, Tennessee, Vermont, Virginia, West Virginia, Wisconsin

analysis on race, Analysis A used projected 2010 data for census blocks, the smallest geographical area, bounded by visible borders, for which census data are collected.[e] For the analysis on income, Analysis A used county-level data. Analysis B used 2000 data for census tracts, small statistical subdivisions of a county originally designed to have between 2,500 and 8,000 people and to be homogeneous with respect to population characteristics, economic status, and living conditions.[f]

Race Variables

For Analysis A, racial categories included African Americans, Asians, Caucasians, Native Americans and Others (group that encompasses all other races). Hispanics and non-Hispanics were also considered.

For Analysis B, the percentage of the census tract population that is nonwhite was calculated. In addition, the tract was identified as "minority" if the resulting percentage was higher than the average percentage minority for a respective state. This was used to compare areas with higher numbers of minorities to areas with lower numbers of minorities.

Income Variables

For Analysis A, the number of people above and below the poverty line at the county level was used to define low and high income categories, respectively.[g]

For Analysis B, the percentage of each census tract population below the poverty threshold was calculated. In addition, the tract was identified as "poor" if the resulting percentage was higher than the average percentage of population under the poverty threshold for the eastern U.S.

Analytical Methods

Analysis A tallied average change in each population group's exposure to $PM_{2.5}$ due to the ARP.

Analysis B ran statistical regressions relating the change in $PM_{2.5}$ concentrations with the demographic variables to evaluate whether poverty or race was associated with changes in air quality. The poor and minority variables were used in separate regressions because they were highly correlated. State dummy variables were added to account for between-state variation. Statistical significance was calculated at the 99% level. Regressions were run and coefficients calculated for the following:

- Tract below poverty percentage (eastern average)
- Tract below nonwhite percentage (state average)

[e] There are 5,127 square grid cells in the REMSAD modeling domain.

[f] Census tracts that straddle more than one REMSAD grid cell were assigned weighted averages based on the proportion of the tract in each cell. This assumes population is distributed evenly throughout the census tract.

[g] Note that since the grid cell and county boundaries are not nested, two rules were developed to calculate the poverty data for each grid cell: (1) If a grid cell falls completely with a county, the poverty data for that county were used, and (2) For those grid cells falling in multiple counties, a population-weighted average of the percentage of people below and above poverty line in the counties were used.

Results

Despite variations in methods used, both analyses had similar results. First, both analyses show that the aggregate improvement in $PM_{2.5}$ is similar for all groups studied. The projected annual average reduction in $PM_{2.5}$ concentration for the eastern U.S. in 2010 under the ARP is approximately 1.5 $\mu g/m^3$ for Analysis A and 1.6 $\mu g/m^3$ for Analysis B.[h] As we will describe later, any small differences in exposure to $PM_{2.5}$ that occurred between the population groups appear to be very small compared to the overall improvements for everybody.

Overall, the results of both Analysis A and Analysis B indicate that the ARP has been effective in achieving its intended results – broad regional reductions in air pollution for all Americans.

- The ARP improved air quality substantially overall.
- The ARP improved air quality substantially for each population group.
- No disproportionately high and adverse human health or environmental effects were found for minority or low-income groups.

Analysis A

Table 2 shows the population-weighted average exposure change for $PM_{2.5}$ for the many population groups studied in Analysis A. It also presents the population-weighted average percentage change in $PM_{2.5}$ exposure. In general, $PM_{2.5}$ improvements were much more significant in the East compared to the West, mainly because there are more power plants in the East.

When interpreting the results in Table 2 for the entire country, one should note that the largest numbers of Hispanic and Native American census tracts are in the West. These groups tend to live in areas where pollution from ARP sources is low and, thus, tend to have lower exposure to $PM_{2.5}$ from ARP sources with or without the ARP. They do, however, seem to receive the greatest benefit from the ARP in the West compared to the other groups analyzed.

[h] The differences between the change in exposure for the two analyses is due to different methods of assigning air quality to the population using census data identified in Table 1.

Table 2: Absolute and Percentage Decrease in $PM_{2.5}$ Levels in 2010 by Race, Ethnic and Income Group

		Population Weighted Average Absolute Change (ug/m^3)			Population Weighted Average Percentage Change (%)		
Category	Group	All US	Eastern US	Western US	All US	Eastern US	Western US
All	All	1.1	1.5	0.04	7.9	10.2	0.9
Race	African American	1.4	1.6	0.03	8.9	9.8	0.6
	Asian	0.8	1.4	0.01	4.7	8.3	0.3
	Caucasian	1.1	1.5	0.05	8.2	10.4	1.1
	Native American	0.7	1.3	0.06	5.8	9.8	1.5
	Other	0.6	1.2	0.03	4.2	7.7	0.8
Ethnicity	Hispanic	0.6	1.2	0.04	4.7	7.8	1.03
	Non-Hispanic	1.2	1.5	0.04	8.4	10.4	0.9
Income	Below Poverty	1.1	1.5	0.04	7.7	10.1	1.1
	Above Poverty	1.1	1.5	0.04	7.9	10.2	0.9

Source: McCubbin et al., 2005.

