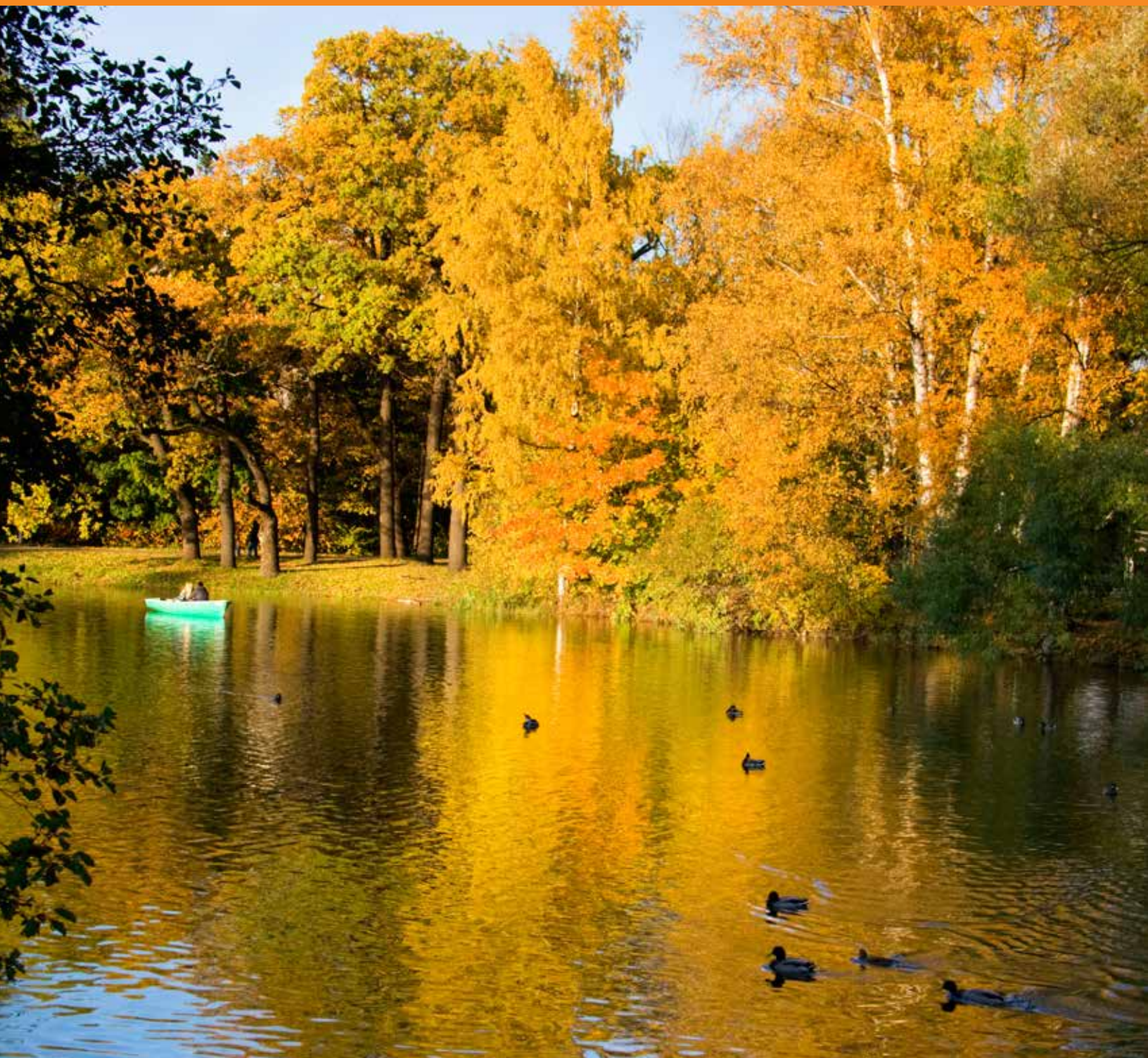
2014 Program Progress

Clean Air Interstate Rule, Acid Rain Program, and Former NO_X Budget Trading Program

Program Basics	Affected Units	Emission Reductions
Emission Controls & Monitoring	Program Compliance	Market Activity
Air Quality	Acid Deposition	Ecosystem Response



Executive Summary

This report summarizes annual progress through 2014 under the Acid Rain Program (ARP), the NO_x Budget Trading Program (NBP), and the Clean Air Interstate Rule (CAIR). Progress under the Cross-State Air Pollution Rule (CSAPR), which went into effect in 2015, is not currently covered in this report, as it presents data from years prior to CSAPR implementation.

A cornerstone of effective emission reduction programs is transparency and data availability. This report highlights data on emissions, compliance, and environmental effects that EPA systematically collects. The success of these programs is highlighted through substantial reductions in power sector emissions of SO_2 and NO_x and improvements in air quality and the environment.

Contents

2014 ARP and CAIR at a Glance

- **CAIR and ARP annual SO_2 emissions:**
  3.2 million tons (69 percent below 2005)
- **CAIR and ARP annual NO_x emissions:**
  1.7 million tons (54 percent below 2005)
- **CAIR ozone season NO_x emissions:**
  450,000 tons (44 percent below 2005)
- **Perfect compliance:**
  100 percent of covered facilities in the ARP and CAIR programs were in compliance
- **Ambient particulate sulfate concentrations:** decreased 64 to 68 percent in observed regions (from 1989–1991 to 2012–2014)
- **Wet sulfate deposition:** Northeast and Mid-Atlantic states saw the greatest improvement (69 percent reduction) from 1989–1991 to 2012–2014
- **Levels of acid neutralizing capacity (ANC):** increased in Adirondack Mountains and Northern Appalachian Plateau lake and stream monitoring sites

Chapter 1: Program Basics

The Acid Rain Program (ARP) and the Clean Air Interstate Rule (CAIR) are cap and trade programs designed to reduce emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO_x) from covered power plants. Both programs were in effect in 2014. The ARP covers power plants across the contiguous United States, while CAIR covered power plants in the East. The NO_x Budget Trading Program (NBP) operated from 2003 to 2008 in the eastern United States during the ozone season (May 1 – September 30) and was replaced by CAIR in 2009. In 2015, EPA's Cross-State Air Pollution Rule (CSAPR) replaced CAIR.

Analysis and Background Information

Acid Rain Program

Title IV of the 1990 Clean Air Act (CAA) Amendments established the ARP to address acid deposition nationwide by reducing SO_2 and annual NO_x emissions from coal-fired power plants. In contrast to traditional command and control regulatory methods that establish specific emissions limitations, the ARP SO_2 program introduced a novel allowance trading system that harnessed the incentives of the market to reduce pollution. This market-based cap and trade program was implemented in two phases. Phase I began in 1995 and affected the most polluting coal-burning units in 21 eastern and Midwestern states. Phase II began in 2000 and expanded the program to include other units fired by coal, oil, and gas. Under Phase II, EPA also tightened the annual SO_2 emissions cap, with a permanent annual cap set at 8.95 million allowances, starting in 2010. The NO_x program has a similar results-oriented approach and ensures program integrity through measurement and reporting. However, it does not cap NO_x emissions as the SO_2 program does, nor does it utilize an allowance trading system. Instead, the ARP NO_x program provisions apply boiler-specific NO_x emission limits–or rates–in pounds per million British thermal units (lb/mmBtu) on certain coal-fired boilers.

NO_x Budget Trading Program

The NBP was a market-based cap and trade program created to reduce NO_x emissions from power plants and other large combustion sources during the summer ozone season to address regional air pollution transport that contributes to the formation of smog (ozone) in the eastern United States. The program was a central component of the NO_x State Implementation Plan (SIP) Call, promulgated in 1998, to help states meet the 1997 ozone air quality standard (known as the National Ambient Air Quality Standard, or NAAQS). All 21 states (20 states plus Washington, D.C.) covered by the NO_x SIP Call participated in the NBP, which operated during the ozone season from 2003 to 2008. In 2009, CAIR's NO_x ozone season program began, effectively replacing the NBP to continue achieving ozone season NO_x emission reductions from the power sector.

Clean Air Interstate Rule

CAIR required 28 eastern states (27 states plus Washington, D.C.) to make reductions in SO_2 and NO_X emissions that contribute to unhealthy levels of fine particulate matter (soot) and ozone pollution in downwind states. CAIR required 25 eastern states (24 states plus Washington, D.C.) to limit annual power sector emissions of NO_x and SO_2 to address regional transport that contributes to the formation of fine particulates. It also required 26 states (25 states plus Washington, D.C.) to limit power sector ozone season NO_x emissions to address regional transport of air pollution that contributes to the

formation of ozone during the ozone season. Similar to the ARP, CAIR used three separate market-based cap and trade programs to achieve emission reductions and to help states meet the 1997 ozone and fine particle NAAQS.

The CAIR NO_x ozone season and annual programs began in 2009, while the CAIR SO_2 program began in 2010. The CSAPR replaced CAIR starting on January 1, 2015.

Cross-State Air Pollution Rule

EPA issued the CSAPR in July 2011, requiring 28 states in the eastern half of the United States to significantly improve air quality by reducing power plant emissions that cross state lines and contribute to fine particle and summertime ozone pollution in other states. The CSAPR requires 23 states to reduce annual SO_2 and NO_X emissions to help downwind areas attain the 2006 24-hour and/or 1997 annual fine particle NAAQS. Twenty-five states are required to reduce ozone season NO_X emissions to help downwind areas attain the 1997 8-hour ozone NAAQS. The final CSAPR divides the states required to reduce SO_2 emissions into two groups (Group 1 and Group 2). Both groups must reduce their SO_2 emissions in Phase I. Group 1 states must make additional reductions in SO_2 emissions for Phase II in order to eliminate their significant contribution to air quality problems in downwind areas.

The CSAPR was scheduled to replace CAIR starting on January 1, 2012. However, the timing of the CSAPR's implementation was affected by D.C. Circuit actions that stayed and then vacated the CSAPR before implementation. On April 29, 2014, the U.S. Supreme Court reversed the D.C. Circuit's vacatur, and on October 23, 2014, the D.C. Circuit granted EPA's motion to lift the stay and shift the CSAPR compliance deadlines by three years. Accordingly, CSAPR Phase I implementation began January 1, 2015, with Phase II to begin in 2017.

Cross-State Air Pollution Rule Update

On September 7, 2016, EPA finalized an update to the CSAPR ozone season program by issuing the CSAPR Update. This rule addresses the summertime transport of ozone pollution in the eastern U.S. that crosses state lines and will help downwind states and communities meet and maintain the 2008 ozone NAAQS. Starting in May 2017, the CSAPR Update will further reduce ozone season emissions of NO_X from power plants in 22 states in the eastern U.S.

Next Steps to Address Interstate Air Pollution Transport

The final CSAPR Update will result in meaningful, near-term reductions in ozone pollution that crosses state lines. While the CSAPR Update is focused on the 2008 standard, emission reductions achieved under this final rule will also help states attain and maintain the strengthened 2015 ozone NAAQS. However, it is likely that, after implementation of this rule, some upwind states will need to make additional reductions to address transport of ozone pollution. The EPA will continue to look at the availability, cost-effectiveness, and timing of emissions reductions beyond 2017 for potential inclusion in a future transport rule.

In its 2015 ozone NAAQS implementation memo, the EPA noted that the Clean Air Act's "good neighbor" provision for the 2015 ozone NAAQS can also be addressed in a timely fashion using the 4-step CSAPR framework. The agency intends to provide information regarding the early analytical steps of the CSAPR

framework for the 2015 NAAQS in fall of 2016. In addition, EPA will continue supporting efforts across the United States that reduce SO_2 and NO_x emissions by implementing existing programs; finalizing pending rules; and working with regional, state, and local air quality planners to evaluate the need for complementary clean air actions.

Key Points

Acid Rain Program (ARP)

- The ARP covers fossil fuel-fired power plants across the contiguous United States and sets annual emission requirements for SO_2 and NO_x, the primary precursors of acid rain.
- The market-based SO_2 cap and trade program sets a permanent cap on the cumulative amount of SO_2 that may be emitted by electricity generating units (EGUs). The final annual SO_2 cap is set at 8.95 million tons, a level of about one-half of the emissions from the power sector in 1980.
- NO_x reductions under the ARP are achieved through a rate-based approach that applies to a subset of coal-fired EGUs.

NO_x Budget Trading Program (NBP)

- The NBP was a cap and trade program that operated from 2003 to 2008, requiring NO_x emission reductions from affected power plants and industrial units in 21 eastern states (20 states plus Washington D.C.) during the ozone season.
- In 2009, the CAIR NO_x ozone season program replaced the NBP to continue ozone season NO_x emission reductions from the power sector.

Clean Air Interstate Rule (CAIR)

- CAIR required 28 eastern states (27 states plus Washington, D.C.) to reduce power sector SO_2 and/or NO_x emissions to address regional interstate transport for the 1997 fine particle pollution ($PM_{2.5}$) and ozone NAAQS. CAIR required reductions in annual emissions of SO_2 and NO_x from power plants in 25 eastern states (24 states plus Washington, D.C.) and reductions of NO_x emissions during the ozone season from 26 eastern states (25 states plus Washington, D.C.).
- CAIR included three separate cap and trade programs to achieve the required reductions: the CAIR SO_2 trading program, the CAIR NO_x annual trading program, and the CAIR NO_x ozone season trading program.
- A December 2008 court decision kept the requirements of CAIR in place temporarily but directed EPA to issue a new rule to address interstate transport. The CSAPR replaced CAIR starting on January 1, 2015.

Cross-State Air Pollution Rule (CSAPR)

- The CSAPR was developed in response to the December 2008 court decision on CAIR and replaced CAIR starting on January 1, 2015.

- The CSAPR addresses regional interstate transport of fine particle and ozone pollution for the 1997 ozone and $PM_{2.5}$ NAAQS and the 2006 $PM_{2.5}$ NAAQS. The CSAPR requires a total of 28 eastern states to reduce SO_2 emissions, annual NO_x emissions and/or ozone season NO_x emissions.
- The CSAPR includes four separate cap and trade programs to achieve these reductions: the CSAPR NO_x annual trading program, the CSAPR NO_x ozone season trading program, and the CSAPR SO_2 Group 1 and Group 2 trading programs.

Cross-State Air Pollution Rule Update (CSAPR Update)

- On September 7, 2016, EPA finalized an update to the Cross-State Air Pollution Rule ozone season program by issuing the CSAPR Update.
- Starting in May 2017, the CSAPR Update will further reduce ozone season NO_X emissions from power plants in 22 states in the eastern U.S.
- The CSAPR Update achieves these reductions through an ozone season NO_X cap and trade program.
- The CSAPR Update responds to the July 2015 remand of certain CSAPR budgets and updates the CSAPR ozone season program to help downwind states and communities meet and maintain the 2008 ozone NAAQS.

More Information

- Acid Rain Program (ARP) https://www.epa.gov/airmarkets/acid-rain-program
- Clean Air Interstate Rule (CAIR) https://archive.epa.gov/airmarkets/programs/cair/web/html/index.html
- NO_x Budget Trading Program (NBP) / NO_x SIP Call https://www.epa.gov/airmarkets/nox-budget-trading-program
- Cross-State Air Pollution Rule (CSAPR) https://www3.epa.gov/airtransport/CSAPR/index.html
- Cross-State Air Pollution Update Rule https://www.epa.gov/airmarkets/final-cross-state-air-pollution-rule-update
- National Ambient Air Quality Standards (NAAQS) https://www.epa.gov/criteria-air-pollutants
- Learn more about EPA's Clean Air Market Programs https://www.epa.gov/airmarkets/programs
- Learn more about emissions trading https://www.epa.gov/emissions-trading-resources