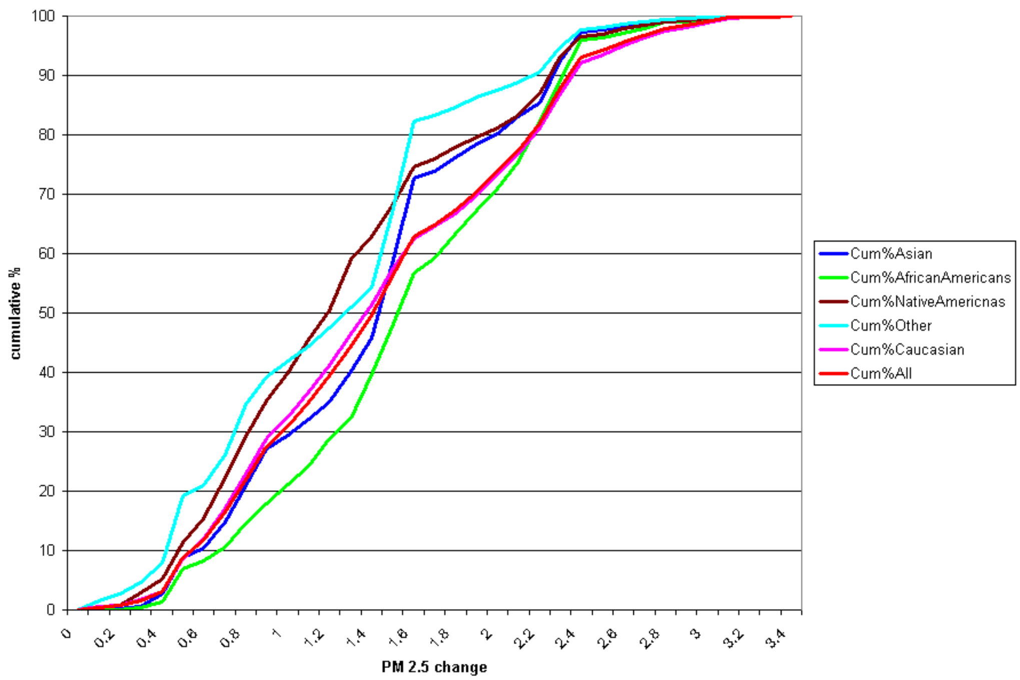
The rest of this discussion focuses on results for the eastern U.S., where $PM_{2.5}$ pollution from power plants was higher prior to the program and where improvement was both needed and achieved.

Analysis A found that of the various racial groups all received significant, yet slightly different, improvements in $PM_{2.5}$ concentrations that were of similar magnitude. Improvements ranged from 1.2 to 1.6 µg/m^3, including:

- African Americans (1.6 µg/m^3)
- Caucasians (1.5 µg/m^3)
- Asians (1.4 µg/m^3)
- Native Americans (1.3 µg/m^3)
- Hispanics (1.2 µg/m^3)

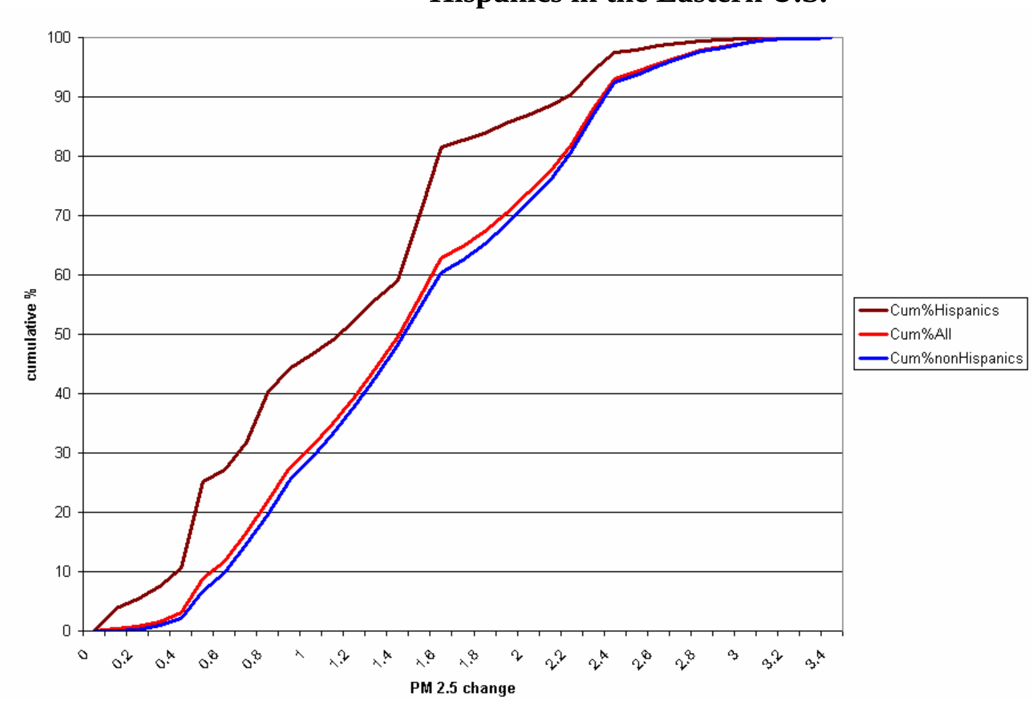
Figures 2 and 3 show the cumulative distribution of the change in $PM_{2.5}$ by race and by Hispanic/Non-Hispanic, respectively. These figures show that all members of all groups received at least some benefit from the Acid Rain Program and that large portions of each group received large improvements in air quality due to the ARP.

Figure 2: Cumulative Distribution of the Decrease in $PM_{2.5}$ (ug/m^3) by Race in the Eastern U.S.



Source: McCubbin et al., 2005

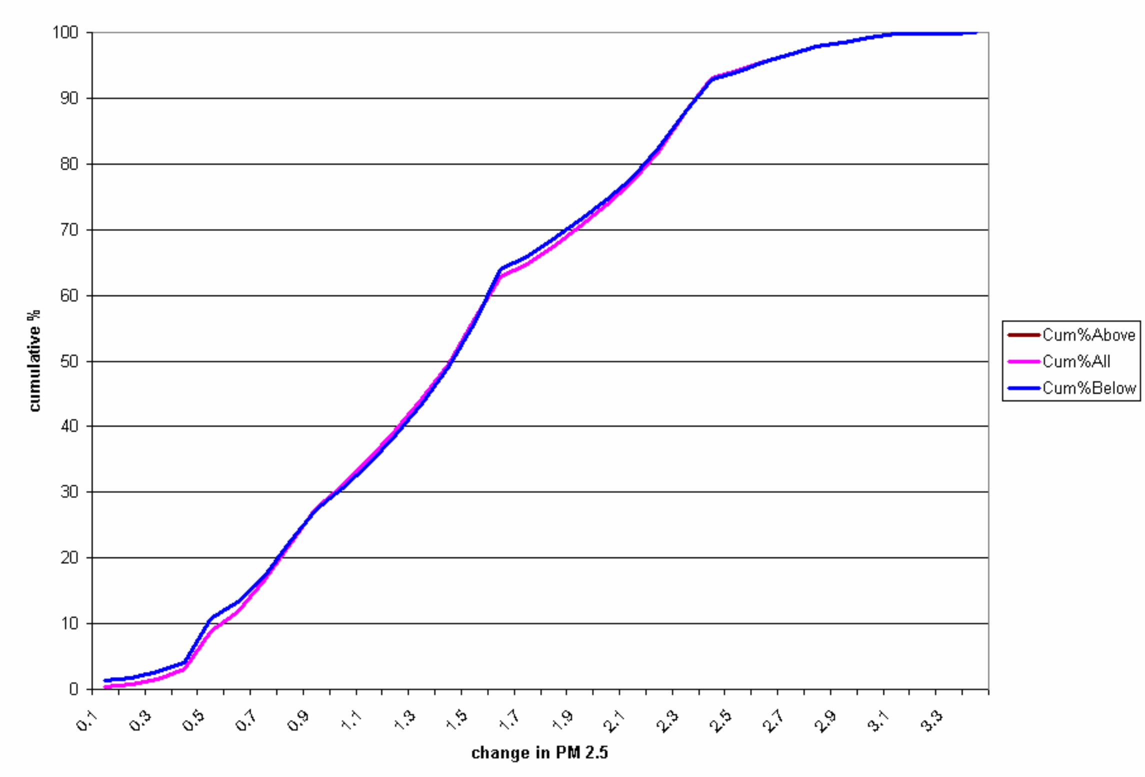
Figure 3: Cumulative Distribution of the Decrease in $PM_{2.5}$ (ug/m^3) for Hispanics and Non-Hispanics in the Eastern U.S.



Source: McCubbin et al., 2005

The analyses of the impacts of the ARP on people below the **poverty** line in Analysis A show that both poor and nonpoor groups received significant – and equal – improvements. Both poor and nonpoor received improvements of 1.5 $\mu g/m^3$ each. Figure 4 shows the cumulative distribution of the change in $PM_{2.5}$ for people above and below the poverty line in the Eastern U.S. This graph shows that improvements were nearly identical for people above and below the poverty line.

Figure 4: Cumulative Distribution of the Decrease in $PM_{2.5}$ (ug/m^3) for Individuals Below and Above the Poverty Line in the Eastern U.S.



Source: McCubbin et al., 2005

Analysis B

Analysis B compared census tracts that were above the average state-level percent minority population to tracts that were below the average. It also compared census tracts that were above the eastern average for percentage in poverty to those below the eastern average. The analysis found that tracts with a higher percentage of minorities or poor people have received slightly greater reductions in $PM_{2.5}$. The differences were very small compared to the overall average improvement that all groups received. However, they were statistically significant. This indicated that, if anything, minorities and poor people received greater benefits from the program.

When Analysis B accounted for the fact that there are similarities within a state with respect to air quality improvements, there appeared to be a high correlation between percent of minority population in a tract and $PM_{2.5}$ improvements.

Limitations to the Analysis of 2010 ARP Projections

This analysis is based on modeled forecasts of changes in power plant emissions in 2010 as a result of the ARP compared to the hypothetical of emissions that would have occurred if the program had not been implemented. The accuracy of these analyses is dependent on the accuracy of the various models and the assumptions built into the models.

Overview Analysis of the Acid Rain Program

To supplement modeled projections of the impact of the ARP in 2010, we also include in this report analyses of how emissions have already changed since the ARP was passed by Congress in 1990.[i] We focus here on the SO_2 component of the program to understand, specifically, the impact of emissions trading on local communities.