Figures

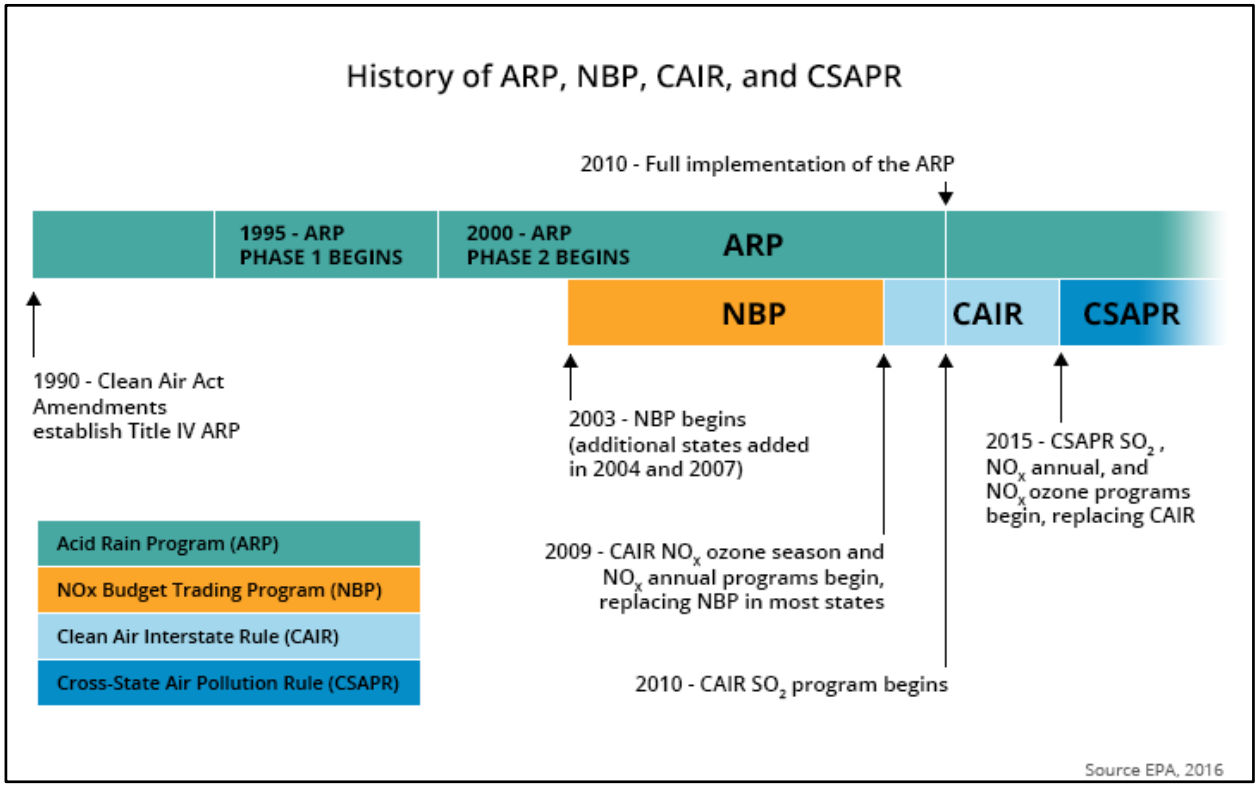


Figure 1. History of ARP, NBP, CAIR, and CSAPR

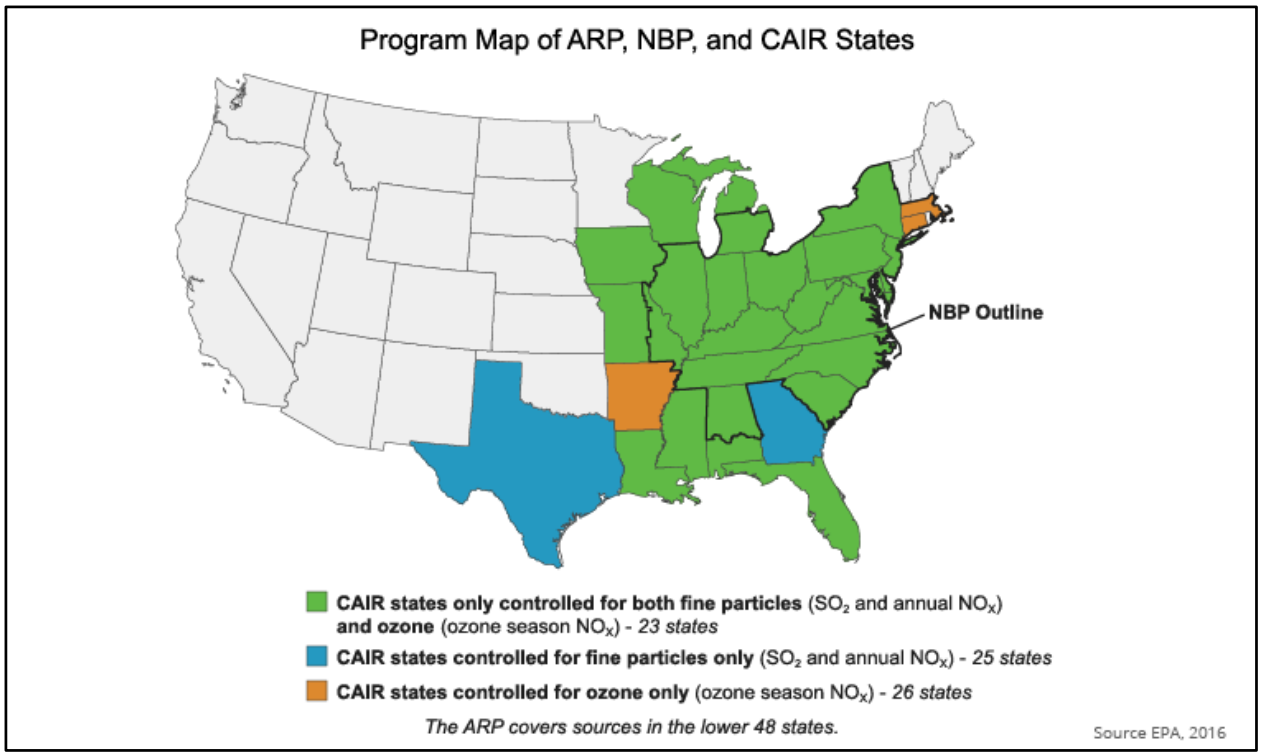


Figure 2. Program Map of ARP, NBP, and CAIR States

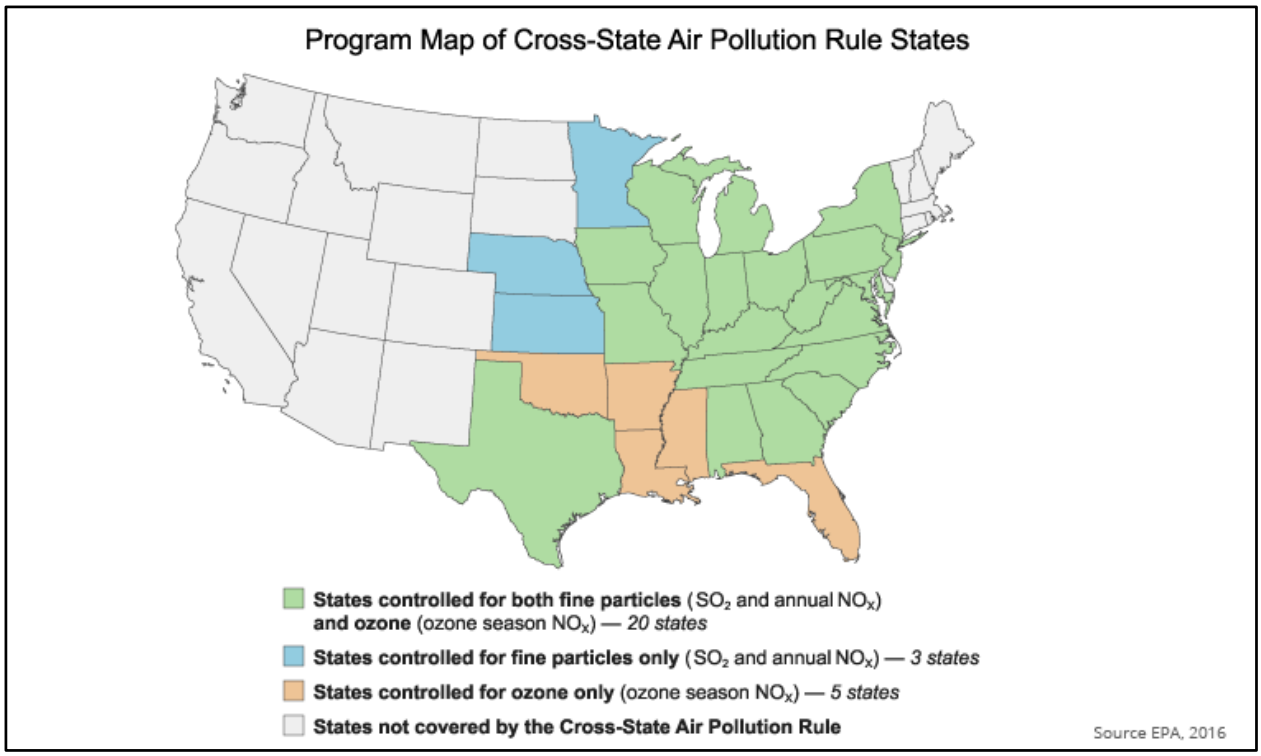


Figure 3. Large Map of Cross-State Air Pollution Rule

Chapter 2: Affected Units

Under the Acid Rain Program (ARP) and Clean Air Interstate Rule (CAIR) sulfur dioxide (SO_2) and nitrogen oxides (NO_x) annual programs, emission reductions generally apply to large electricity generating units (EGUs)—boilers, turbines, and combined cycle units– that burn fossil fuels to generate electricity for sale. The CAIR NO_x ozone season program included EGUs and, in some states, large industrial units that burn fossil fuels and have been carried over from the NO_x Budget Trading Program (NBP). This section covers units affected in 2014, and does not include programs not being implemented in 2014 (NBP and Cross-State Air Pollution Rule [CSAPR]).

Analysis and Background Information

The ARP affects EGUs with an output capacity greater than 25 megawatts that burn coal, oil, or gas, as well as all new EGUs. The ARP NO_x program affects boilers mostly at coal-fired power plants.

The CAIR SO_2 and NO_x annual programs generally applied to large EGUs that burned fossil fuels to generate electricity for sale. EGUs in the CAIR programs covered a range of unit types, including units that operated year-round to provide baseload power to the electric grid, as well as units that provided power only on peak demand days.

In addition to including large EGUs that generated electricity for sale, the CAIR NO_x ozone season program included some other fossil fuel-fired facilities that were carried over from the NBP. Such facilities may include large industrial units, such as boilers and turbines at heavy manufacturing facilities (including paper mills, petroleum refineries, and iron and steel production facilities). These units also included some fossil fuel-fired steam plants at institutions such as large universities or hospitals.

Key Points

Acid Rain Program (ARP)

- In 2014, the ARP SO_2 requirements applied to 3,597 fossil fuel-fired combustion units at 1,239 facilities across the country; 845 units at 351 facilities were subject to the ARP NO_x program.

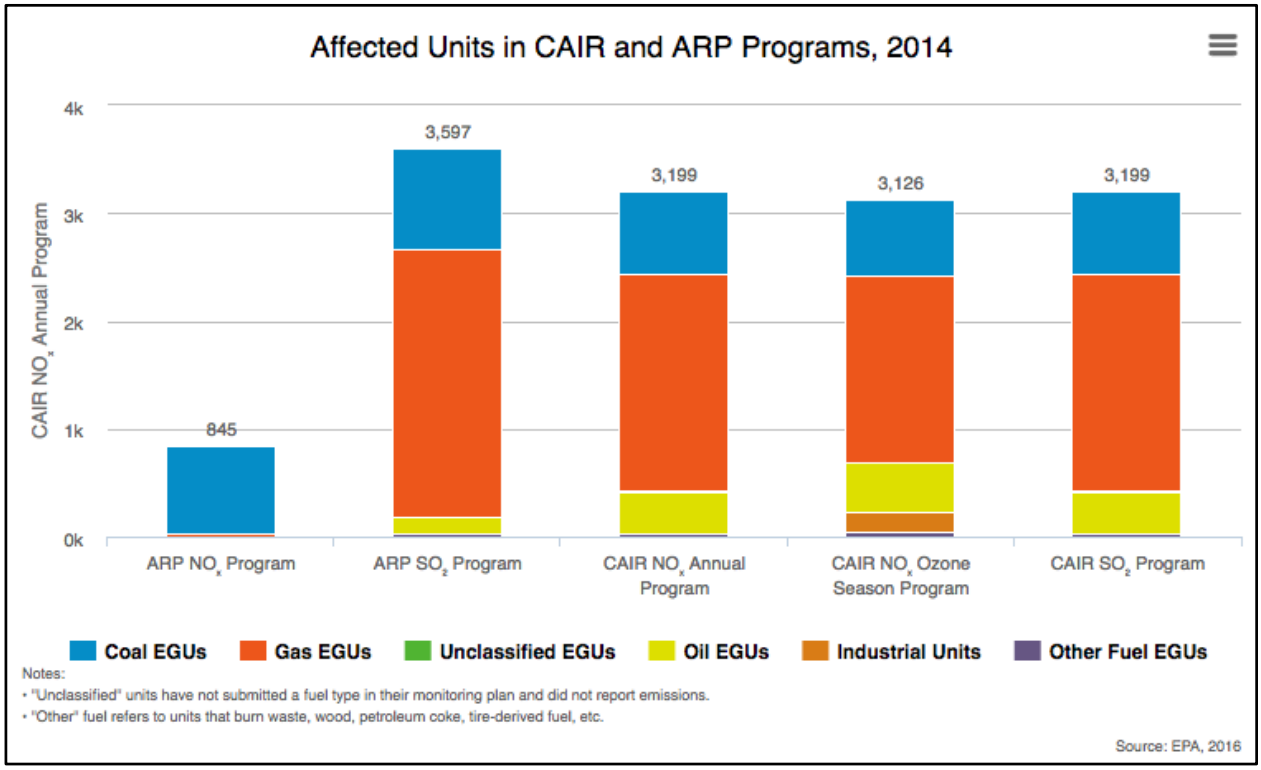
Clean Air Interstate Rule (CAIR)

- In 2014, there were 3,199 affected EGUs at 926 facilities in the CAIR SO_2 program. Of those, 2,529 (79 percent) were also covered by the ARP.
- In 2014, there were 3,199 affected EGUs at 926 facilities in the CAIR NO_x annual program and 3,126 EGUs and industrial units at 914 facilities in the CAIR NO_x ozone season program.

More Information

- Acid Rain Program (ARP) https://www.epa.gov/airmarkets/acid-rain-program
- Clean Air Interstate Rule (CAIR) https://archive.epa.gov/airmarkets/programs/cair/web/html/index.html

Figures



Notes:

- "Unclassified" units have not submitted a fuel type in their monitoring plan and did not report emissions.
- "Other" fuel refers to units that burn waste, wood, petroleum coke, tire-derived fuel, etc.

Figure 1. Affected Units in CAIR and ARP Programs, 2014

Affected Units in the CAIR and ARP Programs, 2014

Fuel	ARP NO_x Program	ARP SO_2 Program	CAIR NO_x Annual Program	CAIR NO_x Ozone Season Program	CAIR SO_2 Program
Coal EGUs	816	929	757	701	757
Gas EGUs	25	2480	2019	1730	2019
Oil EGUs	0	151	381	467	381
Industrial Units	0	0	0	186	0
Unclassified EGUs	0	9	4	1	4
Other EGUs	4	28	38	41	38
Total Units	**845**	**3597**	**3199**	**3126**	**3199**

Notes:
• "Unclassified" units have not submitted a fuel type in their monitoring plan and did not report emissions.
• "Other" fuel refers to units that burn waste, wood, petroleum coke, tire-derived fuel, etc.

Source EPA, 2016

Notes:

- "Unclassified" units have not submitted a fuel type in their monitoring plan and did not report emissions.
- "Other" fuel refers to units that burn waste, wood, petroleum coke, tire-derived fuel, etc.

Figure 2. Affected Units in the CAIR and ARP Programs, 2014

Chapter 3: Emission Reductions

The Acid Rain Program (ARP) and Clean Air Interstate Rule (CAIR) programs significantly reduced sulfur dioxide (SO_2), annual nitrogen oxides (NO_X), and ozone season NO_x emissions. These reductions occurred while electricity demand (measured as heat input) remained relatively stable, indicating that the emission reductions were not driven by decreased electric generation.

These emission reductions are a result of an overall increase in the environmental efficiency of these sources as power generators installed controls, ran their controls year-round, switched to lower emitting fuels, or otherwise reduced their SO_2 and NO_x emissions while meeting relatively steady electricity demand. Most of the emission reductions since 2005 are from early reduction incentives and stricter emission cap levels under CAIR.

Sulfur Dioxide (SO_2)

Analysis and Background Information

SO_2 is a highly reactive gas that is generated primarily from the burning of fossil fuels at power plants. In addition to contributing to the formation of fine particle pollution ($PM_{2.5}$), SO_2 is linked with a number of adverse effects to human health and ecosystems.

The states with the highest emitting sources in 1990 have generally seen the greatest SO_2 emission reductions under the ARP, and this trend continued under CAIR. Most of these states are located in the Ohio River Valley and are upwind of the areas the ARP and CAIR were designed to protect. Reductions under the ARP and CAIR have provided important environmental and health benefits over a large region.

Key Points

SO_2 Emission Trends

- **ARP:** Units in the ARP emitted 3.1 million tons of SO_2 in 2014, well below the ARP's statutory annual cap of 8.95 million tons. ARP sources reduced emissions by 12.6 million tons (80 percent) from 1990 levels and 14.1 million tons (82 percent) from 1980 levels.
- **CAIR and ARP:** In 2014, the fourth year of operation of the CAIR SO_2 program, sources in both the CAIR SO_2 annual program and the ARP together reduced SO_2 emissions by 12.6 million tons (80 percent) from 1990 levels (before implementation of the ARP), 8.1 million tons (72 percent) from 2000 levels (ARP Phase II), and 7.1 million tons (69 percent) from 2005 levels (before implementation of CAIR). All ARP and CAIR sources together emitted a total of 3.2 million tons of SO_2 in 2014.
- **CAIR:** Annual SO_2 emissions from sources in the CAIR SO_2 program alone fell from 9.1 million tons in 2005 to 2.7 million tons in 2014, a 71 percent reduction. Between 2013 and 2014, SO_2 emissions fell 48,000 tons (2 percent) and were about 970,000 tons below the regional CAIR emission budget.

SO_2 State-by-State Emissions

- **CAIR and ARP:** From 1990 to 2014, annual SO_2 emissions in the ARP and the CAIR SO_2 program dropped in 43 states (42 states plus Washington, D.C.) by a total of approximately 12.6 million tons. In contrast, annual SO_2 emissions increased in five states (Arkansas, Idaho, Nebraska, Oregon, and Vermont) by a combined total of 20,000 tons from 1990 to 2014.
- **CAIR:–** In 2014, seventeen states (16 states plus Washington, D.C.) had emissions below their CAIR allowance budgets, collectively by about 1.1 million tons. Another six states exceeded their 2014 budgets by a combined total of about 140,000 tons, indicating that, on an aggregate basis, sources within those states covered a portion of their emissions with allowances banked from earlier years, transferred from an out-of-state account, or purchased from the market.

SO_2 Emission Rates

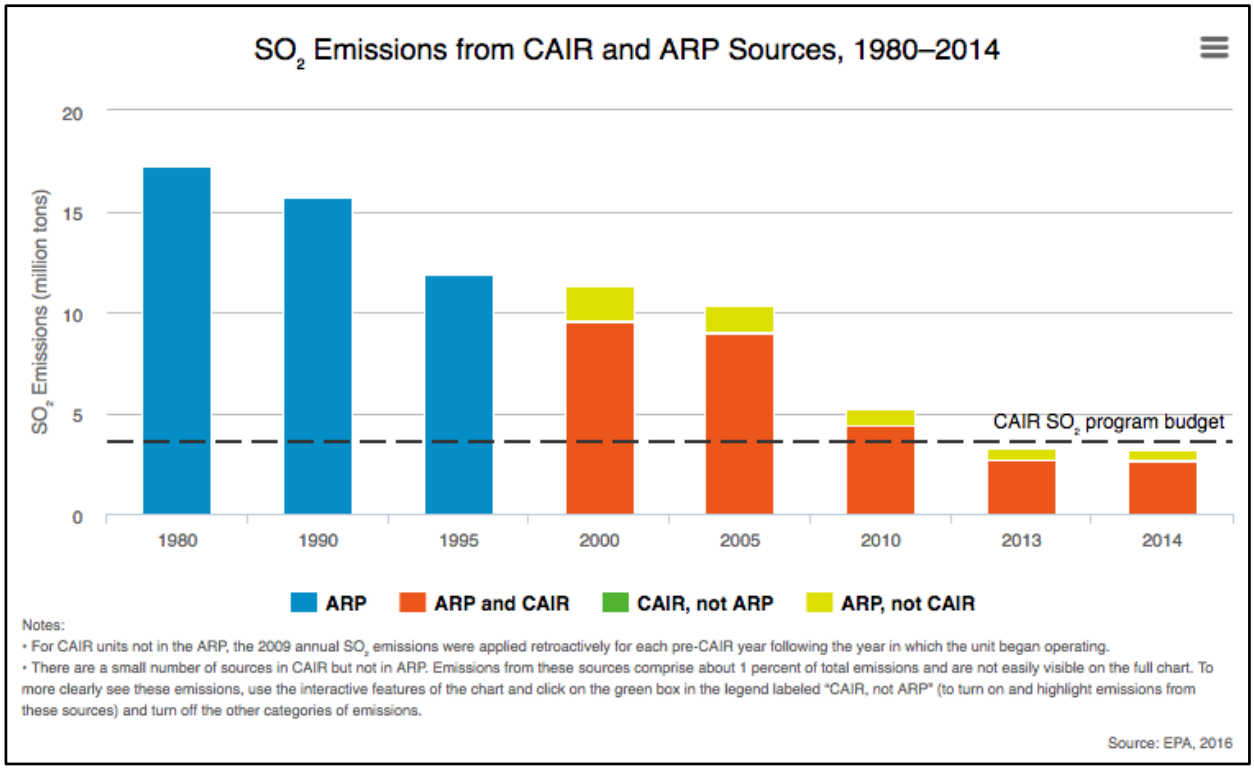
- In 2014, the average SO_2 emission rate for units in the ARP and CAIR SO_2 program fell to 0.25 lb/mmBtu. This indicates a 71 percent reduction from 2000 rates, with the majority of reductions coming from coal-fired units.
- Although heat input has remained steady over the past 14 years, emissions have decreased dramatically since 2000, indicating an improvement in emission rate at the sources. This is due in large part to greater use of control technology on coal-fired units and increased generation at natural gas-fired units that emit very little SO_2.

More Information

- Visit EPA's Power Plant Emission Trends site for the most up-to-date emissions and control data for sources in CAIR and the ARP https://www3.epa.gov/airmarkets/progress/datatrends/index.html
- Air Markets Program Data (AMPD) https://ampd.epa.gov/ampd/
- Acid Rain Program (ARP) https://www.epa.gov/airmarkets/acid-rain-program
- Clean Air Interstate Rule (CAIR) https://archive.epa.gov/airmarkets/programs/cair/web/html/index.html
- Learn more about sulfur dioxide (SO_2) https://www.epa.gov/so2-pollution
- Learn more about particulate matter (PM) https://www.epa.gov/pm-pollution

Figures

Subtopic: Sulfur Dioxide (SO_2)



Notes:

- For CAIR units not in the ARP, the 2009 annual SO_2 emissions were applied retroactively for each pre-CAIR year following the year in which the unit began operating.
- There are a small number of sources in CAIR but not in ARP. Emissions from these sources comprise about 1 percent of total emissions and are not easily visible on the full chart. To more clearly see these emissions, use the interactive features of the chart and click on the green box in the legend labeled "CAIR, not ARP" (to turn on and highlight emissions from these sources) and turn off the other categories of emissions.

Figure 1. SO_2 Emissions from CAIR and ARP Sources, 1980–2014

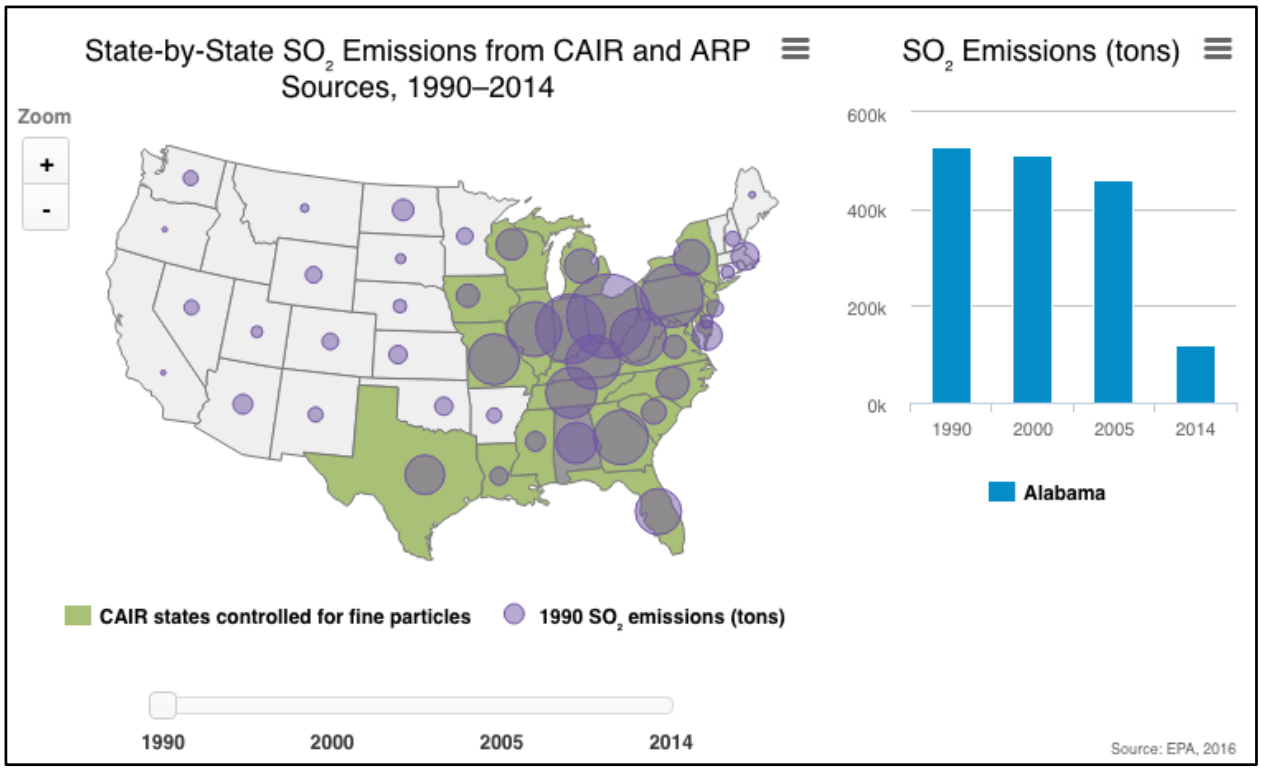
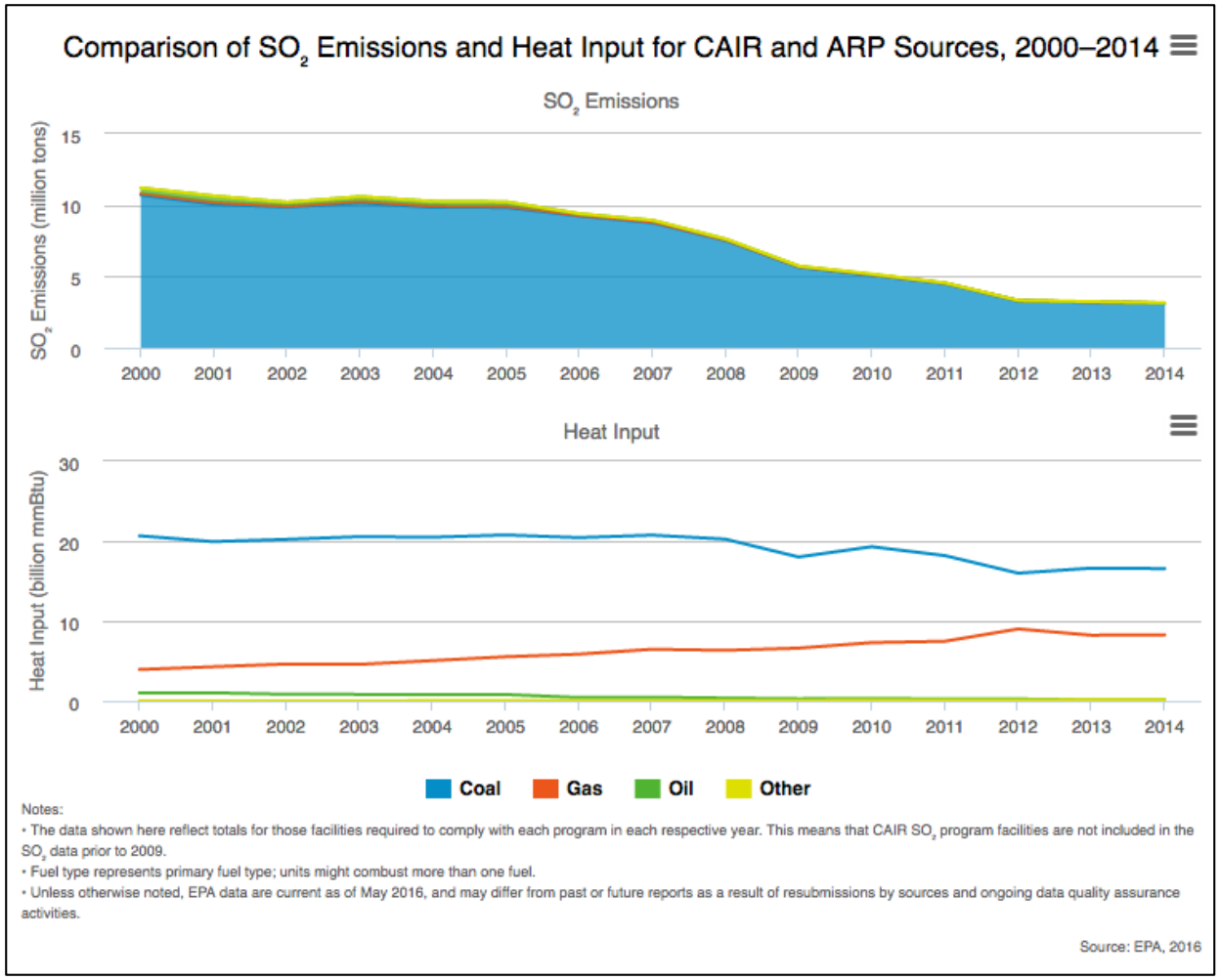


Figure 2. State-by-State SO_2 Emissions from CAIR and ARP Sources, 1990–2014



Notes:

- The data shown here reflect totals for those facilities required to comply with each program in each respective year. This means that CAIR SO_2 program facilities are not included in the SO_2 data prior to 2009.
- Fuel type represents primary fuel type; units might combust more than one fuel.
- Unless otherwise noted, EPA data are current as of May 2016, and may differ from past or future reports as a result of resubmissions by sources and ongoing data quality assurance activities.

Figure 3. Comparison of SO_2 Emissions and Heat Input for CAIR and ARP Sources, 2000–2014

CAIR and ARP SO_2 Trends

	SO_2 Emissions (thousand tons)				SO_2 Rate (lb/mmBtu)				Heat Input (billion mmBtu)			
Primary Fuel	2000	2005	2010	2014	2000	2005	2010	2014	2000	2005	2010	2014
Coal	10,708	9,835	5,090	3,118	1.04	0.95	0.53	0.38	20.67	20.77	19.30	16.56
Gas	108	91	20	9	0.06	0.03	0.01	0.00	3.88	5.49	7.28	8.27
Oil	385	292	31	10	0.73	0.70	0.19	0.13	1.06	0.84	0.33	0.15
Other	1	4	26	18	0.22	0.27	0.53	0.21	0.01	0.03	0.10	0.17
Total	**11,201**	**10,223**	**5,168**	**3,155**	**0.88**	**0.75**	**0.38**	**0.25**	**25.61**	**27.13**	**27.00**	**25.15**

- The data shown here reflect totals for those facilities required to comply with each program in each respective year. This means that CAIR SO_2 program facilities are not included in the SO_2 data prior to 2009.
- Fuel type represents primary fuel type; units might combust more than one fuel.
- Totals may not reflect the sum of individual rows due to rounding.
- Each year's total emission rate does not equal the arithmetic mean of the four fuel-specific rates, as each facility influences the annual emission rate in proportion to its heat input, and heat input is unevenly distributed across the fuel categories.
- Unless otherwise noted, EPA data are current as of May 2016, and may differ from past or future reports as a result of resubmissions by sources and ongoing data quality assurance activities.

Source EPA, 2016

Notes:

- The data shown here reflect totals for those facilities required to comply with each program in each respective year. This means that CAIR SO_2 program facilities are not included in the SO_2 data prior to 2009.
- Fuel type represents primary fuel type; units might combust more than one fuel.
- Totals may not reflect the sum of individual rows due to rounding.
- Each year's total emission rate does not equal the arithmetic mean of the four fuel-specific rates, as each facility influences the annual emission rate in proportion to its heat input, and heat input is unevenly distributed across the fuel categories.
- Unless otherwise noted, EPA data are current as of May 2016, and may differ from past or future reports as a result of resubmissions by sources and ongoing data quality assurance activities.

Figure 4. CAIR and ARP SO_2 Trends

Nitrogen Oxides (NO_x)

Analysis and Background Information

NO_x are made up of a group of highly reactive gases that are emitted from power plants and motor vehicles, as well as other sources. NO_x contributes to the formation of ground-level ozone and fine particle pollution, which cause a variety of adverse health effects.

Overall, NO_x emissions have declined dramatically under the ARP, former NO_X Budget Trading Program (NBP), and CAIR programs, with the majority of reductions coming from coal-fired units. Other programs—such as regional and state NO_x emission control programs—also contributed significantly to the annual NO_x emission reductions achieved by sources in 2014.

Key Points

Annual NO_x Trends

- **ARP:** Units in the ARP NO_x program emitted 1.6 million tons of NO_x in 2014, indicating that ARP sources reduced emissions by 6.5 million tons from the projected level in 2000 without the ARP, and over three times the Title IV NO_x emission reduction objective.
- **CAIR and ARP:** In 2014, the sixth year of operation of the CAIR NO_x annual program, sources in both the CAIR NO_x annual program and the ARP together emitted 1.7 million tons, a reduction of 4.7 million tons (73 percent reduction) from 1990 levels, 3.5 million tons (67 percent reduction) from 2000, and 2.0 million tons (54 percent reduction) from 2005 levels.
- **CAIR:** Emissions from CAIR NO_x annual program sources alone were about 1.2 million tons in 2014. This is about 1.5 million tons (56 percent) lower than in 2005 and 340,000 tons (23 percent) below the CAIR NO_x annual program's 2014 regional budget of 1,504,871 tons.

Annual NO_x State-by-State Emissions

- **CAIR and ARP:** All states participating in the ARP and CAIR NO_x annual programs decreased their NO_x emissions from 1990 to 2014.
- **CAIR:** Seventeen states (16 states plus Washington, D.C.) had emissions below their CAIR 2014 allowance budgets, collectively by about 380,000 tons. Another six states exceeded their 2014 budgets by a combined total of about 53,000 tons. This indicates that, on an aggregate basis, sources within those states covered a portion of their emissions with allowances banked from earlier years, transferred from an out-of-state account, or purchased from the market. Overall, in 2014 the total NO_x emissions from participating sources were about 330,000 tons below the CAIR regional emission budget of 1,504,871 tons.

Annual NO_x Emission Rates

- In 2014, the CAIR and ARP average annual NO_x emission rate was 0.13 lb/mmBtu, a 50 percent reduction from 2005.

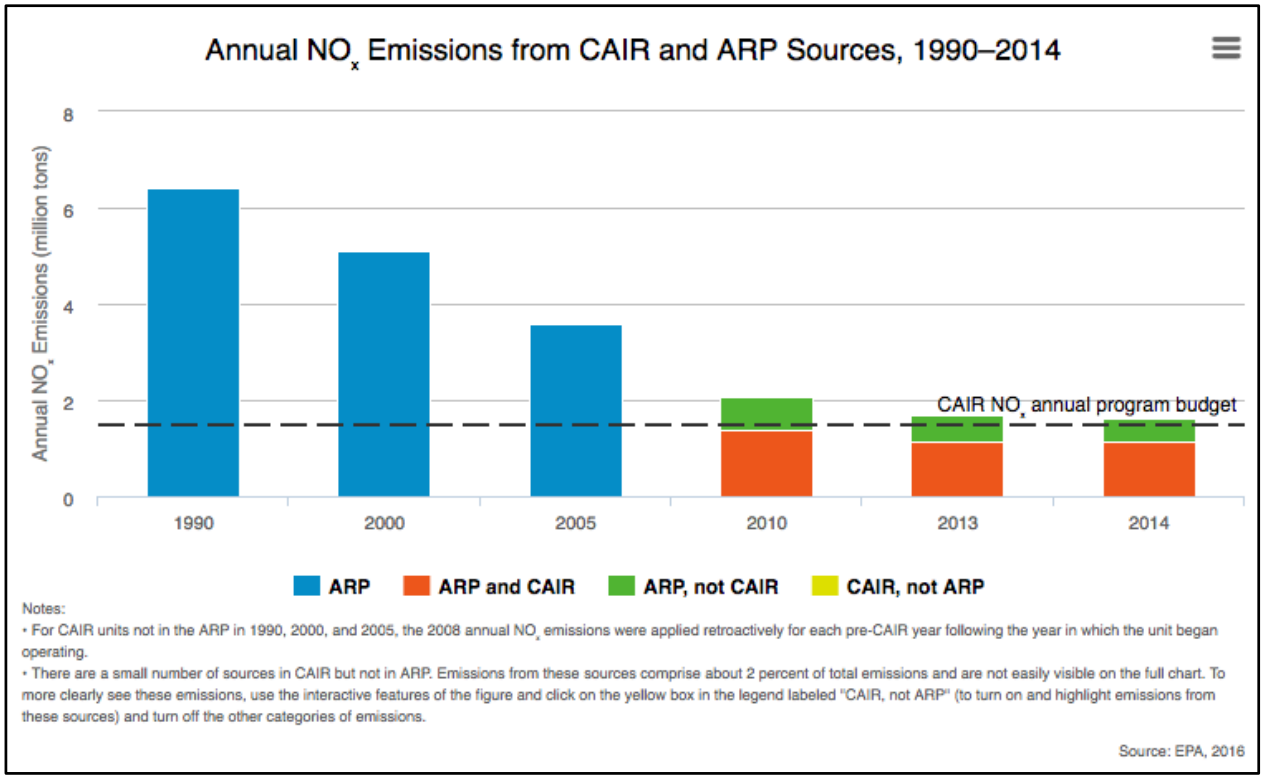
- Although heat input has remained relatively steady over the past 14 years, emissions have decreased dramatically since 2000, indicating an improvement in NO_X emission rates (see Figure 4, below). This is due in large part to greater use of control technology on coal-fired units and increased heat input at natural gas-fired units that emit less NO_X than coal-fired units.

More Information

- Visit EPA's Power Plant Emission Trends site for the most up-to-date emissions and control data for sources in CAIR and the ARP https://www3.epa.gov/airmarkets/progress/datatrends/index.html Air Markets Program Data (AMPD) https://ampd.epa.gov/ampd/
- Acid Rain Program (ARP) https://www.epa.gov/airmarkets/acid-rain-program
- Clean Air Interstate Rule (CAIR) https://archive.epa.gov/airmarkets/programs/cair/web/html/index.html
- Learn more about nitrogen oxides (NO_x) https://www3.epa.gov/airquality/nitrogenoxides/
- Learn more about particulate matter (PM) https://www.epa.gov/pm-pollution

Figures

Subtopic: Nitrogen Oxides (NO_x)

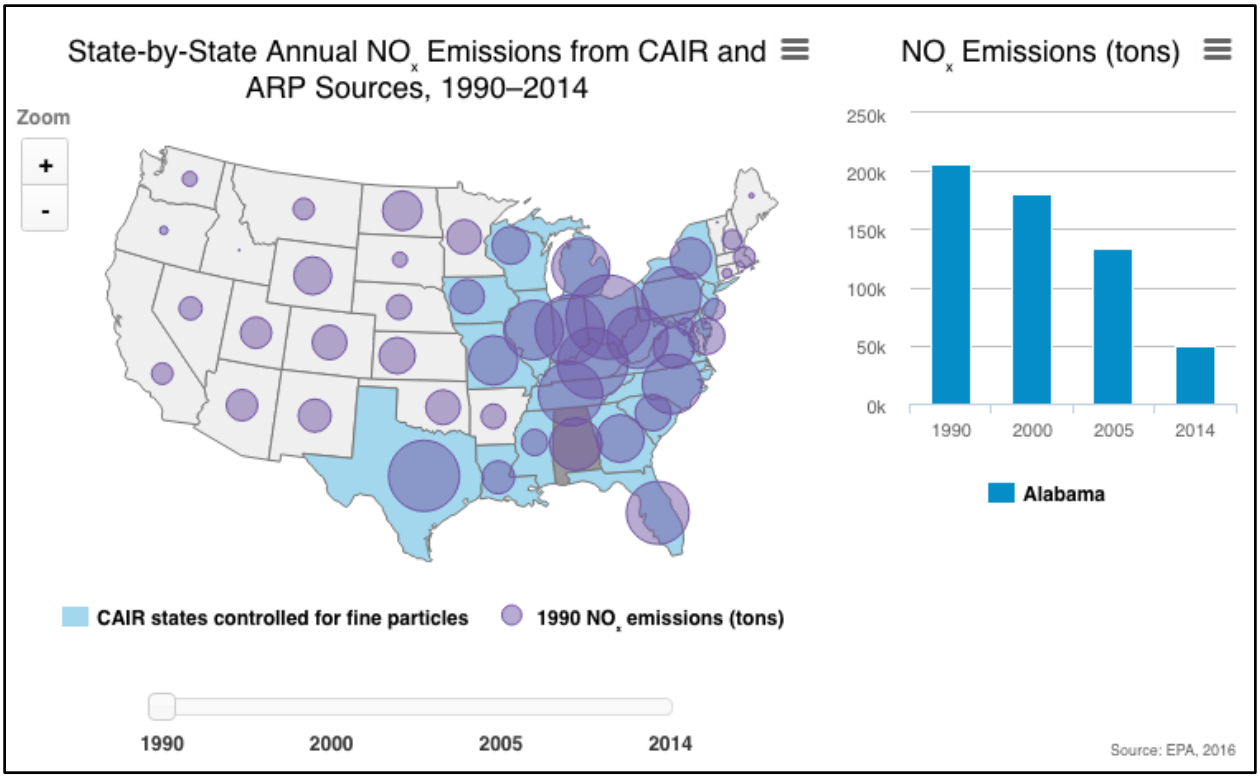


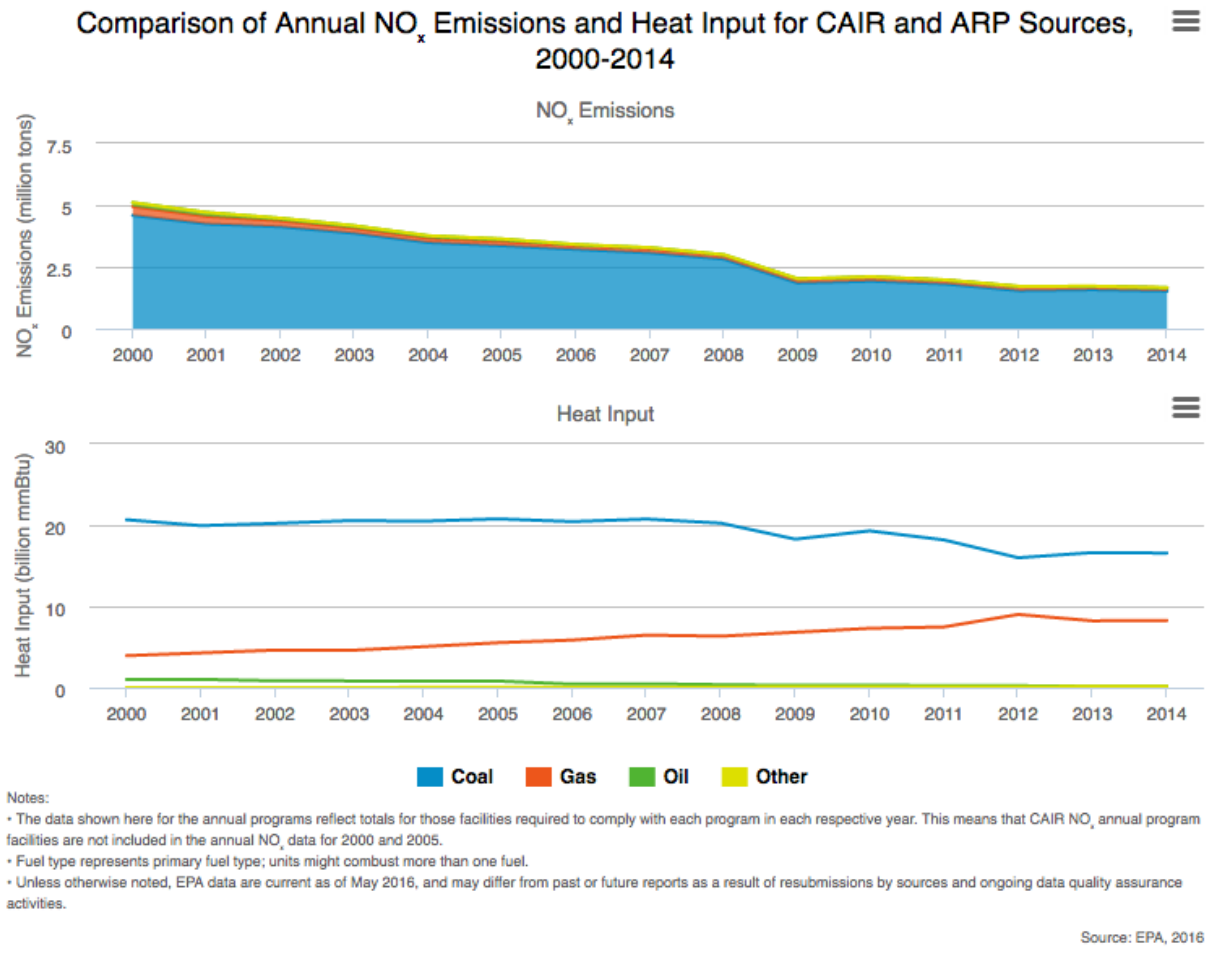
Notes:

- For CAIR units not in the ARP in 1990, 2000, and 2005, the 2008 annual NO_x emissions were applied retroactively for each pre-CAIR year following the year in which the unit began operating.
- There are a small number of sources in CAIR but not in ARP. Emissions from these sources comprise about 2 percent of total emissions and are not easily visible on the full chart. To more clearly see these emissions, use the interactive features of the figure and click on the yellow box in the legend labeled "CAIR, not ARP" (to turn on and highlight emissions from these sources) and turn off the other categories of emissions.

Figure 1. Annual NO_x Emissions from CAIR and ARP Sources, 1990–2014

Figure 2. State-by-State Annual NO_x Emissions from CAIR and ARP Sources, 1990–2014





Notes:

- The data shown here for the annual programs reflect totals for those facilities required to comply with each program in each respective year. This means that CAIR NO_x annual program facilities are not included in the annual NO_x data for 2000 and 2005.
- Fuel type represents primary fuel type; units might combust more than one fuel.
- Unless otherwise noted, EPA data are current as of May 2016, and may differ from past or future reports as a result of resubmissions by sources and ongoing data quality assurance activities.