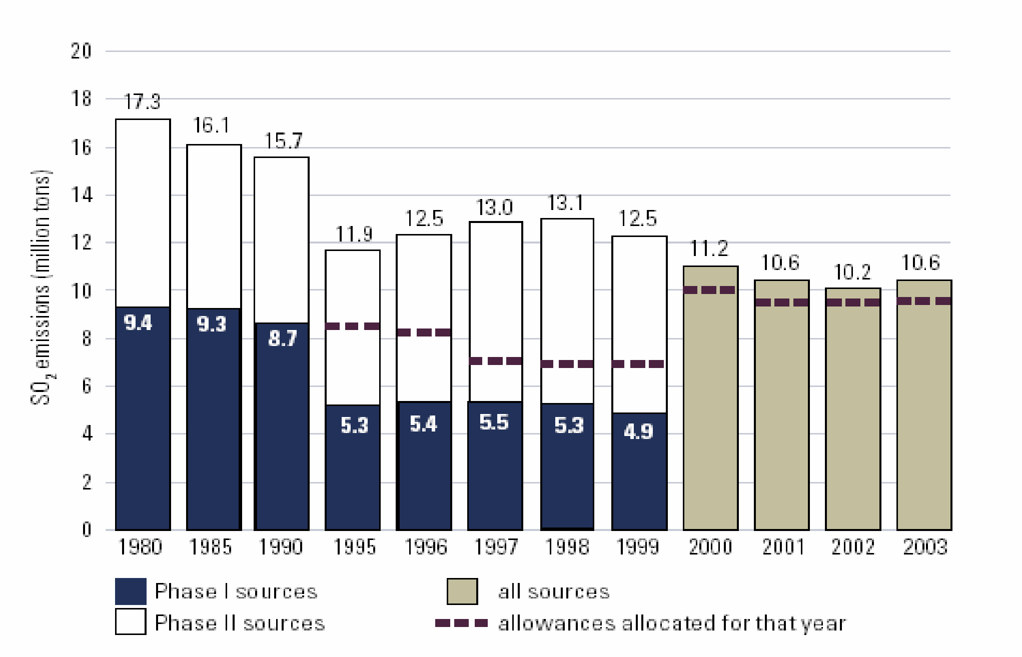
In the past, most of EPA's assessments of the ARP have focused on national and regional level results because the ARP's goals were national in scale. However, because local increases in emissions could have implications for various population groups, we examine the regional, state, and local level. Emissions analyses are best used as an initial screening assessment to identify plants and regions that might require further study. Because SO_2 emissions are transported regionally, the location of emission increases is not a good indicator of the location of the air quality and health impacts of those emissions.

National Emissions Have Been Reduced 32% from 1990 Levels

The ARP successfully reduced emissions at the national level. In 2003, annual national SO_2 emissions were 38% lower than 1980 levels and 32% lower than 1990 levels (see Figure 5). These reductions occurred despite a substantial nationwide increase in power generation at these sources.

[i] In this report, 1990 is used as a baseline for analyses of emissions because that is the year the ARP was signed into law. The Acid Rain Program was implemented beginning in 1995. Using a year prior to 1995 as a baseline is important because many plants reduced emissions beyond expectations prior to 1995 in anticipation of the program.

Figure 5: National SO_2 Emissions under the ARP



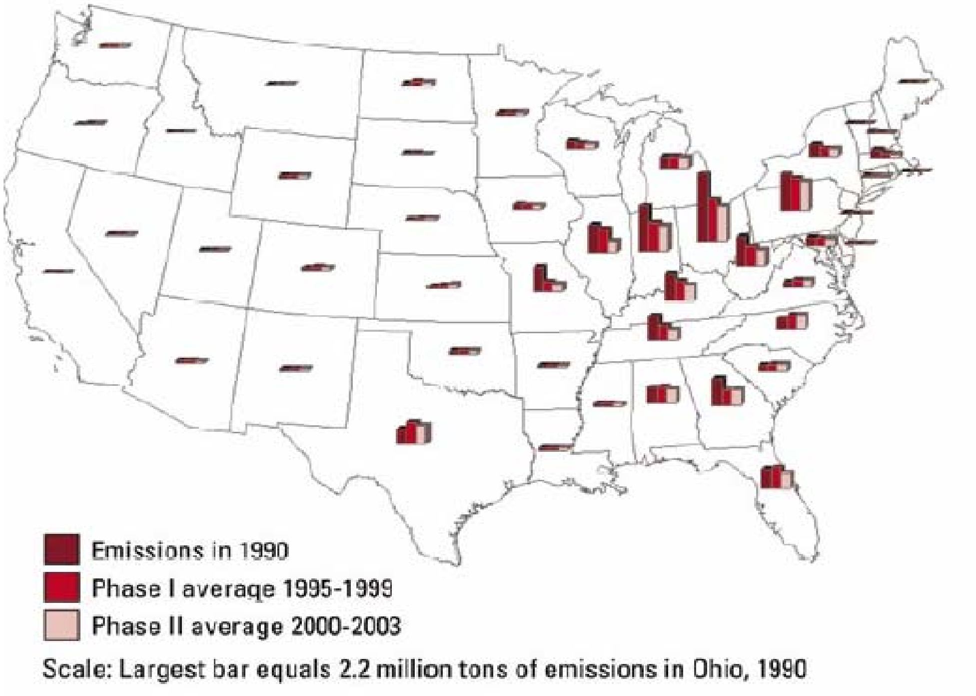
Source: EPA, 2004

Regions and States with Highest Emissions Prior to the ARP Reduced the Most

Before the ARP began, some were concerned that the large coal plants of the Midwest would purchase allowances and increase emissions under the program, adding to poor air quality and acid rain throughout the Midwest and Northeast. Researchers at the Environmental Law Institute, Massachusetts Institute of Technology, and Environmental Defense have found that, generally, the opposite has occurred. Most of the SO_2 reductions have occurred at large units – particularly those burning high sulfur coal in the Midwest – because that is where the cheapest reductions were available.[8,9] Also, most allowances in the early years of the program (Phase I) were used in the state where they were issued, indicating that there were not large shifts in emissions across the regions.[10]

EPA analyses comparing 1990 emissions to an average of Phase II (average of 2000-2003) emissions also found that states with high emissions prior to the program were most likely to achieve deep reductions. Figure 6 shows that most of these states with high emissions prior to the ARP are located upwind of the areas the ARP was designed to protect. Reductions in these states resulted in important environmental and health benefits over a large regional scale. In addition, the states that reduced emissions had large annual reductions, while the states that had increased emissions – largely attributable to growth and not increases in emissions rates – had much smaller annual increases. The states with the greatest reductions were in the Midwest and included Ohio, Illinois, Indiana, and Missouri.

Figure 6: State-level SO_2 Emissions



Source: EPA, 2004

Plants with the Highest Emissions Prior to the Program Generally Achieved Greatest Reductions

It is not surprising that some of the plants under the ARP increased emissions while others decreased emissions because there is no requirement under a cap and trade program for any one power plant to reduce emissions as long as emissions from all sources are reduced. If the lowest emitting sources increase emissions by a small amount, it is unlikely that such increases would cause significant impacts on the local air quality. This is because the program has resulted in large regional reductions in emissions. However, if some sources increase emissions substantially, there is greater potential that local impacts could occur.

To identify the size of the plants that reduced emissions between 1990 and the 2001-03 average, Figure 7 plots annual SO_2 emissions for each plant in 1990 versus the change in emissions at that plant during the ARP (between 1990 and 2001-03).[11] The red line indicates emissions reductions that would have occurred if all sources had reduced the same amount (approximately one-third from 1990 levels). Dots above the line represent the plants with less than average emission reductions, while dots below the line represent the plants with greater than average reductions.

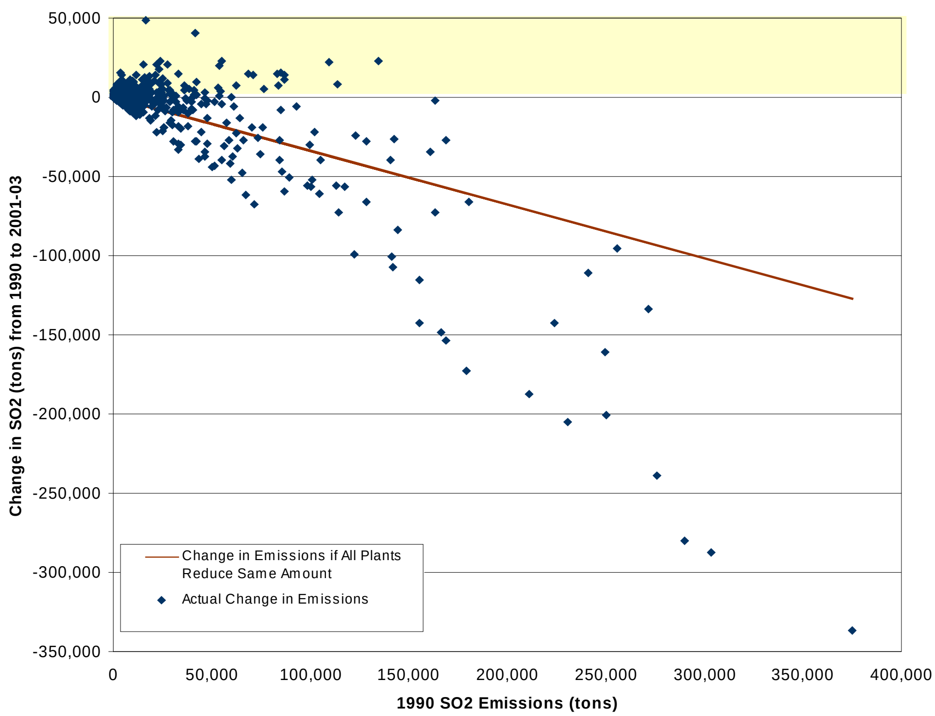
The results of this analysis include:

- The plants with the highest emissions in 1990 tended to reduce their pollution the most.
- Some plants (those plotted in the yellow area of the figure) increased emissions. These plants tended to have lower emissions in 1990 (under 100,000 tons).

- Plants that had high emissions in 1990 were also more likely to reduce beyond what they would have reduced if all plants reduced emissions the same percentage (approximately one-third).

In conclusion, trading under the ARP has generally reduced emissions most at the highest-emitting power plants, while emissions at some smaller power plants have experienced small increases. Plants with the highest emissions in 1990 tended to achieve the greatest tons of reduction and percentage of reduction. This confirms results of studies by external researchers.[8,9,10,1213]

Figure 7: Plant-Level 1990 SO_2 Emissions Compared to Changes in SO_2 Emissions between 1990 and the 2000-03 Average



The red line represents the expected change in SO_2 from 1990 levels if each plant achieved the same percent reduction as the entire universe of affected sources did in aggregate (approximately one-third). This analysis does not include plants that were not in operation in 1990.

Source: EPA, 2004

Case Study: Local Emission Increases in the Study Area Are Balanced Out by Nearby Emission Decreases

For a cap and trade program to achieve positive environmental and health outcomes in all locations, emissions increases in one area must be offset by reductions of at least the same magnitude in a location close enough in proximity to ensure that air quality improves everywhere. The radius within which such “off-setting” reductions must occur differs depending on the pollutant in question and other factors, such as meteorological conditions. To further explore local impacts of trading emissions, EPA also conducted a case study analysis on a particular cluster of Midwestern power plants that increased emissions and could have resulted in elevated local levels of air pollution.