Figure 3. Comparison of Annual NO_X Emissions and Heat Input for CAIR and ARP Sources, 2000–2014

CAIR and ARP Annual NO_X Trends

	NO_x Emissions (thousand tons)				NO_x Rate (lb/mmBtu)				Heat Input (billion mmBtu)			
Primary Fuel	2000	2005	2010	2014	2000	2005	2010	2014	2000	2005	2010	2014
Coal	4,587	3,356	1,923	1,517	0.44	0.32	0.20	0.18	20.67	20.77	19.30	16.61
Gas	354	167	150	124	0.18	0.06	0.04	0.03	3.88	5.49	7.28	8.27
Oil	162	104	24	11	0.31	0.25	0.15	0.15	1.06	0.84	0.33	0.15
Other	2	6	7	10	0.25	0.42	0.13	0.11	0.01	0.03	0.10	0.17
Total	**5,104**	**3,633**	**2,103**	**1,663**	**0.40**	**0.27**	**0.16**	**0.13**	**25.61**	**27.13**	**27.00**	**25.16**

- The data shown here for the annual programs reflect totals for those facilities required to comply with each program in each respective year. This means that CAIR NO_x annual program facilities are not included in the annual NO_x data for 2000 and 2005.
- Fuel type represents primary fuel type; units might combust more than one fuel.
- Totals may not reflect the sum of individual rows due to rounding.
- Each year's total emission rate does not equal the arithmetic mean of the four fuel-specific rates, as each facility influences the annual emission rate in proportion to its heat input, and heat input is unevenly distributed across the fuel categories.
- Unless otherwise noted, EPA data are current as of May 2016, and may differ from past or future reports as a result of resubmissions by sources and ongoing data quality assurance activities.

Source EPA, 2016

Notes:

- The data shown here includes emissions and heat input data for 2000 and 2005 that were reported under other programs. For facilities that were not covered by another program and did not report 2005 emissions, their reported emissions for the 2008 training year were substituted.
- Fuel type represents primary fuel type; units might combust more than one fuel.
- Totals may not reflect the sum of individual rows due to rounding.
- Each year's total emission rate does not equal the arithmetic mean of the four fuel-specific rates, as each facility influences the annual emission rate in proportion to its heat input, and heat input is unevenly distributed across the fuel categories.
- Unless otherwise noted, EPA data are current as of May 2016, and may differ from past or future reports as a result of resubmissions by sources and ongoing data quality assurance activities.

Figure 4. CAIR and ARP Annual NO_x Trends

Ozone Season Nitrogen Oxides (NO_x)

Analysis and Background Information

NO_x are made up of a group of highly reactive gases that are emitted from power plants and motor vehicles, as well as other sources. NO_x contributes to the formation of ground-level ozone and fine particle pollution, which cause a variety of adverse human health effects.

The CAIR NO_x ozone season program was established to reduce interstate transport during the ozone season (May 1 – September 30), the warm summer months when ozone formation is highest, and to help eastern U.S. counties attain the 1997 ozone standard.

In general, the states with the highest emitting sources of ozone season NO_x in 2000 have seen the greatest reductions under the CAIR NO_x ozone season program. Most of these states are in the Ohio River Valley and are upwind of the areas CAIR was designed to protect. Reductions by sources in these states have resulted in important environmental and human health benefits over a large region.

In addition to the CAIR and ARP NO_x programs and the former NBP, current regional and state NO_x emission control programs have also contributed significantly to the ozone season NO_x emission reductions achieved by sources.

Key Points

Ozone Season NO_x Trends

- **CAIR:** Units in the CAIR NO_x ozone season program emitted 450,000 tons in 2014, a reduction of 1.6 million tons (78 percent) from 1990, 1.0 million tons lower (69 percent reduction) than in 2000 (before implementation of the NBP), 350,000 tons lower (44 percent reduction) than in 2005 (before implementation of CAIR), and about 25,000 tons lower (5 percent reduction) than in 2013. In 2014, CAIR NO_x ozone season program emissions were 21 percent below the regional emission budget of 567,744 tons.
- **CAIR and NBP:** In 2014, sources from both CAIR and the former NBP, together with a small number of sources that were previously in the NBP but did not enter CAIR, reduced their overall NO_x emissions from 820,000 tons in 2005 (before implementation of CAIR) to 450,000 tons in 2014 (45 percent reduction).

Ozone Season NO_x State-by-State Emissions

- **CAIR and NBP:** Between 2005 and 2014, ozone season NO_x emissions from CAIR and former NBP sources fell in every state participating in the CAIR NO_x ozone season program except Arkansas, Rhode Island, and West Virginia, where emissions increased by a combined total of 3,000 tons.
- **CAIR:** In 2014, every state and Washington, D.C. had emissions below their CAIR allowance budgets, collectively by about 250,000 tons.

Ozone Season NO_x Emission Rates

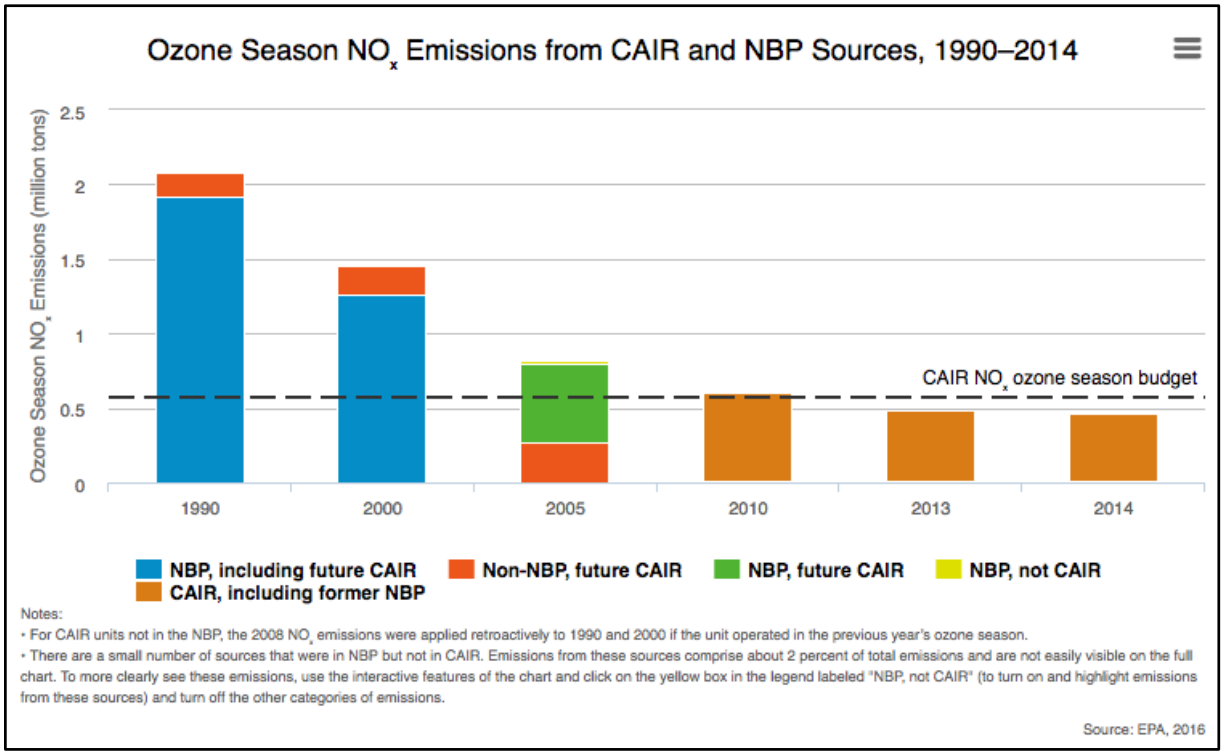
- In 2014, the average NO_x ozone season emission rate fell to 0.13 lb/mmBtu. This indicates a 68 percent reduction from 2000 emission rates, with the majority of reductions coming from coal-fired units.
- Although heat input has remained relatively constant over the past 14 years, emissions have decreased dramatically since 2000, indicating an improvement in NO_X emission rate. This is due in large part to greater use of control technology on coal-fired units and increased heat input at natural gas-fired units, which emit less NO_X than coal-fired units.

More Information

- Visit EPA's Power Plant Emission Trends site for the most up-to-date emissions and control data for sources in CAIR and the ARP https://www3.epa.gov/airmarkets/progress/datatrends/index.html
- Air Markets Program Data (AMPD) https://ampd.epa.gov/ampd/
- NO_x Budget Trading Program (NBP) / NO_x SIP Call https://www.epa.gov/airmarkets/nox-budget-trading-program
- Clean Air Interstate Rule (CAIR) https://archive.epa.gov/airmarkets/programs/cair/web/html/index.html
- Learn more about nitrogen oxides (NO_x) https://www3.epa.gov/airquality/nitrogenoxides/
- Learn more about ozone https://www.epa.gov/ozone-pollution

Figures

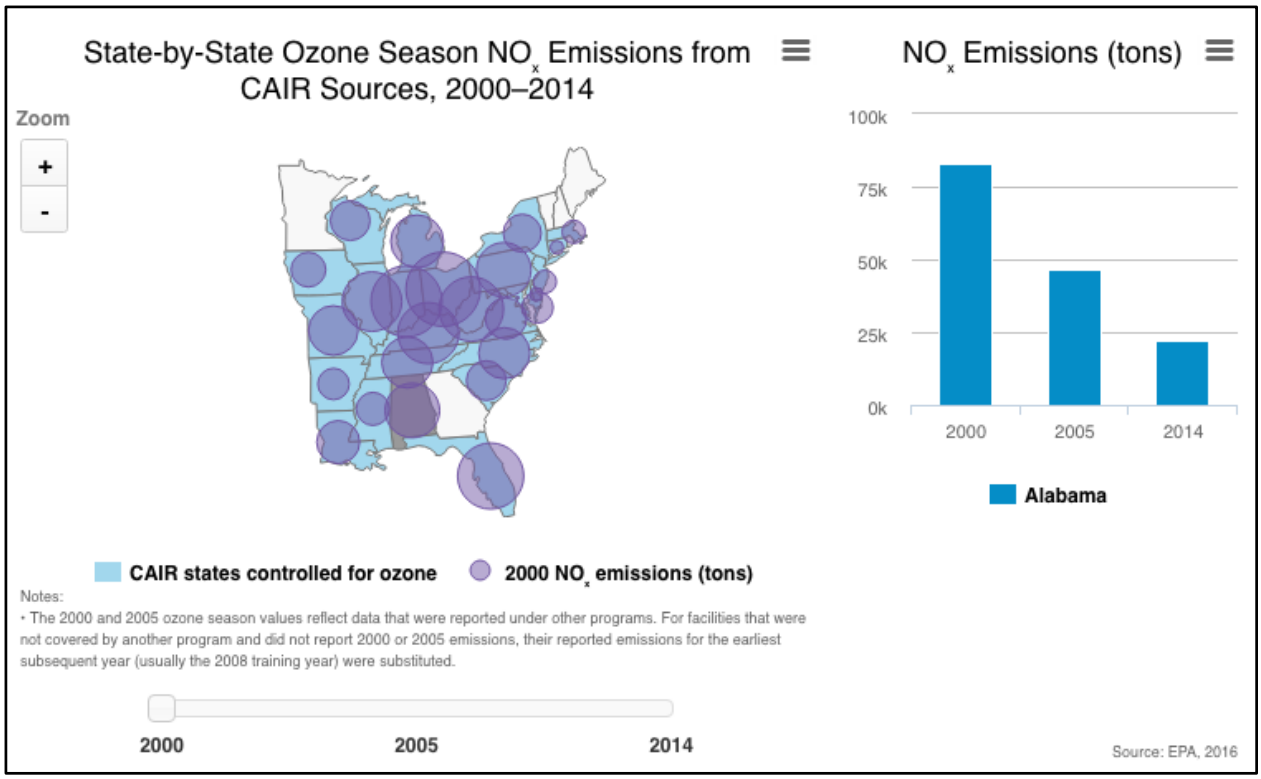
Subtopic: Ozone Season Nitrogen Oxides (NO_x)



Notes:

- For CAIR units not in the NBP, the 2008 NO_X emissions were applied retroactively to 1990 and 2000 if the unit operated in the previous year's ozone season.
- There are a small number of sources that were in NBP but not in CAIR. Emissions from these sources comprise about 2 percent of total emissions and are not easily visible on the full chart. To more clearly see these emissions, use the interactive features of the chart and click on the yellow box in the legend labeled "NBP, not CAIR" (to turn on and highlight emissions from these sources) and turn off the other categories of emissions.

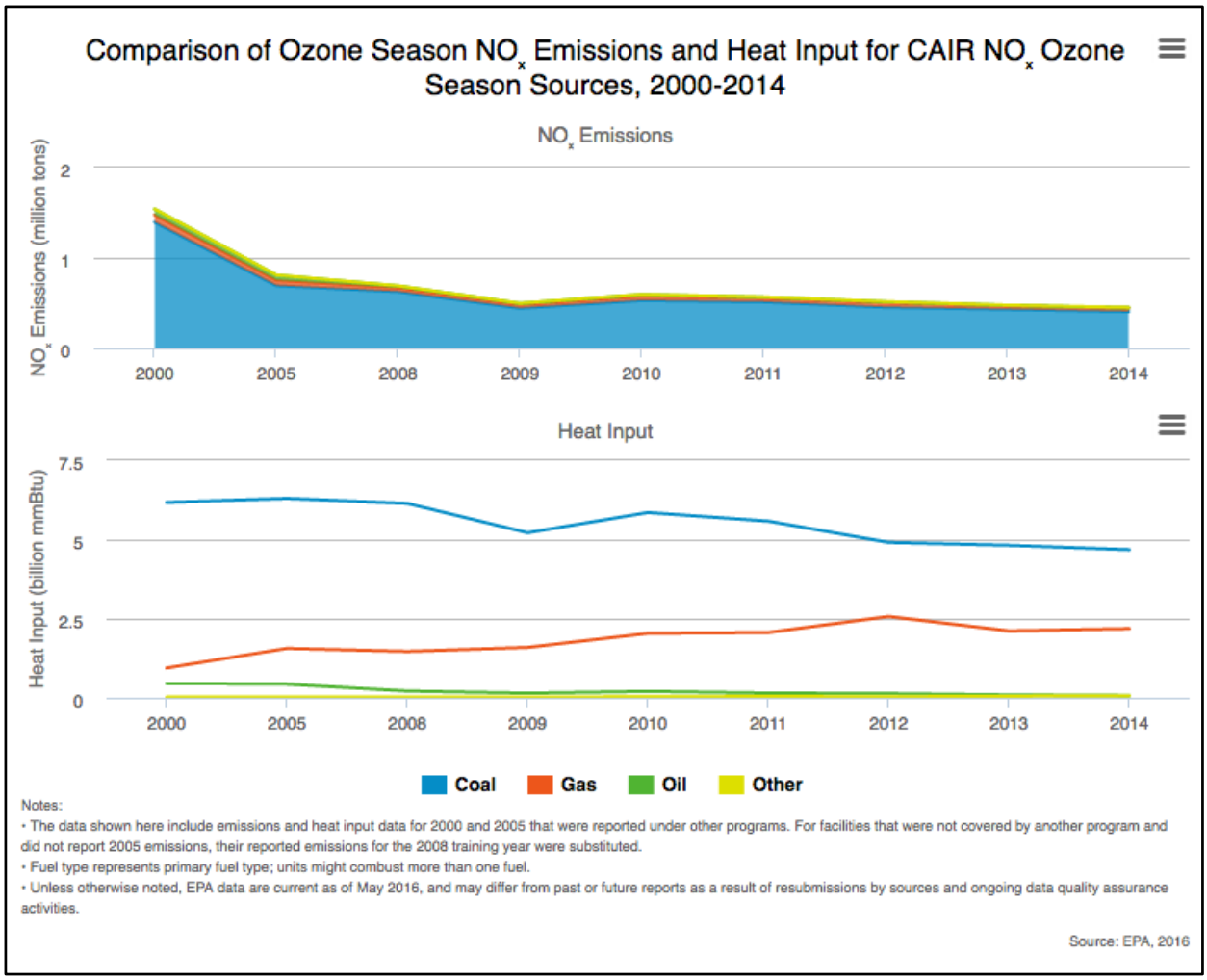
Figure 1. Ozone Season NO_x Emissions from CAIR and NBP Sources, 1990–2014



Notes:

- The 2000 and 2005 ozone season values reflect data that were reported under other programs. For facilities that were not covered by another program and did not report 2000 or 2005 emissions, their reported emissions for the earliest subsequent year (usually the 2008 training year) were substituted.

Figure 2. State-by-State Ozone Season NO_x Emissions from CAIR Sources, 2000–2014



Notes:

- The data shown here include emissions and heat input data for 2000 and 2005 that were reported under other programs. For facilities that were not covered by another program and did not report 2005 emissions, their reported emissions for the 2008 training year were substituted.
- Fuel type represents primary fuel type; units might combust more than one fuel.
- Unless otherwise noted, EPA data are current as of May 2016, and may differ from past or future reports as a result of resubmissions by sources and ongoing data quality assurance activities.

Figure 3. Comparison of Ozone Season NO_X Emissions and Heat Input for CAIR Sources, 2000–2014

CAIR Ozone Season NO_X Trends

	NO_x Emissions (thousand tons)				NO_x Rate (lb/mmBtu)				Heat Input (billion mmBtu)			
Primary Fuel	2000	2005	2010	2014	2000	2005	2010	2014	2000	2005	2010	2014
Coal	1,395	692	527	404	0.45	0.22	0.18	0.17	6.17	6.30	5.85	4.68
Gas	78	58	49	37	0.17	0.08	0.05	0.03	0.92	1.54	2.02	2.18
Oil	66	57	16	4	0.27	0.25	0.15	0.12	0.48	0.45	0.22	0.07
Other	1	2	2	3	0.15	0.17	0.12	0.10	0.02	0.02	0.04	0.07
Total	**1,541**	**809**	**594**	**449**	**0.41**	**0.20**	**0.15**	**0.13**	**7.59**	**8.31**	**8.13**	**7.00**

- The data shown here includes emissions and heat input data for 2000 and 2005 that were reported under other programs. For facilities that were not covered by another program and did not report 2005 emissions, their reported emissions for the 2008 training year were substituted.
- Fuel type represents primary fuel type; units might combust more than one fuel.
- Totals may not reflect the sum of individual rows due to rounding.
- Each year's total emission rate does not equal the arithmetic mean of the four fuel-specific rates, as each facility influences the annual emission rate in proportion to its heat input, and heat input is unevenly distributed across the fuel categories.
- Unless otherwise noted, EPA data are current as of May 2016, and may differ from past or future reports as a result of resubmissions by sources and ongoing data quality assurance activities.

Source EPA, 2016

Notes:

- The data shown here include emissions and heat input data for 2000 and 2005 that were reported under other programs. For facilities that were not covered by another program and did not report 2005 emissions, their reported emissions for the 2008 training year were substituted.
- Fuel type represents primary fuel type; units might combust more than one fuel.
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- Each year's total emission rate does not equal the arithmetic mean of the four fuel-specific rates, as each facility influences the annual emission rate in proportion to its heat input, and heat input is unevenly distributed across the fuel categories.
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Figure 4. CAIR Ozone Season NO_x Trends

Chapter 4: Emission Controls and Monitoring

Allowance trading allows sources in cap and trade programs to adopt the most cost-effective strategy to reduce emissions. To meet the Acid Rain Program (ARP) and Clean Air Interstate Rule (CAIR) emission reduction targets, some sources opted to install control technologies. A wide set of controls is available to help reduce emissions. The tracking and reporting of accurate and consistent emissions monitoring data is important to ensure program compliance and is achieved through the use of continuous emission monitoring systems (CEMS). The following is an analysis of controls on ARP and CAIR units.

Analysis and Background Information

Continuous Emission Monitoring Systems (CEMS)

Accurate and consistent emissions monitoring is the foundation of a successful cap and trade program. EPA has developed detailed procedures codified in federal regulations (40 CFR Part 75) to ensure that sources monitor and report emissions with a high degree of precision, accuracy, reliability, and consistency. Sources are required to use CEMS or other approved methods to record and report pollutant emissions data. Sources conduct stringent quality assurance tests of their monitoring systems to ensure the accuracy of emissions data and to provide assurance to market participants that a ton of emissions measured at one facility is equivalent to a ton measured at a different facility. EPA conducts comprehensive electronic and field data audits to validate the reported data.

SO_2 Controls

Sources in the ARP and CAIR SO_2 program have a number of SO_2 control options available. These include switching to low sulfur coal, employing various types of flue gas desulfurization technologies (FGDs), or utilizing fluidized bed limestone units. FGDs on coal-fired generators are the principal means of controlling SO_2 and tend to be present on the highest generating coal-fired units. While some units with low levels of emissions are allowed to use other approved methods, the vast majority of SO_2 emissions–over 99 percent–were measured by CEMS.

NO_x Controls

Sources in the ARP and CAIR NO_X annual and ozone season programs have a variety of options by which to reduce NO_x emissions, including advanced controls such as selective catalytic reduction (SCR) or selective non-catalytic reduction (SNCR), combustion controls, and others. While some units with low levels of emissions are allowed to use other approved methods, the vast majority of NO_x emissions—over 99 percent—were measured by CEMS.

Key Points

ARP and CAIR SO_2 Program Controls

- Of all coal-fired generation (measured in megawatt hours, or MWh) from sources participating in the ARP and CAIR SO_2 program, 73 percent was produced in 2014 by units with pollution controls.
- FGD-controlled units accounted for 51 percent of coal-fired units and 72 percent of coal-fired generation in 2014.

- In 2014, 77 percent of units, accounting for 38 percent of energy generation, primarily use natural gas, oil, or other fuel sources, and make up 1 percent of SO_2 emissions.
- In 2014, CEMS monitored over 99 percent of SO_2 emissions from CAIR sources, including 100 percent from coal-fired units.