For this case study examining local impacts of the ARP, EPA chose plants that fit the following criteria that could indicate a potential local problem:

1) Had emissions in the top 50 plants for current emissions
2) Increased their emissions between 1990 and the 2001-03 average
3) Did not improve their rates of SO_2 emissions per unit of heat input (SO_2 rates) between 1990 and the 2001-03 average
4) Were clustered with at least one other plant (within 50 kilometers)

While several plants fit one or two criteria, only one pair of plants fit all of these criteria. The two plants are Keystone and Homer City, both located in Pennsylvania.

Using Geographic Information System (GIS) software, buffers were drawn around the Keystone and Homer City plants at various distances (50 km, 100 km, 200 km). We chose 50 km (30 miles) and 200 km (125 miles) using a study by Levy et al.[14], which showed that a significant portion of total population exposure (around half) occurred beyond 200 km of a power plant, while approximately 20% of the exposure occurs within 50 km of the plant.[j] Another study by the same authors found similar results for sulfate and nitrate particles at power plants in the Washington, DC, area.[15] These findings suggest that, while pollution from an individual power plant remains important, reducing total, aggregate emissions within both a 50 and 200 kilometer buffer from a plant is also important for reducing the population’s exposure. In comparison, some other pollutants, such as tiny particles emitted directly from diesel engine vehicles, deposit closer to the sources and affect pollution levels closer to the sources than NO_x and SO_2, which come out of the stack in gaseous form and settle further away from their source.

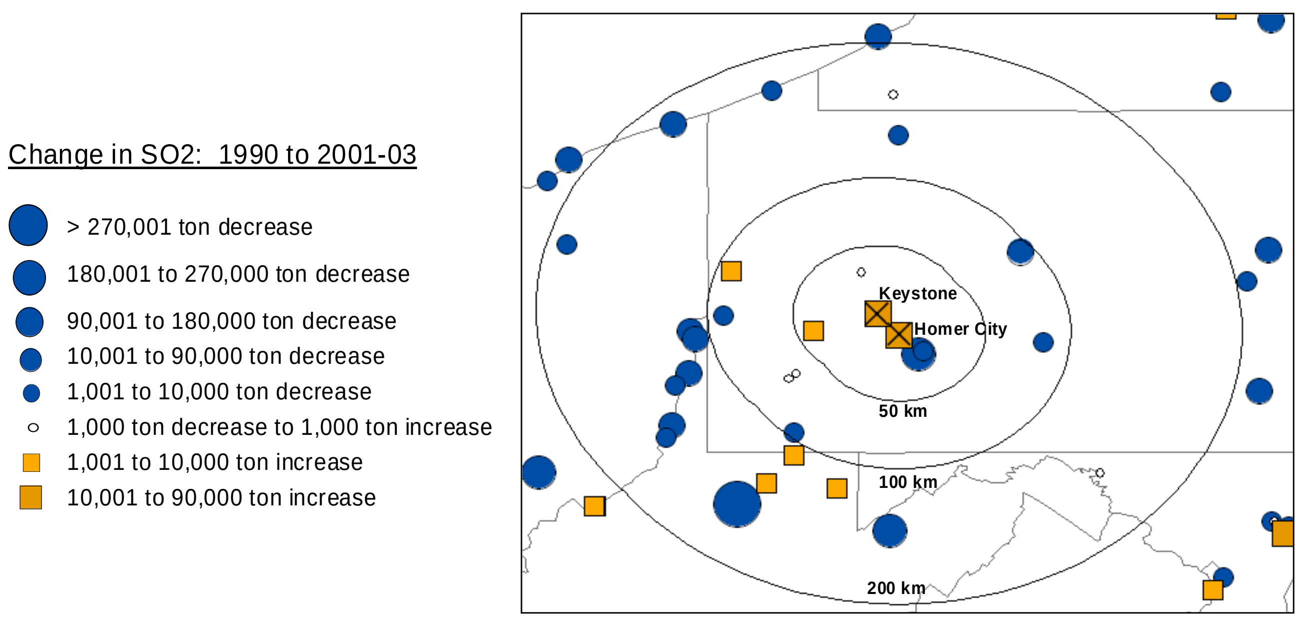
Together, the Homer City and Keystone plants increased emissions by 45,000 tons between 1990 and the 2001-03 average (a 19% increase). Figure 8 shows, however, that this increase occurred in an area where there were many power plants that both increased and decreased emissions

[j] This study used the CALPUFF atmospheric dispersion model to look at the health benefits of installing controls at individual power plants in Illinois to populations living at various distances from power plants. For sulfates, approximately 20% of the total exposure to sulfates (range 1% - 45%) is located within 50 kilometers of the plant. Half of the total population exposure to a plant’s pollution was found to occur beyond 200 kilometers of the plant. While these results are specific to Illinois, they do indicate that the vast majority of the exposure from a given power plant occurs beyond 50 kilometers from the plant and a substantial portion of the exposure occurs even beyond 200 kilometers from the plant.

during this period. For example, the total emissions within a 50 km buffer zone around Homer City and Keystone (including these two plants) were 30% lower on average over 2001-03 than they had been in 1990. This decrease occurred mainly because the Conemaugh plant (located within 50 kilometers of these plants) installed control technology for SO_2 on its two coal-fired units in the mid-1990s. The emission decreases at Conemaugh more than compensated for the increases at Homer City and Keystone. In addition, emissions within a 200 kilometers buffer zone decreased by 41% during the same time period due to reductions at many other plants, most notably Rivesville (WV), Mount Storm (WV), Cardinal (OH), and Ashtabula (OH). In this region of the country, the cap and trade component of the program was extremely effective in reducing emissions, despite some increases at certain plants. As a result, one would expect improvements in air quality and environmental benefits throughout the area.

The Homer City/Keystone case study illustrates the importance of looking broadly when assessing the impacts of emissions from individual power plants. This case study is a "perfect storm" situation where all of the factors that could cause potential problems line up. In addition, it is located in an area of potential concern due to the number of large coal-fired power plants, high concentrations of air pollution, and large population centers. Yet, our analysis indicates that people living in this area had substantially less SO_2 emissions coming from the set of power plants around them after 2000 than occurred in 1990. In addition, the results of comparable analyses in other areas are expected to be similar. Support for this comes from looking at Figure 1 earlier that shows forecasted air quality improvements nationwide although not all power plants in the trading program are lowering emissions.

Figure 8: Homer City and Keystone Case Study: Local Emissions within Various Distances from Power Plants



Source: EPA, 2004

Regional-Scale Air Quality Improved Significantly

While identifying plants and regions that have increased or decreased emissions is important, EPA is most interested in whether air quality actually improved. EPA found that, even in areas where some plants increased emissions, emission reductions throughout the eastern U.S. appear to have resulted in overall improvements in air quality. Data from EPA's Clean Air Status and Trends Network (CASTNET) indicate that SO_2 and sulfate improvements occurred throughout the U.S., even in areas where individual plants increased emissions.

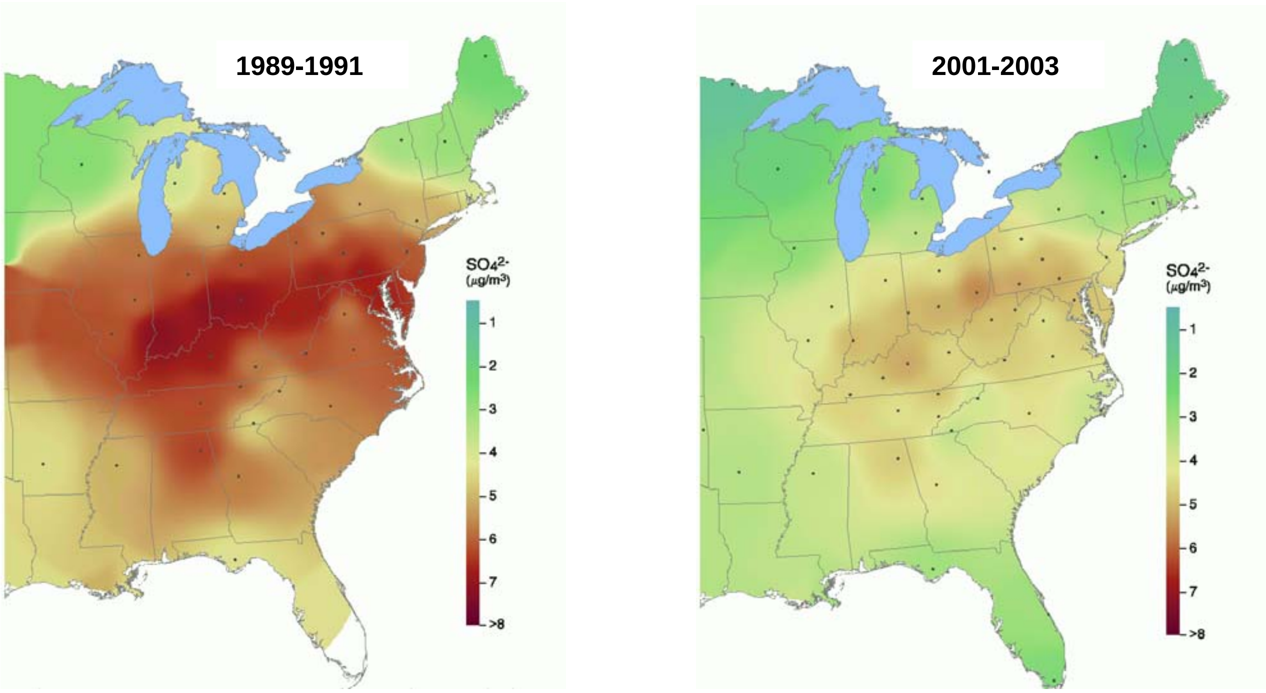
During the late 1990s, following implementation of the ARP, dramatic regional improvements in SO_2 and sulfate concentrations were observed at long-term monitoring sites throughout the eastern U.S. This was not surprising, as reductions in SO_2 emissions can reduce ambient concentrations of both SO_2 and sulfates (as explained earlier, sulfates are a component of $PM_{2.5}$). This is due to the large reductions in SO_2 emissions from Acid Rain sources. Analyses of regional monitoring data from CASTNET show the geographic pattern of SO_2 and airborne sulfate in the eastern U.S.

From 1989 through 1991, prior to implementation of the ARP, the highest ambient concentrations of SO_2 in the East were observed in western Pennsylvania and along the Ohio River Valley. Ambient SO_2 concentrations have decreased significantly since 1991, with average concentrations in the eastern U.S. decreasing 57% in the Northeast and 38% in the Mid-Atlantic region.