CAIR NO_x Annual Program Controls

- In 2014, the 371 coal-fired units with add-on controls (either SCRs or SNCRs) generated 70 percent of coal-fired generation. At oil- and natural gas-fired units, SCR- and SNCR- controlled units produced 71 percent of generation.
- Although 52 coal-fired units remain uncontrolled, they represent one percent of coal-fired generation under the CAIR NO_x annual program in 2014.
- In 2014, CEMS monitored over 99 percent of SO_2 emissions from CAIR sources, including 100 percent from coal-fired units.

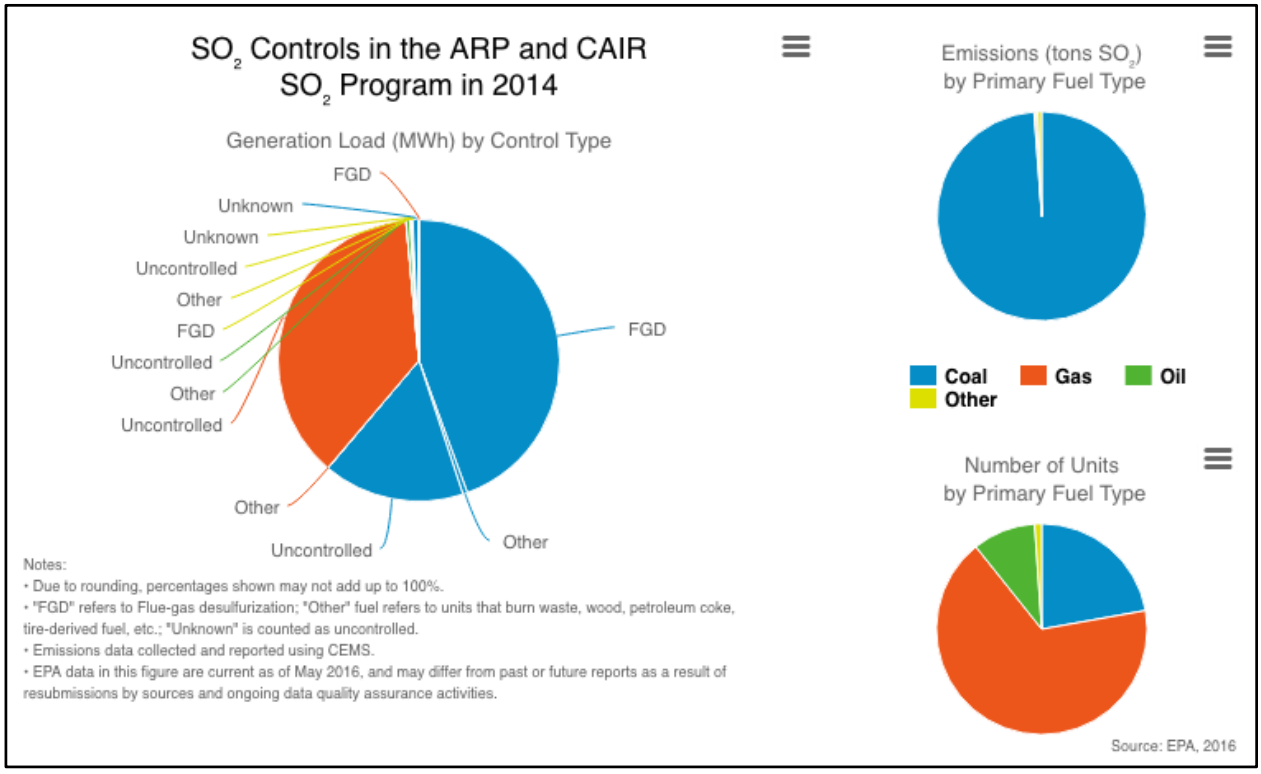
CAIR NO_x Ozone Season Program Controls

- In 2014, SCR or SNCR accounted for 72 percent of coal-fired generation. At oil- and natural gas-fired units, SCR- and SNCR- controlled units produced 74 percent of generation.
- Although 63 coal-fired units remain uncontrolled in 2014, they represent 2 percent of coal-fired generation under the CAIR NO_x ozone season program.

More Information

- Visit EPA's Power Plant Emission Trends site for the most up-to-date emissions and control data for sources in CAIR and the ARP https://www3.epa.gov/airmarkets/progress/datatrends/index.html
- Air Markets Program Data (AMPD) https://ampd.epa.gov/ampd/
- Learn more about emissions monitoring https://www.epa.gov/airmarkets/emissions-monitoring
- Continuous emission monitoring systems (CEMS) https://www3.epa.gov/ttnemc01/cem.html
- Plain English guide to 40 CRF Part 75 https://www.epa.gov/airmarkets/plain-english-guide-part-75-rule

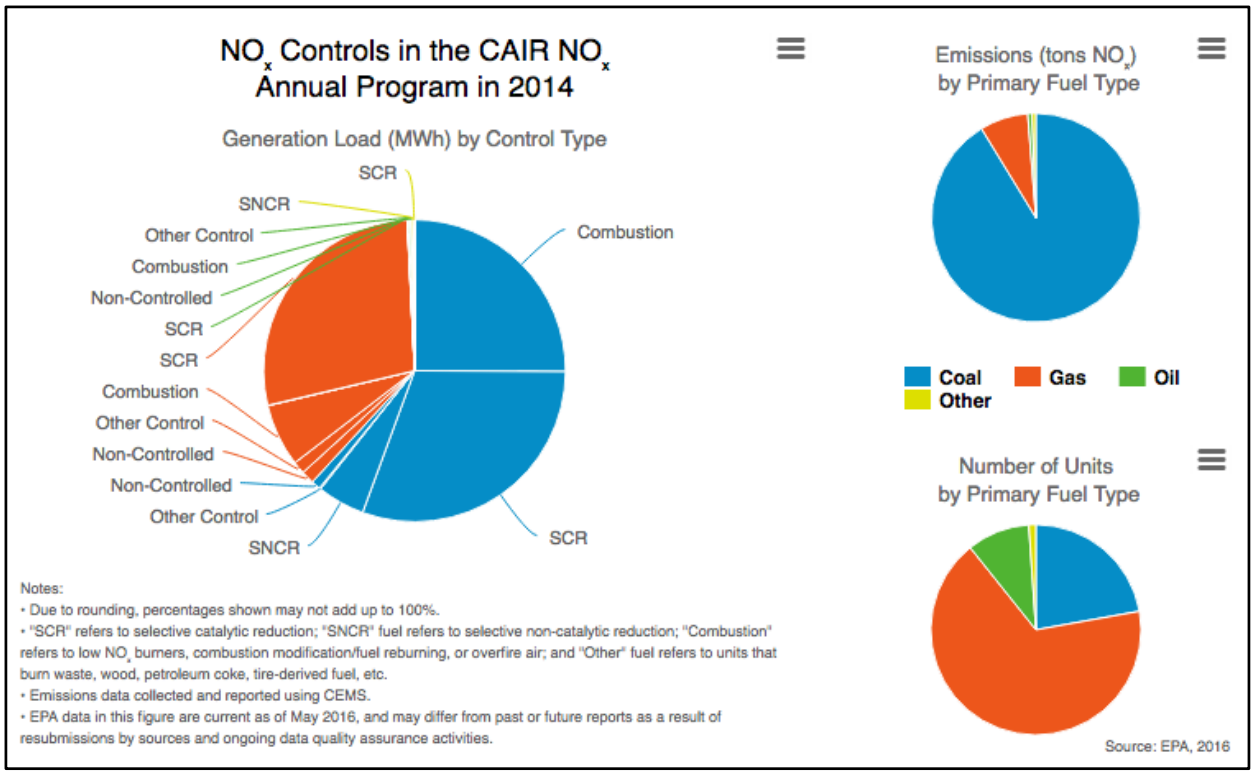
Figures



Notes:

- Due to rounding, percentages shown may not add up to 100%.
- "FGD" refers to Flue-gas desulfurization; "Other" fuel refers to units that burn waste, wood, petroleum coke, tire-derived fuel, etc.; "Unknown" is counted as uncontrolled.
- Emissions data collected and reported using CEMS.
- EPA data in this figure are current as of May 2016, and may differ from past or future reports as a result of resubmissions by sources and ongoing data quality assurance activities.

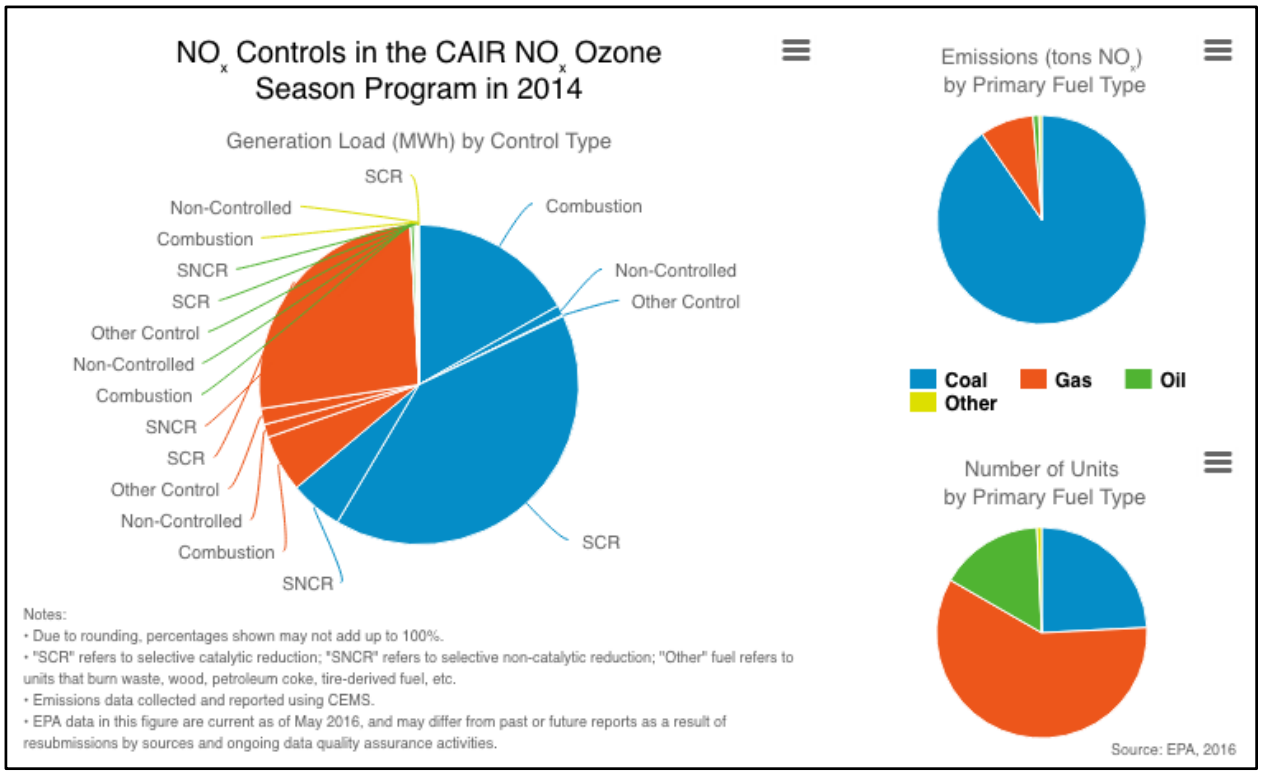
Figure 1. SO_2 Controls in the ARP and CAIR SO_2 Program in 2014



Notes:

- Due to rounding, percentages shown may not add up to 100%.
- "SCR" refers to selective catalytic reduction; "SNCR" fuel refers to selective non-catalytic reduction; Combustion" refers to low NO_x burners, combustion modification/fuel reburning, or overfire air; and "Other" fuel refers to units that burn waste, wood, petroleum coke, tire-derived fuel, etc.
- Emissions data collected and reported using CEMS.
- EPA data in this figure are current as of May 2016, and may differ from past or future reports as a result of resubmissions by sources and ongoing data quality assurance activities.

Figure 2. NO_x Controls in the CAIR NO_x Annual Program in 2014



Notes:

- Due to rounding, percentages shown may not add up to 100%.
- "SCR" refers to selective catalytic reduction; "SNCR" fuel refers to selective non-catalytic reduction; "Other" fuel refers to units that burn waste, wood, petroleum coke, tire-derived fuel, etc.
- Emissions data collected and reported using CEMS.
- EPA data in this figure are current as of May 2016, and may differ from past or future reports as a result of resubmissions by sources and ongoing data quality assurance activities.

Figure 3. NO_x Controls in the CAIR NO_x Ozone Season Program in 2014

Chapter 5: Program Compliance

This analysis shows how the Acid Rain Program (ARP) and Clean Air Interstate Rule (CAIR) allowances are used for compliance under the trading programs in 2014. Because sulfur dioxide (SO_2) allowances from the ARP are used by sources to comply with the CAIR SO_2 program, compliance results for both programs are displayed together.

Analysis and Background Information

The year 2014 was the fifth and final year for compliance with the CAIR SO_2 program. Under this program, allowances are used to cover emissions based on the vintage year of the allowances, with pre-2010 vintage allowances used at one allowance for 1 ton of SO_2 emissions, and 2010–2014 vintage allowances used at two allowances for 1 ton of SO_2 emissions. For facilities covered by both CAIR and the ARP, reconciliation is a two-step process. First, ARP deductions are made; then, any additional deductions to comply with the CAIR SO_2 program are made. The additional deductions under CAIR could be used to cover the two-for-one use of 2010–2014 allowances or to cover emissions for units that are subject to CAIR, but not the ARP.

Because of variation in rounding conventions, changes due to resubmissions by sources, and allowance compliance issues at certain units, the compliance summary emissions number cited in "Key Points" may be lower than the sums of emissions used for reconciliation purposes shown in the "Allowance Reconciliation Summary" figures. Therefore, the allowance totals deducted for actual emissions in those figures differ from the number of emissions shown elsewhere in this report.

Key Points

ARP and CAIR SO_2 Programs

- The reported 2014 SO_2 emissions by CAIR and ARP sources totaled 3,155,031 tons.
- Over 33 million SO_2 allowances were available for compliance under both programs (9 million vintage 2014 and over 24 million banked from prior years).
- Just over 3.1 million allowances were deducted for ARP compliance and an additional 2.3 million allowances were deducted to complete reconciliation for CAIR. After reconciliation for both programs, over 27.7 million ARP SO_2 allowances were banked and carried forward to the 2015 ARP compliance year.
- All ARP and CAIR SO_2 facilities were in compliance for both programs in 2014 and held enough allowances to cover their SO_2 emissions.

CAIR NO_x Annual Program

- The reported 2014 annual NO_x emissions by CAIR sources totaled 1,164,280 tons.
- All covered facilities were in compliance with the CAIR NO_x annual program in 2014 and held enough allowances to cover their NO_x emissions.

CAIR NO_x Ozone Season Program

- The reported 2014 ozone season NO_x emissions by CAIR sources totaled 448,991 tons.
- All covered facilities were in compliance with the CAIR NO_X ozone season program in 2014 and held enough allowances to cover their NO_X emissions.

More Information

- Learn more about allowance markets https://www.epa.gov/airmarkets/allowance-markets
- Air Markets Business Center https://www.epa.gov/airmarkets/business-center
- Air Markets Program Data (AMPD) https://ampd.epa.gov/ampd/
- Learn more about emissions trading https://www.epa.gov/emissions-trading-resources

Figures

ARP and CAIR SO_2 Allowance Reconciliation Summary, 2014

Total Allowances Held (1995–2014 Vintage)	**33,203,985**	Held by Affected Facility Accounts	22,486,133
		Held by Other Accounts (General and Non-Affected Facility Accounts)	10,717,852
Allowances Deducted for Acid Rain Compliance*	3,132,176		
Penalty Allowance Deductions	0		
Banked Allowances (after ARP Compliance)	**30,071,809**	Held by Affected Facility Accounts	19,353,957
		Held by Other Accounts (General and Non-Affected Facility Accounts)	10,717,852
Acid Rain Program Allowances Deducted for CAIR	2,289,419		
Banked Allowances (after ARP and CAIR)	**27,782,390**	Held by Affected Facility Accounts	17,064,538
		Held by Other Accounts (General and Non-Affected Facility Accounts)	10,717,852

ARP and CAIR SO_2 Program Compliance Results

Reported emissions (tons)	3,155,031
Compliance issues, rounding, and report resubmission adjustments (tons)	-31,644
Emissions not covered by allowances (tons)	0
Additional vintage 2010 - 2014 allowances deducted for CAIR	2,289,419
Total allowances deducted for emissions (includes some 2 for 1 CAIR deductions)	5,412,806

Notes:
- *Include 8,789 allowances deducted from opt-ins for reduced utilization.
- Compliance emissions data may vary from other report sections as a result of variation in rounding conventions, changes due to resubmissions by sources, or allowance compliance issues at certain units.
- Reconciliation and compliance data are current as of May 2016 and subsequent adjustments or penalties are not reflected.

Source EPA, 2016

Notes:
- *Include 8,789 allowances deducted from opt-ins for reduced utilization.
- Compliance emissions data may vary from other report sections as a result of variation in rounding conventions, changes due to resubmissions by sources, or allowance compliance issues at certain units.
- Reconciliation and compliance data are current as of May 2016, and subsequent adjustments of penalties are not reflected.

Figure 1. ARP and CAIR SO_2 Allowance Reconciliation Summary, 2014

CAIR NO_X Annual Allowance Reconciliation Summary, 2014

Total Allowances Held (2009–2014 Vintage)	**2,596,619**	Held by Affected Facility Accounts	**2,268,483**
		Held by Other Accounts (General, State Holding, and Non-Affected Facility Accounts)	**328,136**
Allowances Deducted for CAIR NO_x Annual Trading Program	1,164,345		
Penalty Allowance Deductions	0		
Banked Allowances	**1,432,274**	Held by Affected Facility Accounts	**1,104,138**
		Held by Other Accounts (General, State Holding, and Non-Affected Facility Accounts)	**328,136**

CAIR NO_X Annual Program Compliance Results

Reported emissions (tons)	**1,164,280**
Compliance issues, rounding, and report resubmission adjustments (tons)	**65**
Emissions not covered by allowances (tons)	**0**
Total allowances deducted for emissions	**1,164,345**

Notes:

- Compliance emissions data may vary from other report sections as a result of variation in rounding conventions, changes due to resubmissions by sources, or allowance compliance issues at certain units.
- Reconciliation and compliance data are current as of May 2016 and subsequent adjustments or penalties are not reflected.

Source EPA, 2016

Notes:

- Compliance emissions data may vary from other report sections as a result of variation in rounding conventions, changes due to resubmissions by sources, or allowance compliance issues at certain units.
- Reconciliation and compliance data are current as of May 2016 and subsequent adjustments of penalties are not reflected.

Figure 2. CAIR NO_x Annual Allowance Reconciliation Summary, 2014

CAIR NO_x Ozone Season Allowance Reconciliation Summary, 2014

Total Allowances Held (2009–2014 Vintage)	**1,269,146**	Held by Affected Facility Accounts	**1,051,553**
		Held by Other Accounts (General, State Holding, and Non-Affected Facility Accounts)	**217,593**
Allowances Deducted for CAIR NO_x Ozone Season Trading Program	449,287		
Penalty Allowance Deductions	0		
Banked Allowances	**819,859**	Held by Affected Facility Accounts	**602,266**
		Held by Other Accounts (General, State Holding, and Non-Affected Facility Accounts)	**217,593**

CAIR NO_x Ozone Season Program Compliance Results

Reported emissions (tons)	**448,991**
Compliance issues, rounding, and report resubmission adjustments (tons)	**296**
Emissions not covered by allowances (tons)	**0**
Total allowances deducted for emissions	**449,287**

Notes:

- Compliance emissions data may vary from other report sections as a result of variation in rounding conventions, changes due to resubmissions by sources, or allowance compliance issues at certain units.
- Reconciliation and compliance data are current as of May 2016 and subsequent adjustments or penalties are not reflected.

Source EPA, 2016

Notes:

- Compliance emissions data may vary from other report sections as a result of variation in rounding conventions, changes due to resubmissions by sources, or allowance compliance issues at certain units.
- Reconciliation and compliance data are current as of May 2016 and subsequent adjustments of penalties are not reflected.

Figure 3. CAIR NO_x Ozone Season Allowance Reconciliation Summary, 2014

Chapter 6: Market Activity

Allowance trading allows sources in cap and trade programs to adopt the most cost-effective strategy to reduce emissions. Sources that reduce their emissions below the number of allowances they hold may trade allowances with other sources in their system, sell them to other sources on the open market or through EPA auctions, or bank them for use in future years.

While all transactions are important to proper market operation, EPA follows trends in transactions between distinct economic entities with particular interest. These transactions represent an actual exchange of assets between unaffiliated participants, which reflect companies making the most of the cost-minimizing flexibility of emission trading programs by finding the cheapest emission reductions across the marketplace.

Analysis and Background Information

Transaction Types and Volumes

Allowance transfer activity includes two types of transfers: EPA transfers to accounts and private transactions. EPA transfers to accounts include the initial allocation of allowances by states or EPA, as well as transfers into accounts related to set-asides. This category does not include transfers due to allowance retirements. Private transactions include all transfers initiated by authorized account representatives for any compliance or general account purposes.

To help better understand the trends in market performance and transfer history, EPA classifies private transfers of allowance transactions into two categories:

- Transfers between separate and unrelated parties (distinct organizations), which may include companies with contractual relationships (such as power purchase agreements), but excludes parent-subsidiary types of relationships.
- Transfers within a company or between related entities (e.g., holding company transfers between a facility compliance account and any account held by a company with an ownership interest in the facility).

Allowance Markets

The 2014 emissions were below emission budgets for the Acid Rain Program (ARP) and for all three Clean Air Interstate Rule (CAIR) programs. As a result, CAIR allowance prices were well below the marginal cost for reductions projected at the time of the final rule, and are subject, in part, to downward pressure from the available banks of allowances.

Overall, allowance prices in 2014 remained relatively stable until October 23, 2014 when the D.C. Circuit granted EPA's motion to lift the stay on the Cross-State Air Pollution Rule (CSAPR) and allow it to replace CAIR starting in 2015. The increased certainty regarding CSAPR implementation and the resulting phase-out of CAIR, including the future use of CAIR allowances, significantly decreased the value of CAIR allowances.

Key Points

Transaction Types and Volumes

- In 2014, the majority of ARP and CAIR sulfur dioxide (SO_2) program allowances were traded between related organizations. In contrast, about one-third of CAIR nitrogen oxides (NO_X) ozone season and CAIR NO_X annual program allowance transactions were between unrelated parties (distinct organizations), often with a broker facilitating the trade.

2014 Allowance Prices

- ARP* SO_2 allowance prices averaged less than $1 per ton.
- CAIR NO_x annual program allowances averaged** $50 per ton.
- CAIR NO_x ozone season program allowances averaged** $24 per ton.

  * ARP allowances are used for CAIR compliance at a two-to-one ratio, with two ARP allowances available to cover 1 ton of emissions under CAIR.

  ** Average spot price was calculated between January and October. All CAIR NO_X allowance prices dropped to $10 per ton after the October 2014 D.C. Circuit decision to lift the stay on the CSAPR.

More Information

- Learn more about allowance markets https://www.epa.gov/airmarkets/allowance-markets
- Air Markets Business Center https://www.epa.gov/airmarkets/business-center
- Air Markets Program Data (AMPD) https://ampd.epa.gov/ampd/
- Learn more about emissions trading https://www.epa.gov/emissions-trading-resources

Figures

2014 Allowance Transfers under CAIR and ARP

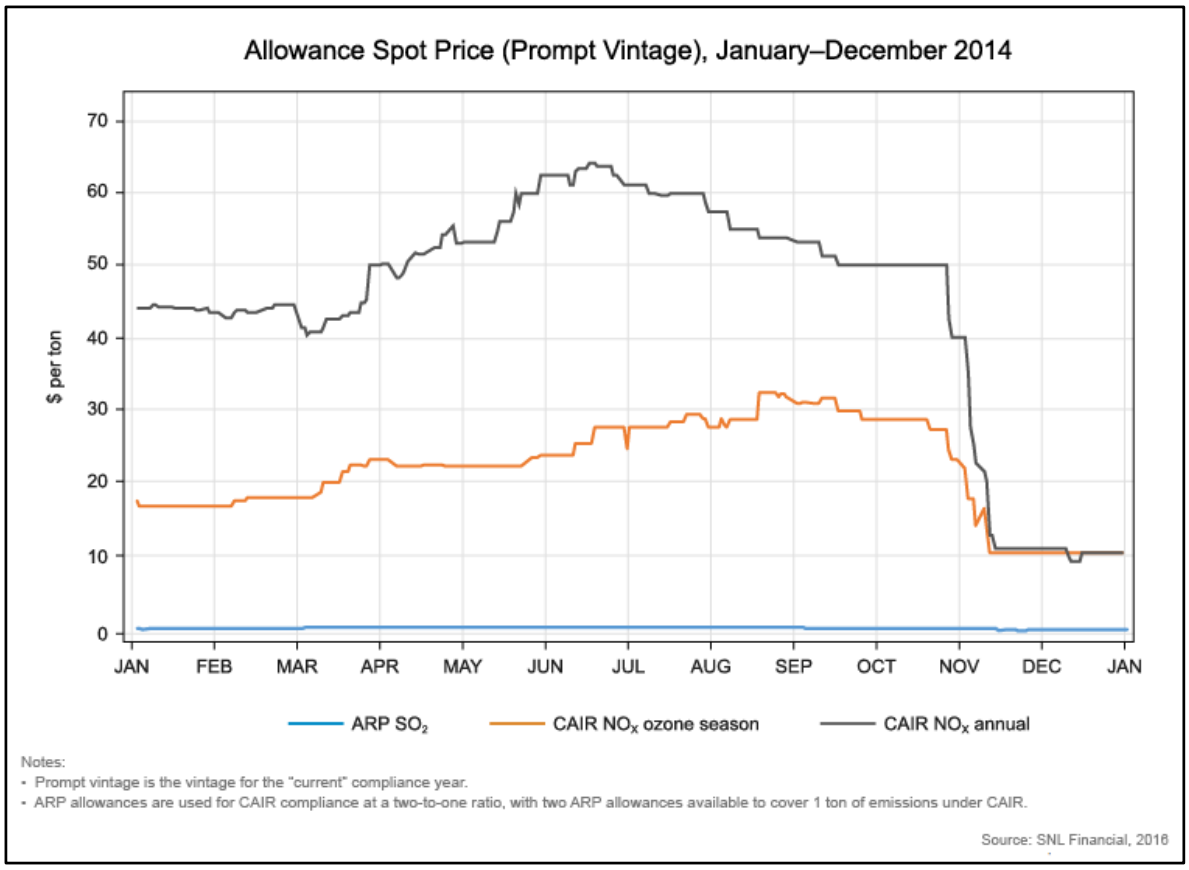
	Transactions Conducted in 2014	Allowances Transferred in 2014	Share of Program's Allowances Transferred in 2014	
ARP and CAIR SO_2 Programs	1,196 transactions	8,111,813 allowances	Distinct Organizations	18%
			Related Organizations	82%
CAIR NO_x Annual Program	1,064 transactions	700,747 allowances	Distinct Organizations	28%
			Related Organizations	72%
CAIR NO_x Ozone Season Program	863 transactions	251,436 allowances	Distinct Organizations	35%
			Related Organizations	65%

Notes:
- Most, but not all, of the transactions are shown above. The actual percentage shares may vary by less than 1% of the total allowances transferred for each program.
- Percentages may not add up to 100% due to rounding.
- ARP allowances are used for CAIR compliance at a two-to-one ratio, with two ARP allowances available to cover 1 ton of emissions under CAIR.

Source EPA, 2016

Notes:
- Most, but not all, of the transactions are shown above. The actual percentage shares may vary by less than 1% of the total allowances transferred for each program.
- Percentages may not add up to 100% due to rounding.
- ARP allowances are used for CAIR compliance at a two-to-one ratio, with two ARP allowances available to cover 1 ton of emissions under CAIR.

Figure 1. 2014 Allowance Transfers under CAIR and ARP



Notes:

- Prompt vintage is the vintage for the "current" compliance year.
- ARP allowances are used for CAIR compliance at a two-to-one ratio, with two ARP allowances available to cover 1 ton of emissions under CAIR.

Figure 2. Allowance Spot Price (Prompt Vintage), January–December 2014

Chapter 7: Ambient Air Quality

The Acid Rain Program (ARP), NO_x Budget Trading Program (NBP), and Clean Air Interstate Rule (CAIR) were designed to reduce sulfur dioxide (SO_2) and nitrogen oxides (NO_x) emissions from power plants. These pollutants contribute to the formation of ground level ozone (smog) and particulate matter (soot), which cause a range of serious health effects and visibility degradation in National Parks. The dramatic emission reductions achieved under these programs have improved air quality and delivered significant human health and ecological benefits across the United States.

To evaluate the impact of emission reductions on air quality, scientists and policymakers use data collected from long-term national air quality monitoring networks. These networks provide information on a variety of indicators useful for tracking and understanding trends in regional air quality over time and in different areas.

Sulfur Dioxide and Nitrogen Oxides Trends

Analysis and Background Information

Sulfur Dioxide

SO_2 is one of a group of highly reactive gases known as "oxides of sulfur." The primary source of SO_2 emissions is fossil fuel combustion at power plants. Smaller sources of SO_2 emissions include industrial processes, such as extracting metal from ore, as well as the burning of high sulfur-containing fuels by locomotives, large ships, and non-road equipment. SO_2 contributes to the formation of fine particle pollution ($PM_{2.5}$) and is linked with a number of adverse health effects on the respiratory system.[1] In addition, particulate sulfates degrade visibility and, because they are typically acidic, can harm ecosystems when deposited.

Nitrogen Oxides

NO_x is a group of highly reactive gases including nitric oxide (NO) and nitrogen dioxide (NO_2). In addition to contributing to the formation of ground-level ozone and $PM_{2.5}$, NO_x is linked with a number of adverse health effects on the respiratory system.[2, 3] NO_x also reacts in the atmosphere to form nitric acid (HNO_3) and particulate ammonium nitrate (NH_4NO_3). HNO_3 and NH_4NO_3, reported as total nitrate, can also lead to adverse health effects and, when deposited, cause damage to sensitive ecosystems.

Although the ARP, NBP, and CAIR NO_x programs have significantly reduced NO_x emissions (primarily from power plants) and improved air quality, emissions from other sources (such as motor vehicles and agriculture) contribute to total nitrate concentrations in many areas. Ambient nitrate levels can also be affected by emissions transported via air currents over wide regions.

Key Points

National SO_2 Air Quality

- Based on EPA's air trends data, the national average of SO_2 annual mean ambient concentrations decreased from 12.1 parts per billion (ppb) to 1.5 ppb (87 percent) between 1980 and 2014.

- The two largest single-year reductions (over 20 percent) occurred in the first year of the ARP, between 1994 and 1995, and more recently between 2008 and 2009, just prior to the start of the CAIR SO_2 program.

Regional Changes in Air Quality

- Average ambient SO_2 concentrations declined in the eastern United States following implementation of the ARP and other emission reduction programs. Regional average concentrations declined 84 percent from the 1989–1991 to 2012–2014 observation periods.
- Ambient particulate sulfate concentrations have decreased since the ARP was implemented, with average concentrations decreasing by 64 to 68 percent in observed regions from 1989–1991 to 2012–2014.
- Average annual ambient total nitrate concentrations declined 48 percent from 1989–1991 to 2012–2014 in the eastern United States, with the largest reductions in the Mid-Atlantic and Northeast.

More Information

- Clean Air Status and Trends Network (CASTNET) https://www.epa.gov/castnet
- Air Quality System (AQS) https://www.epa.gov/aqs
- National Ambient Air Quality Standards (NAAQS) https://www.epa.gov/criteria-air-pollutants
- Learn more about sulfur dioxide (SO_2) https://www.epa.gov/so2-pollution
- Learn more about nitrogen oxides (NO_x) https://www3.epa.gov/airquality/nitrogenoxides/
- Learn more about EPA's Clean Air Market Programs https://www.epa.gov/airmarkets/programs

References

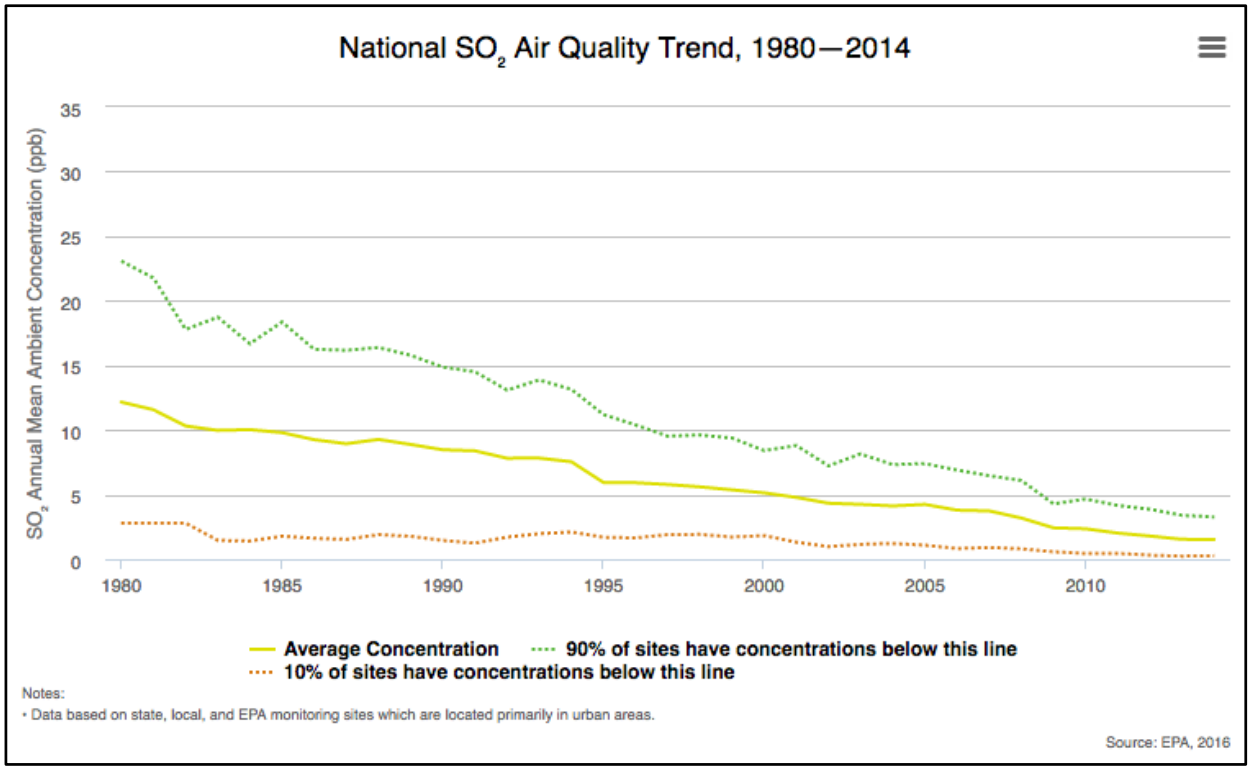
1. Katsouyanni, K., Schwartz, J., Spix, C., Touloumi, G., Zmirou, D., Zanobetti, A., Wojtyniak, B., Vonk, J.M., Tobias, A., Pönkä, A., Medina, S., Bachárová, L., & Anderson, H.R. (1996). *J. of Epidemiol Community Health,* 50: S12–S18.

2 Peel, J.L., Tolbert, P.E., Klein, M., Metzger, K.B., Flanders, W.D., Todd, K., Mulholland, J.A., Ryan, P.B., & Frumkin, H. (2005). Ambient air pollution and respiratory emergency department visits. *Epidemiology,* 16: 164–174.

3. Hong, C., Goldberg, M.S., Burnett, R.T., Jerrett, M., Wheeler, A.J., & Villeneuve, P.J. (2013) Long-term exposure to traffic-related air pollution and cardiovascular mortality. *Epidemiology,* 24: 35–43.

Figures

Subtopic: Sulfur Dioxide and Nitrogen Oxides Trends



Notes:

- Data based on state, local, and EPA monitoring sites which are located primarily in urban areas.

Figure 1. National SO_2 Air Quality Trend, 1980–2014

Regional Changes in Air Quality

Measurement	Region	Annual Average, 1989-1991	Annual Average, 2012-2014	Percent Change	Number of Sites	Statistical Significance
Ambient particulate sulfate concentration (µg/m³)	Mid-Atlantic	6.3	2.1	-67	12	***
	Midwest	5.8	2.1	-64	9	***
	Northeast	3.4	1.1	-68	4	
	Southeast	5.5	1.9	-65	8	***
Ambient sulfur dioxide concentration (µg/m³)	Mid-Atlantic	13.0	2.0	-85	12	***
	Midwest	11.0	2.1	-81	9	***
	Northeast	5.2	0.7	-86	4	
	Southeast	5.1	0.7	-86	8	***
Ambient total nitrate concentration (µg/m³)	Mid-Atlantic	3.3	1.6	-52	12	***
	Midwest	4.6	2.6	-43	9	***
	Northeast	1.7	0.8	-53	4	
	Southeast	2.2	1.1	-50	8	***

Notes:
- Averages are the arithmetic mean of all sites in a region that were present and met the completeness criteria in both averaging periods. Thus, average concentrations for 1989 to 1991 may differ from past reports.
- Statistical significance was determined at the 95 percent confidence level ($p < 0.05$) using Student's t-test. Changes that are not statistically significant may be unduly influenced by measurements at only a few locations or large variability in measurements.

Source EPA, 2016

Notes:
- Averages are the arithmetic mean of all sites in a region that were present and met the completeness criteria in both averaging periods. Thus, average concentrations for 1989 to 1991 may differ from past reports.
- Statistical significance was determined at the 95 percent confidence level ($p < 0.05$) using Student's t-test. Changes that are not statistically significant may be unduly influenced by measurements at only a few locations or large variability in measurements.

Figure 2. Regional Changes in Air Quality

Ozone

Analysis and Background Information

Ozone pollution forms when NO_x and volatile organic compounds (VOCs) react in the presence of sunlight. Major sources of NO_x and VOC emissions include electric power plants, motor vehicles, solvents, and industrial facilities. Meteorology plays a significant role in ozone (smog) formation and hot, sunny days are most favorable for ozone production. For ozone, EPA and states typically regulate NO_x emissions during the ozone season (May 1–September 30) when sunlight intensity and temperatures are highest.

Ozone Standards

In 1979, EPA established the National Ambient Air Quality Standard (NAAQS) for 1-hour ozone at 0.12 parts per million (ppm) (124 ppb), and in 1997, a more stringent daily maximum 8-hour ozone standard of 84 ppb was finalized, revising the 1979 standard. CAIR was designed to help downwind states in the eastern United States achieve the 1997 ozone NAAQS; therefore, analyses in this report focus on that standard. Based on extensive scientific evidence about ozone's effects on public health and welfare, EPA strengthened the daily maximum 8-hour ozone standard to 75 ppb in March 2008 and further strengthened the 8-hour NAAQS for ground-level ozone to 70 ppb in October 2015. EPA revoked the 1-hour ozone standard in 2005 and also recently revoked the 1997 8-hour standard in April 2015.

Regional Trends in Ozone

EPA investigated trends in daily maximum 8-hour ozone concentrations as measured at rural Clean Air Status and Trends Network (CASTNET) monitoring sites within the CAIR NO_x ozone season program region and in adjacent states. Rural ozone measurements are useful in assessing the impacts on air quality resulting from regional NO_x emission reductions because they are typically less affected by local sources of NO_x (e.g., industrial and mobile) than urban measurements. Reductions in rural ozone concentrations are largely attributed to reductions in regional NO_x emissions and transported ozone.

An Autoregressive Integrated Moving Average (ARIMA) model is an advanced statistical analysis tool used to determine the trend in regional ozone concentrations since implementation of various programs geared toward reducing ozone season NO_x emissions. The average of the 99th percentile of the daily maximum 8-hour ozone concentrations measured at CASTNET sites (as described above) was modeled to show the shift in the highest daily ozone levels. The decrease in the modeled trend is likely due to actions taken for CAIR compliance however, other factors may include meteorology and changes in electricity demand.

Meteorologically–Adjusted Daily Maximum 8-Hour Ozone Concentrations

Meteorologically–adjusted ozone trends provide additional insight on the influence of CAIR NO_x ozone season program emission reductions on regional air quality. Daily maximum 8-hour ozone concentration data from EPA and daily meteorology data from the National Weather Service were retrieved for 81 urban areas and 39 rural CASTNET monitoring sites located in the CAIR NO_x ozone season program region. EPA uses these data in a statistical model to account for the influence of weather on seasonal average ozone concentrations at each monitoring site.[1, 2]

Changes in Ozone Nonattainment Areas

The majority of ozone season NO_x emission reductions in the power sector that occurred after 2003 are attributable to the NBP and CAIR. As power sector emissions are an important component of the NO_x emission inventory, it is reasonable to conclude that ozone season NO_x emission reduction programs have significantly contributed to these improvements in ozone air quality. However, because areas continue to be out of attainment for both the 1997 and 2008 ozone NAAQS, additional NO_x ozone season emission reductions are needed to attain EPA's health-based air quality standards.

As part of an effort to help address the Agency's Clean Air Act (CAA) role to backstop states' obligations to address the problem of air pollution that is transported across state lines, the EPA issued the Cross-State Air Pollution Rule (CSAPR) in July 2011. The CSAPR addresses interstate transport of ozone pollution with respect to the 1997 ozone NAAQS. Additionally, on September 7, 2017, EPA finalized an update to the CSAPR ozone season program by issuing the CSAPR Update to address interstate transport of air pollution for the newer 2008 ozone NAAQS.

Key Points

Changes in 1-Hour Ozone during Ozone Season

- An overall regional reduction in ozone levels was observed between 2000–2002 and 2012–2014, with a 19 percent reduction in the highest (99th percentile) ozone concentrations in CAIR states.
- Results demonstrate how NO_x emission reduction policies have affected ozone concentrations in the eastern United States–the region the policies were designed to target.

Trends in Rural Ozone

- The ARIMA model of rural ozone concentrations shows ozone reductions of 20 ppb (23 percent) from 1990 to 2014.
- A significant decrease of modeled ozone concentrations occurred in 2003, following implementation of the NBP (12 ppb reduction from the previous year). That event was followed by an additional 14 percent (11 ppb) reduction just prior to the start of the CAIR NO_x ozone season program in 2009.

Changes in 8-Hour Ozone Concentrations

- The average reduction in ozone concentrations not adjusted for weather in the CAIR NO_x ozone season program region from 2000–2002 to 2012–2014 was about 8 ppb (15 percent).
- The average reduction in the meteorologically-adjusted ozone concentrations in the CAIR NO_x ozone season program region from 2000–2002 to 2012–2014 was about 10 ppb (17 percent).