Before the program, in 1989 through 1991 (see Figure 9), the highest ambient sulfate concentrations were observed in western Pennsylvania, along the Ohio River Valley, and in northern Alabama. Like SO_2 concentrations, related sulfate concentrations in ambient air have decreased since the program was implemented, with average concentrations decreasing approximately 30% in all regions of the eastern U.S. Both the magnitude of the highest concentrations and the size of the region where they occur were dramatically reduced following implementation of the ARP. The largest decreases were observed along the Ohio River Valley (see Figure 9). Similar results have been shown for wet sulfate concentrations in precipitation.

Because of these improvements in air quality and reductions in sulfur deposition, acidified lakes and streams have recovered in many areas and very substantial human health benefits occurred as people throughout the East were exposed to much lower levels of $PM_{2.5}$.

Figure 9. Mean Ambient Sulfate Concentrations in 1989-1991 and 2001-2003 in the Eastern United States



Source: EPA, 2004

Limitations of these Analyses

EPA has employed well-accepted analytical methods and models in these analyses. However, in any complex analyses using estimated parameters and inputs from numerous models, there are likely to be limitations and sources of uncertainty. These analyses are no exception. As outlined in this report, these analyses used many inputs and tools, including projected emission inventories, air quality models (with their associated parameters and inputs), and population and income estimates. Each of these inputs includes uncertainties but reflect the best available information at the time the analysis was conducted. Each tool has limitations and reflects the uncertainty of its data inputs, but all are well-respected and frequently used in scientific analyses. The Clean Air Markets Division also recognizes that there may be additional approaches and methods used to address this issue.

A potential limitation of these analyses involves the spatial relationship between analytical tools and some aspects of environmental justice impacts. Local scale and environmental justice impacts of the emissions controlled by the Acid Rain Program are a combined consequence of both long-range transport of emissions and those emitted from nearby sources. The two models used in these analyses (IPM to project power plant emissions; the REMSAD air quality model to estimate fine particle concentrations) are well-respected models that have been used for numerous EPA analyses of emissions and air quality impacts from power generation sources. They are best when used to characterize the long-range transport aspects of regional air pollution problems. The 36 km^2 grid size in REMSAD and averaging of values to aggregate up for regional analyses create limitations in capturing smaller-scale gradations in concentration of fine particles and in estimating exposure to pollutants.

In general, analyses relying on the location of power plant emissions as an indicator of their potential health effects may overemphasize the contribution of specific local sources to local-scale health effects, while inadequately accounting for the contribution of long-range transport. This limitation applies to the emissions case study portion of these analyses. The location of power plant emissions is not always a good indicator of the health effects of those emissions. Health effects of power plant emissions depend on factors such as meteorology, wind speed and direction, and stack height of plants, as well as the frequency and duration of human exposure. As already noted, many of the health effects of power plants occur in communities hundreds of miles downwind from specific sources.

Air quality data from the CASTNET monitoring network is provided in these analyses to demonstrate that regional air quality has improved substantially since implementation of the Acid Rain Program. As fine particle pollution is a regional problem, often occurring hundreds of miles from the emissions that caused it, this monitoring network provides an appropriate perspective to characterize the regional impact of emissions changes from power plants. However, the analyses do not include urban air quality monitoring sites and do not fully depict small-scale changes in air quality at locations between monitoring sites, such as those that could occur due to changes in emissions from power plants.

Conclusions

This staff paper shows that the ARP is expected to improve air quality for *all* population groups in 2010 when it is fully implemented and that improvements for each population group will be similar. It shows that the ARP will not have disproportionately high and adverse human health or environmental effects on minority, low-income, or other populations. Moreover, analyses of emission changes from each source demonstrate that cap and trade has been an effective policy tool to achieve the greatest emission reductions at power plants that had the highest emissions of SO_2 in 1990. This has led to large, regional improvements in air quality.

Any discussion of the ARP, however, must consider that it is part of the Clean Air Act, a suite of provisions and programs designed to ensure that all areas meet air quality goals. These include the NAAQS, SIPs, New Source Review, New Source Performance Standards, mobile source controls, and toxic emission control programs, as well as the ARP. If certain plants in the ARP either fail to contribute to air quality improvement in polluted areas or even cause air quality to worsen, these other Clean Air Act provisions and programs are available to ensure that all areas will meet air quality goals. Taken separately, each provision is unlikely to ensure full protection, but together they improve air quality for all Americans.

As an example of this, EPA recently recognized that further reductions in SO_2 and NO_x from power plants are necessary to ensure that the $PM_{2.5}$ NAAQS are met. The goal was not to get rid of the cap and trade mechanism but to reassess the cap and set it at a level that would result in additional emission reductions from plants contributing to lingering air quality problems. Building on the success of the ARP, EPA promulgated a new cap and trade program, the Clean Air Interstate Rule (CAIR), in March 2005 to achieve additional large reductions in emissions of SO_2 and NO_x from power sources located in the eastern U.S. Another recent rule, the Clean Air Visibility Rule, will further reduce emissions of SO_2 and NO_x in the western U.S.

As CAMD continues to implement programs like CAIR to help bring all areas into attainment with the NAAQS, the Division is committed to continuing to evaluate its cap and trade programs. This is essential for both EPA and the public to learn about the successes, challenges, and appropriate uses of such policy tools.

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