Changes in Ozone Nonattainment Areas

- Ninety-one of the 113 areas originally designated as nonattainment for the 1997 8-hour ozone NAAQS (0.08 ppm) are in the eastern United States and are home to about 122 million people.[3] These nonattainment areas were designated in 2004 using air quality data from 2001 to 2003.[4]

- Based on data from 2012 to 2014, 99 percent (90 areas) of the eastern ozone nonattainment areas now show concentrations below the level of the 1997 standard, while one area continues to show concentrations above the 1997 standard.
- Compared with the 2001–2003 period, all 91 areas showed improvement in the 2012–2014 period toward meeting the 1997 standard.
- Given that the majority of ozone season NO_x emission reductions in the power sector that occurred after 2003 are attributable to the NBP and CAIR, it is reasonable to conclude that ozone season NO_x emission reduction programs have significantly contributed to these improvements in ozone air quality.

More Information

- Clean Air Status and Trends Network (CASTNET) https://www.epa.gov/castnet
- Air Quality System (AQS) https://www.epa.gov/aqs
- National Ambient Air Quality Standards (NAAQS) https://www.epa.gov/criteria-air-pollutants
- Learn more about ozone https://www.epa.gov/ozone-pollution
- Learn more about nitrogen oxides (NO_x) https://www3.epa.gov/airquality/nitrogenoxides/
- Learn more about Nonattainment Areas https://www3.epa.gov/airquality/greenbook/
- Learn more about EPA's Clean Air Market Programs https://www.epa.gov/airmarkets/programs

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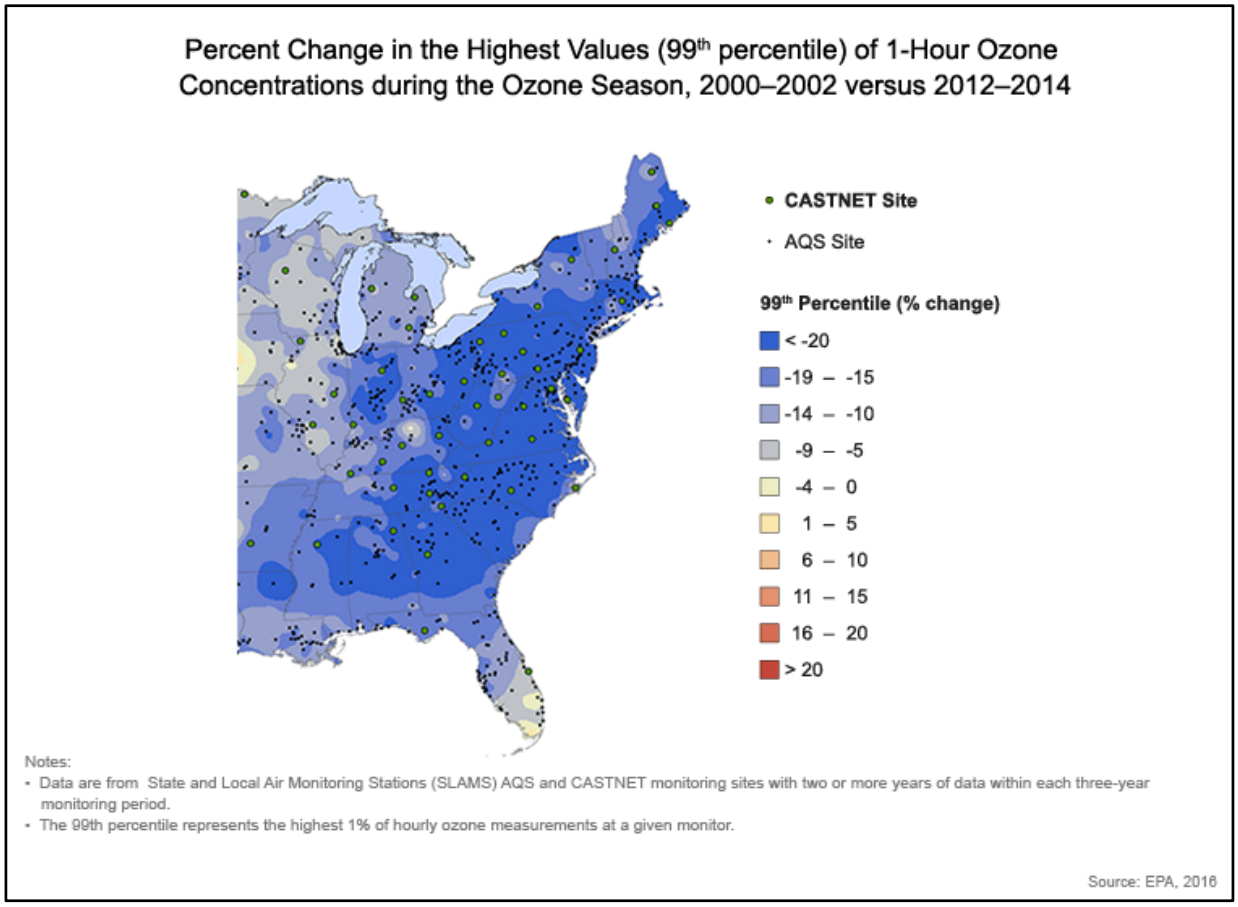
3. U.S. Census. (2010).
4. 40 CFR Part 81. Designation of Areas for Air Quality Planning Purposes.

Figures

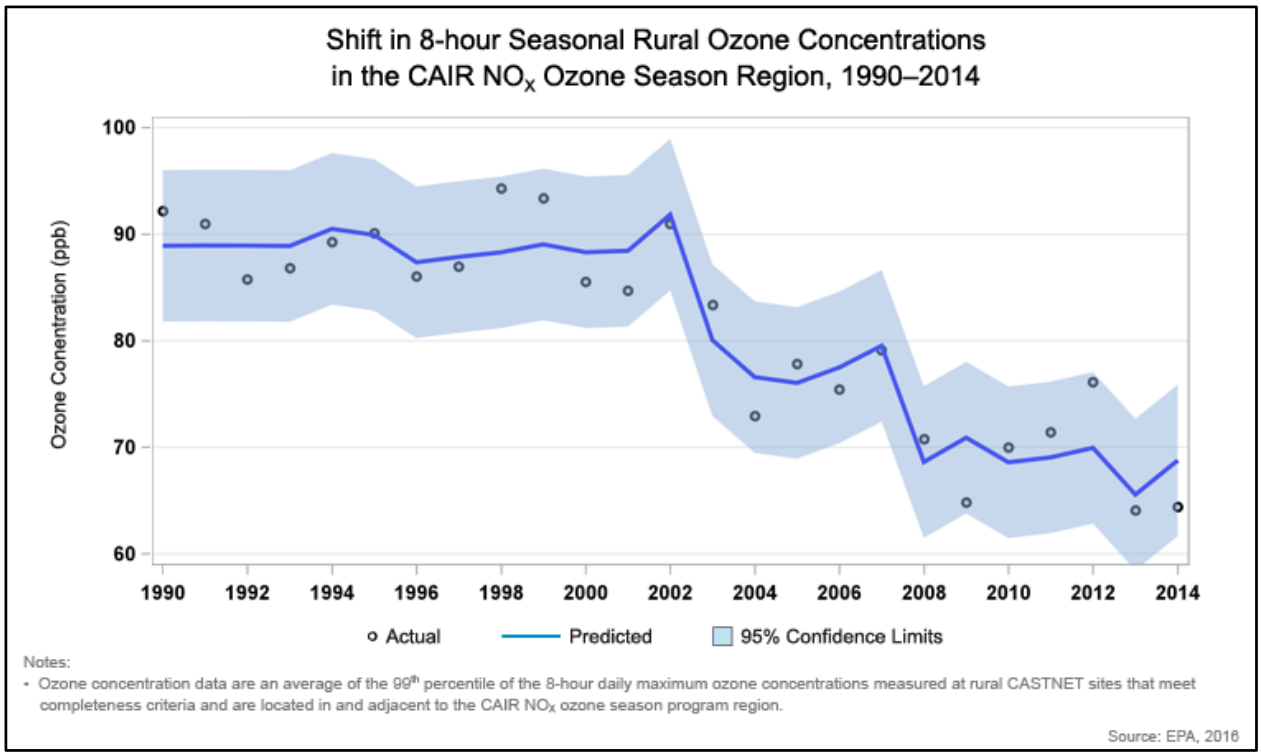
Subtopic: Ozone



Notes:

-
- Data are from State and Local Air Monitoring Stations (SLAMS) AQS and CASTNET monitoring sites with two or more years of data within each three-year monitoring period.
- The 99th percentile represents the highest 1% of hourly ozone measurements at a given monitor.

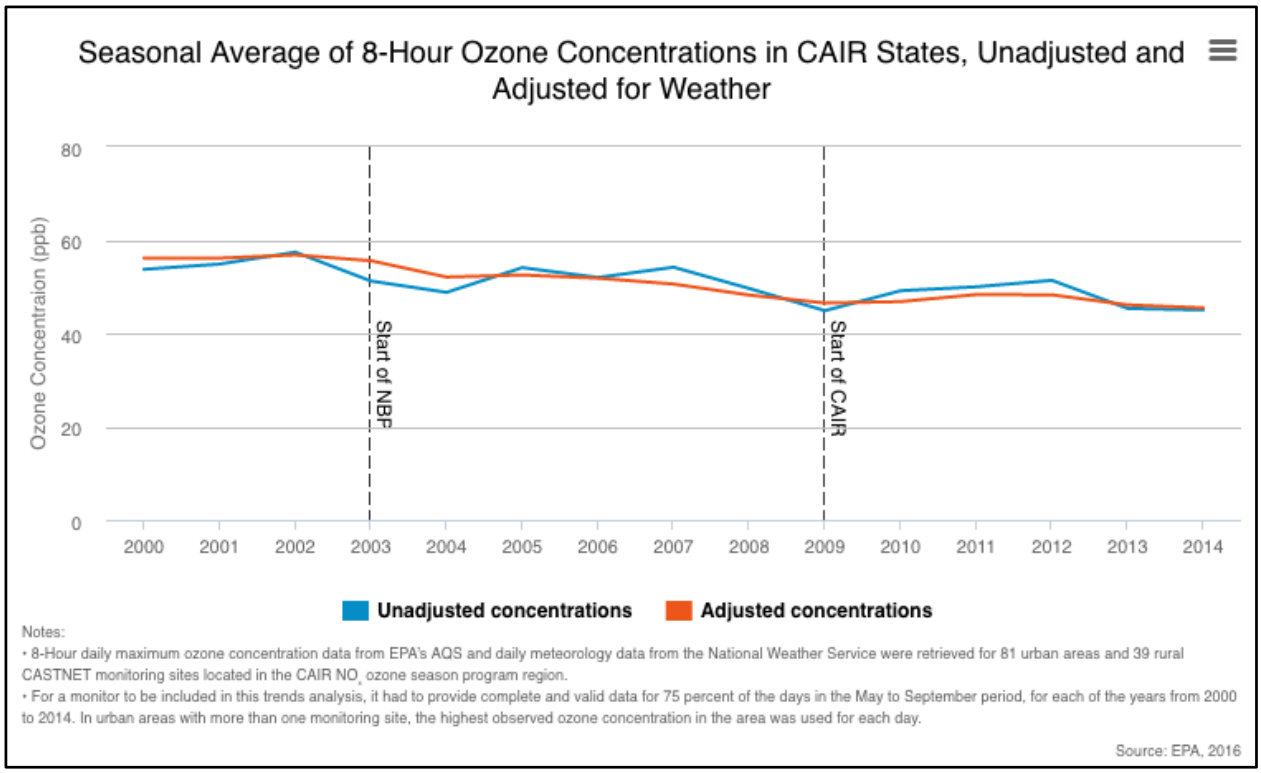
Figure 1. Percent Change in the Highest Values (99th percentile) of 1-hour Ozone Concentrations during the Ozone Season, 2000–2002 versus 2012–2014



Notes:

- Ozone concentration data are an average of the 99th percentile of the 8-hour daily maximum ozone concentrations measured at rural CASTNET sites that meet completeness criteria and are located in and adjacent to the CAIR NO_x ozone season program region.

Figure 2. Shift in 8-hour Seasonal Rural Ozone Concentrations in the CAIR NO_x Ozone Season Region, 1990–2014



Notes:

- 8-Hour daily maximum ozone concentration data from EPA's AQS and daily meteorology data from the National Weather Service were retrieved for 81 urban areas and 39 rural CASTNET monitoring sites located in the CAIR NO_x ozone season program region.
- For a monitor to be included in this trends analysis, it had to provide complete and valid data for 75 percent of the days in the May to September period, for each of the years from 2000 to 2014. In urban areas with more than one monitoring site, the highest observed ozone concentration in the area was used for each day.

Figure 3. Seasonal Average of 8-Hour Ozone Concentrations in CAIR States, Unadjusted and Adjusted for Weather

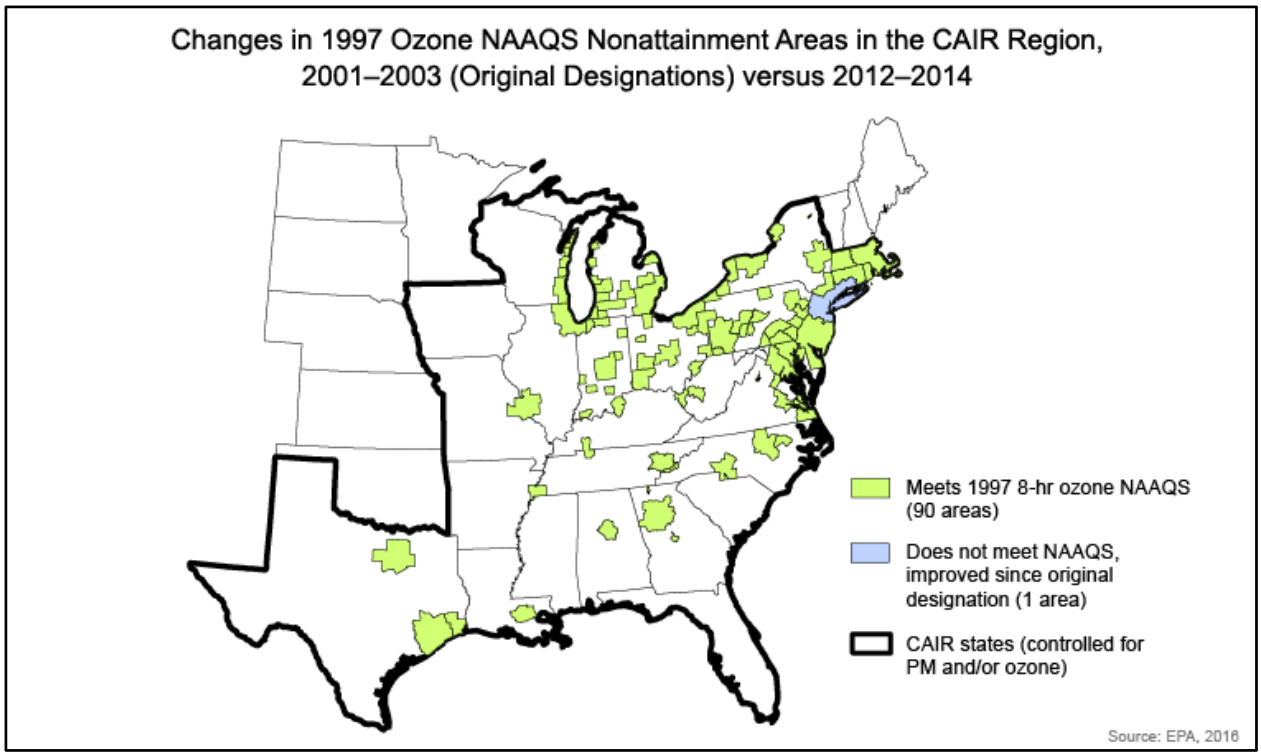


Figure 4. Changes in 1997 Ozone NAAQS Nonattainment Areas in the CAIR Region, 2001–2003 (Original Designations) versus 2012–2014

Particulate Matter

Analysis and Background Information

Particulate matter—also known as soot, particle pollution, or PM—is a complex mixture of extremely small particles and liquid droplets. Particle pollution is made up of a number of components, including acid-forming nitrate and sulfate compounds, organic compounds, metals, and soil or dust particles. Fine particles (defined as particulate matter with aerodynamic diameter < 2.5 µm, and abbreviated as $PM_{2.5}$) can be directly emitted or can form when gases emitted from power plants, industrial sources, automobiles, and other sources react in the air.

Particle pollution—especially fine particles—contains microscopic solids or liquid droplets so small that they can get deep into the lungs and cause serious health problems. Numerous scientific studies have linked particle pollution exposure to a variety of problems, including the following: increased respiratory symptoms, such as irritation of the airways, coughing, or difficulty breathing; decreased lung function; aggravated asthma; development of chronic bronchitis; irregular heartbeat; nonfatal heart attacks; and premature death in people with heart or lung disease.[1,2,3]

Particulate Matter Standards

The CAA requires EPA to set NAAQS for particle pollution. In 1997, EPA set the first PM standard for fine particles at 65 micrograms per cubic meter ($\mu g/m^3$) measured as the three-year average of the 98th percentile for 24-hour exposure, and at 15 $\mu g/m^3$ for annual exposure measured as the three-year annual mean. EPA revised the air quality standards for particle pollution in 2006, tightening the 24-hour fine particle standard to 35 $\mu g/m^3$ and retaining the annual fine particle standard at 15 $\mu g/m^3$. In December 2012, EPA strengthened the annual fine particle standard to 12 $\mu g/m^3$.

CAIR was promulgated to help downwind states in the eastern United States achieve the 1997 annual average $PM_{2.5}$ NAAQS; therefore, analyses in this report focus on that standard.

Changes in $PM_{2.5}$ Nonattainment Areas

The majority of SO_2 and annual NO_x emission reductions in the power sector that occurred after 2003 are attributable to the ARP, NBP, and CAIR. As power sector emissions are an important component of the SO_2 and annual NO_x emission inventory, it is reasonable to conclude that these emission reduction programs have significantly contributed to these improvements in $PM_{2.5}$ air quality. However, because areas continue to be out of attainment for the 1997 $PM_{2.5}$ NAAQS, additional SO_2 and annual NO_x emission reductions are needed to attain EPA's health-based air quality standards.

As part of an effort to help support states' obligations to address the problem of air pollution that is transported across state lines and help address the Agency's Clean Air Act role in backstopping these obligations, the EPA issued the Cross-State Air Pollution Rule (CSAPR) in July 2011. The CSAPR, which began in January 2015, addresses interstate transport of fine particle pollution with respect to the 1997 $PM_{2.5}$ NAAQS.

Key Points

PM Seasonal Trends

- Average $PM_{2.5}$ concentration data were assessed from 195 urban Air Quality System (AQS) areas located in the CAIR SO_2 and NO_x annual program region. Trend lines in $PM_{2.5}$ concentrations show decreasing trends in both the warm months (April to September) and cool months (October to March) unadjusted for the influence of weather.
- The annual average $PM_{2.5}$ concentration has decreased by about 37 percent in both the warm and cool season months between 2000 and 2014.

Changes in $PM_{2.5}$ Nonattainment

- Thirty-six of the 39 designated nonattainment areas for the 1997 annual average $PM_{2.5}$ standard are in the eastern United States and are home to about 75 million people.[4,5] The nonattainment areas were set in January 2005 using 2001 to 2003 data.
- Based on data gathered from 2012 to 2014, 32 of these original eastern areas show concentrations below the level of the 1997 $PM_{2.5}$ standard (15.0 $\mu g/m^3$), indicating improvements in $PM_{2.5}$ air quality. Four areas have incomplete data.
- Given that the majority of power sector SO_2 and annual NO_x emission reductions occurring after 2003 are attributable to the ARP, NBP, and CAIR, it is reasonable to conclude that these emission reduction programs have significantly contributed to these improvements in $PM_{2.5}$ air quality.

More Information

- Clean Air Status and Trends Network (CASTNET) https://www.epa.gov/castnet
- Air Quality System (AQS) https://www.epa.gov/aqs
- National Ambient Air Quality Standards https://www.epa.gov/criteria-air-pollutants
- Learn more about particulate matter (PM) https://www.epa.gov/pm-pollution
- Learn more about sulfur dioxide (SO_2) https://www.epa.gov/so2-pollution
- Learn more about nitrogen oxides (NO_x) https://www3.epa.gov/airquality/nitrogenoxides/
- Learn more about Nonattainment Areas https://www3.epa.gov/airquality/greenbook/
- Learn more about EPA's Clean Air Market Programs https://www.epa.gov/airmarkets/programs

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2. Schwartz, J. & Lucas, N. (2000). Fine particles are more strongly associated than coarse particles with acute respiratory health effects in school children. I 11: 6–10.

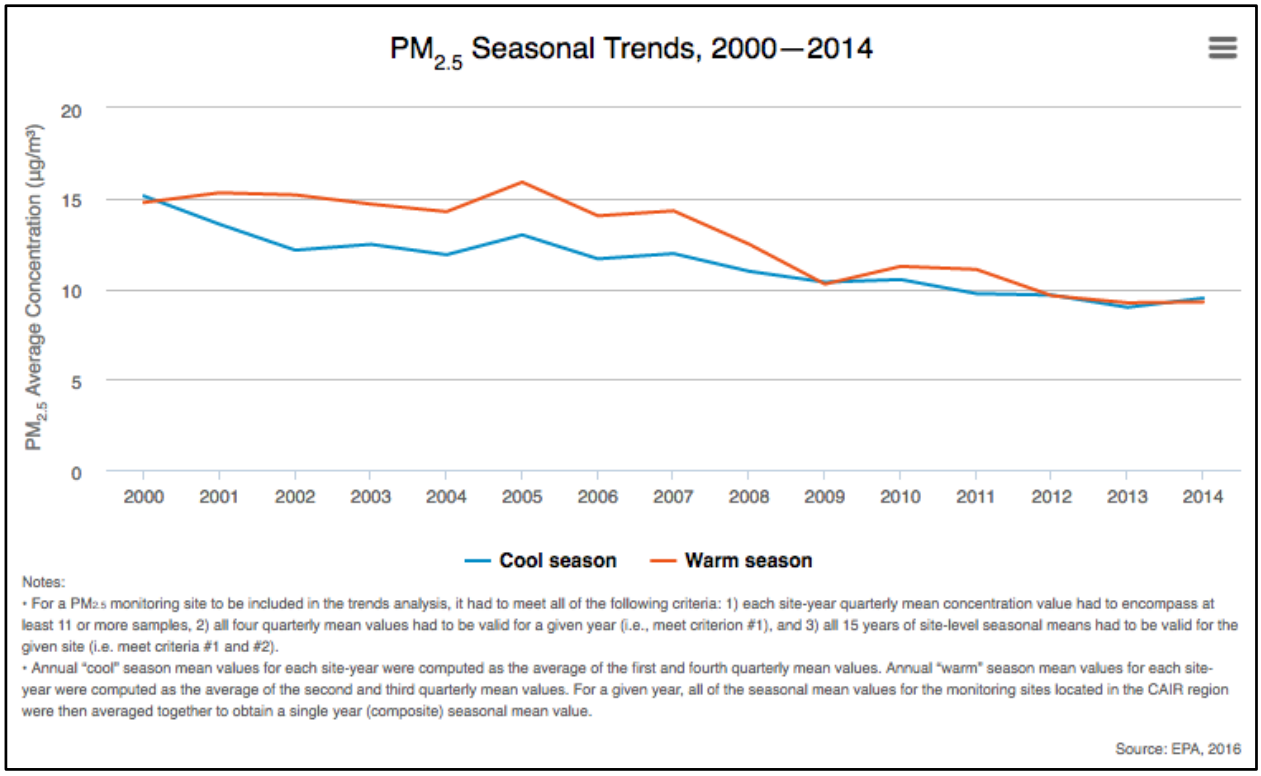
3. Bell, M.L., Dominici, F., Ebisu, K., Zeger, S.L., & Samet, J.M. (2007). Spatial and temporal variation in PM2.5 chemical composition in the United States for health effects studies. *Environmental Health Perspectives* 115: 989–995.

4. 40 CFR Part 81. Designation of Areas for Air Quality Planning Purposes.

5. U.S. Census. (2010).

Figures

Subtopic: Particulate Matter



Notes:

- For a $PM_{2.5}$ monitoring site to be included in the trends analysis, it had to meet all of the following criteria: 1) each site-year quarterly mean concentration value had to encompass at least 11 or more samples, 2) all four quarterly mean values had to be valid for a given year (i.e., meet criterion #1), and 3) all 15 years of site-level seasonal means had to be valid for the given site (i.e., meet criteria #1 and #2).
- Annual "cool" season mean values for each site-year were computed as the average of the first and fourth quarterly mean values. Annual "warm" season mean values for each site-year were computed as the average of the second and third quarterly mean values. For a given year, all of the seasonal mean values for the monitoring sites located in the CAIR region were then averaged together to obtain a single year (composite) seasonal mean value.

Figure 1. $PM_{2.5}$ Seasonal Trends, 2000–2014

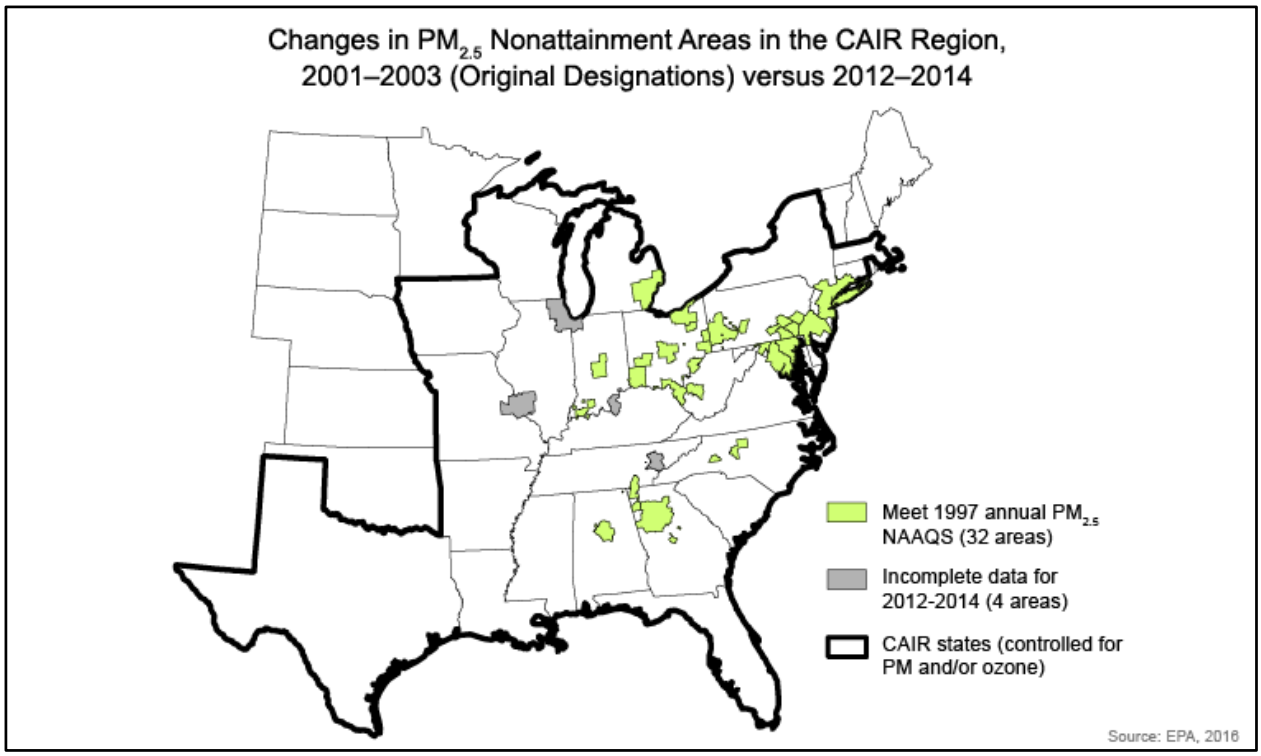


Figure 2. Changes in $PM_{2.5}$ Nonattainment Areas in the CAIR Region, 2001–2003 (Original Designations) versus 2012–2014

Chapter 8: Acid Deposition

Acid deposition, commonly known as "acid rain," is a broad term referring to the mixture of wet and dry deposition from the atmosphere containing higher than normal amounts of sulfuric acids and nitric acids. The precursors of acid deposition are primarily the result of emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO_x) from fossil fuel combustion; however, natural sources, such as volcanoes and decaying vegetation, also contribute a small amount.

Analysis and Background Information

Acid Deposition

As SO_2 and NO_x gases react in the atmosphere with water, oxygen, and other chemicals, they form acidic compounds that get deposited to the ground in the form of wet and dry acid deposition.

Monitoring network data show significant improvements in the primary acid deposition indicators. For example, wet sulfate deposition (sulfate that falls to the earth through rain, snow, and other precipitation) has decreased since the implementation of the Acid Rain Program (ARP) in much of the Ohio River Valley and Northeastern United States. Some of the most dramatic reductions have occurred in the mid-Appalachian region, including Maryland, New York, West Virginia, Virginia, and most of Pennsylvania. Along with wet sulfate deposition, precipitation acidity, expressed as hydrogen ion (H^+) concentration, have also decreased by similar percentages.

Reductions in nitrogen deposition compared to the early 1990s have been less pronounced than those for sulfur. As noted earlier, emissions from source categories other than ARP and CAIR sources contribute to changes in air concentrations and deposition of nitrogen.

Monitoring Networks

The Clean Air Status and Trends Network (CASTNET) provides long-term monitoring of regional air quality to determine trends in atmospheric concentrations and deposition of nitrogen, sulfur, and ozone in order to evaluate the effectiveness of national and regional air pollution control programs. CASTNET now operates more than 90 regional sites throughout the contiguous United States, Alaska, and Canada. Sites are located in areas where urban influences are minimal.

The National Atmospheric Deposition Program/National Trends Network (NADP/NTN) is a nationwide, long-term network tracking the chemistry of precipitation. The NADP/NTN provides concentration and wet deposition data on hydrogen ion (acidity as pH), sulfate, nitrate, ammonium, chloride, and base cations. The NADP/NTN has grown to more than 250 sites spanning the United States, Canada, Puerto Rico, and the Virgin Islands.

Together, these complementary networks provide long-term data needed to estimate spatial patterns and temporal trends in total deposition.

Key Points

Wet Sulfate Deposition

- The Northeast and Mid-Atlantic have shown the greatest improvement with an overall 64 percent reduction in wet sulfate deposition in the eastern United States from 1989–1991 to 2012–2014.
- A decrease in both SO_2 emissions from sources in the Ohio River Valley and the formation of sulfates that are transported long distances have resulted in reduced sulfate deposition in the Northeast. The sulfate reductions documented in the region, particularly across New England and portions of New York, were also affected by lowered SO_2 emissions in eastern Canada.[1]

Wet Inorganic Nitrogen Deposition

- Wet deposition of inorganic nitrogen decreased an average of 33 percent in the Mid-Atlantic and Northeast but decreased only 12 percent in the Midwest from 1989–1991 to 2012–2014.
- Reductions in nitrogen deposition recorded since the early 1990s have been less pronounced than those for sulfur. Emission changes from other source categories (e.g., mobile sources and manufacturing) contribute to changes in air concentrations and deposition of nitrogen.

Regional Trends in Deposition

- Between 1989–1991 and 2012–2014, the Northeast and Mid-Atlantic experienced the largest reductions in wet sulfate deposition, 68 percent and 70 percent, respectively.
- The reduction in total sulfur deposition (wet plus dry) has been of similar magnitude to that of wet deposition with an overall average reduction of 72 percent from 1989–1991 to 2012–2014.
- Decreases in dry and total inorganic nitrogen deposition have generally been greater than that of wet deposition, with average reductions of 56 percent and 34 percent, respectively. In contrast, wet deposition from inorganic nitrate reduced by an average of 21 percent from 1989–1991 to 2012–2014.

More Information

- Learn more about acid rain https://www.epa.gov/acidrain
- Clean Air Status and Trends Network (CASTNET) https://epa.gov/castnet
- National Atmospheric Deposition Program (NADP) http://nadp.isws.illinois.edu/

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1. Government of Canada, Environment Canada. (2015). Canada-United States Air Quality Agreement Progress Report 2014. ISSN: 1910–5223: Cat. No.: En85-1/2014E-PDF.

Figures

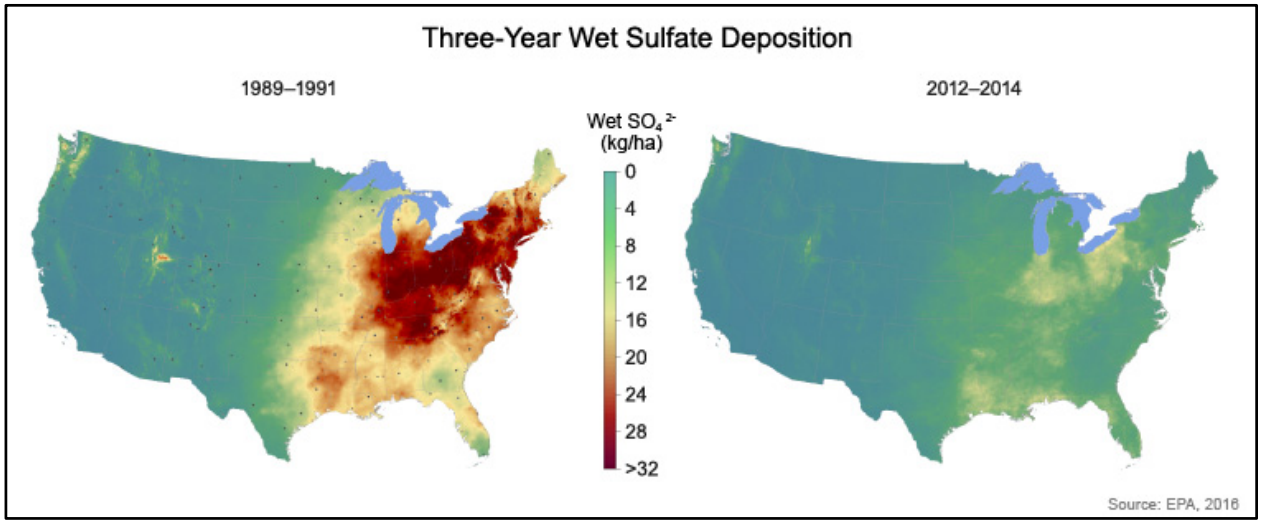

Figure 1. Three-Year Wet Sulfate Deposition

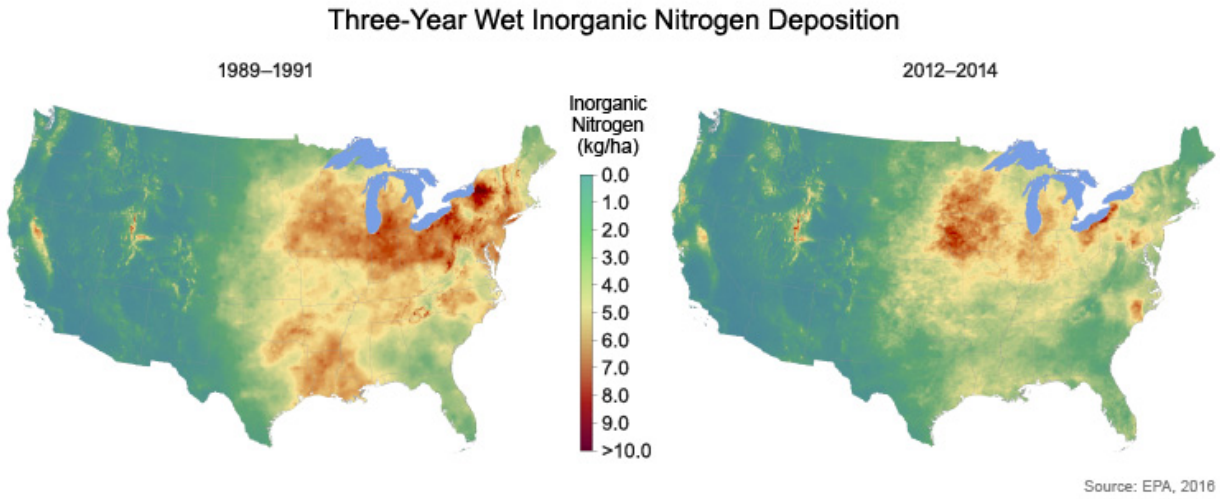

Figure 2. Three-Year Wet Inorganic Nitrogen Deposition

Regional Trends in Deposition

Measurement	Region	Annual Average, 1989-1991	Annual Average, 2012-2014	Percent Change	Number of Sites	Statistical Significance
Dry inorganic nitrogen deposition (kg-N/ha)	Mid-Atlantic	2.5	1.0	-60	12	***
	Midwest	2.4	1.3	-46	9	***
	Northeast	1.3	0.4	-69	4	
	Southeast	1.7	0.8	-53	8	***
Dry sulfur deposition (kg-S/ha)	Mid-Atlantic	7.0	1.1	-84	12	***
	Midwest	6.5	1.4	-78	9	***
	Northeast	2.6	0.4	-85	4	
	Southeast	3.1	0.6	-81	8	***
Total inorganic nitrogen deposition (kg-N/ha)	Mid-Atlantic	8.8	5.2	-41	12	***
	Midwest	8.6	6.4	-26	9	***
	Northeast	6.6	4.2	-36	4	
	Southeast	6.4	4.4	-31	8	***
Total sulfur deposition (kg-S/ha)	Mid-Atlantic	16.0	4.0	-75	12	***
	Midwest	15.0	4.0	-73	9	***
	Northeast	9.5	2.6	-73	4	
	Southeast	10.4	3.2	-69	8	***
Wet nitrogen deposition from inorganic nitrogen (kg-N/ha)	Mid-Atlantic	6.2	4.1	-34	11	***
	Midwest	5.8	5.1	-12	27	***
	Northeast	5.7	3.9	-32	16	***
	Southeast	4.3	3.5	-19	22	***
Wet sulfur deposition from sulfate (kg-S/ha)	Mid-Atlantic	9.2	2.8	-70	11	***
	Midwest	7.1	2.8	-59	27	***
	Northeast	7.5	2.4	-68	16	***
	Southeast	5.9	2.3	-61	22	***

Notes:
- Averages are the arithmetic mean of all sites in a region that were present and met the completeness criteria in both averaging periods. Thus, average concentrations for 1989 to 1991 may differ from past reports.
- Total deposition is estimated from raw measurement data, not rounded, and may not equal the sum of dry and wet deposition.
- Statistical significance was determined at the 95 percent confidence level ($p < 0.05$) using Student's t-test. Changes that are not statistically significant may be unduly influenced by measurements at only a few locations or large variability in measurements.

Source EPA, 2016

Notes:
- Averages are the arithmetic mean of all sites in a region that were present and met the completeness criteria in both averaging periods. Thus, average concentrations for 1989 to 1991 may differ from past reports.
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Figure 3. Regional Trends in Deposition

Chapter 9: Ecosystem Response

Acidic deposition resulting from sulfur dioxide (SO_2) and nitrogen oxides (NO_x) emissions may negatively affect the biological health of lakes, streams, and other ecosystems in the United States. Trends in measured chemical indicators allow scientists to determine whether water bodies are improving and heading towards recovery or if they are still acidifying. Assessment tools, such as critical loads analysis, provide a quantitative estimate of whether acidic deposition levels of sulfur and nitrogen resulting from SO_2 and NO_x emission reductions may protect aquatic resources.

Ecosystem Health

Analysis and Background Information

Acidified Surface Water Trends

Acidified surface water mobilizes toxic forms of aluminum from soils, particularly in clay rich soils, harming fish, other aquatic life, and wildlife. Four chemical indicators of aquatic ecosystem response to emission changes are presented here: trends in sulfate and nitrate anions, acid neutralizing capacity (ANC), and sum of base cations. Aquatic ecosystem recovery is indicated by increasing trends in ANC and base cations and decreasing trends in sulfate and nitrate concentrations in surface waters. The following is a description of each indicator:

- **Sulfate** is the primary anion in most acid-sensitive waters and has the potential to acidify surface waters and leach base cations and toxic forms of aluminum from soils.
- **Nitrate** has the same potential as sulfate to acidify surface waters. However, nitrogen is an important nutrient for plant and algae growth, and most of the nitrogen inputs from deposition are quickly taken up by plants and algae, leaving less in surface waters.
- **ANC** is a key indicator of ecosystem recovery and is a measure of overall buffering capacity of surface waters against acidification; it indicates the ability to neutralize strong acids that enter aquatic systems from deposition and other sources.
- **Base cations** neutralize both sulfate and nitrate anions, thereby preventing surface water acidification. Base cation availability is largely a function of underlying geology, with the weathering of base cations from the underlying rocks, soil age, and vegetation community.

Highly weathered soils of the central Appalachians are able to store deposited sulfate, such that the decrease in acidic deposition has not yet resulted in lower sulfate concentrations in many of the monitored streams. However, as long-term sulfate deposition exhausts the soil's ability to store additional sulfate, a decreasing proportion of the deposited sulfate will be retained in the soil and an increasing proportion is exported to surface waters. Thus, sulfate concentrations in some streams in this region are not changing or are still increasing despite reduced sulfate deposition.[1]

Monitoring Networks

In collaboration with other federal and state agencies and universities, EPA administers two monitoring programs that provide information on the impacts of acidic deposition on otherwise pristine lakes and streams: the Temporally Integrated Monitoring of Ecosystems (TIME) and the Long-term Monitoring (LTM) programs. These programs are designed to track changes in surface water chemistry in the four regions sensitive to acid rain in the eastern United States: New England, the Adirondack Mountains, the Northern Appalachian Plateau, and the central Appalachians (the Valley, Ridge, and Blue Ridge Provinces).

Key Points

Regional Trends in Water Quality

- Between 1990 and 2014, significant improving trends in sulfate concentrations are found at all LTM lake and stream monitoring sites in New England, the Adirondacks, and the Catskill mountains.
- On the other hand, between 2013 and 2014, streams in the central Appalachian region have experienced mixed results. Only 26 percent of monitored streams show lower sulfate concentrations (and statistically significant trends), while 14 percent show increased sulfate concentrations.
- Nitrate concentrations and trends are highly variable and many sites do not show improving trends between 1990 and 2014, despite reductions in NO_x emissions and inorganic nitrogen deposition.
- In 2014, levels of ANC, a key indicator of ecosystem recovery, have increased significantly from 1990 in lake and stream sites in the Adirondack Mountains, New England, and the Catskill mountains.

More Information

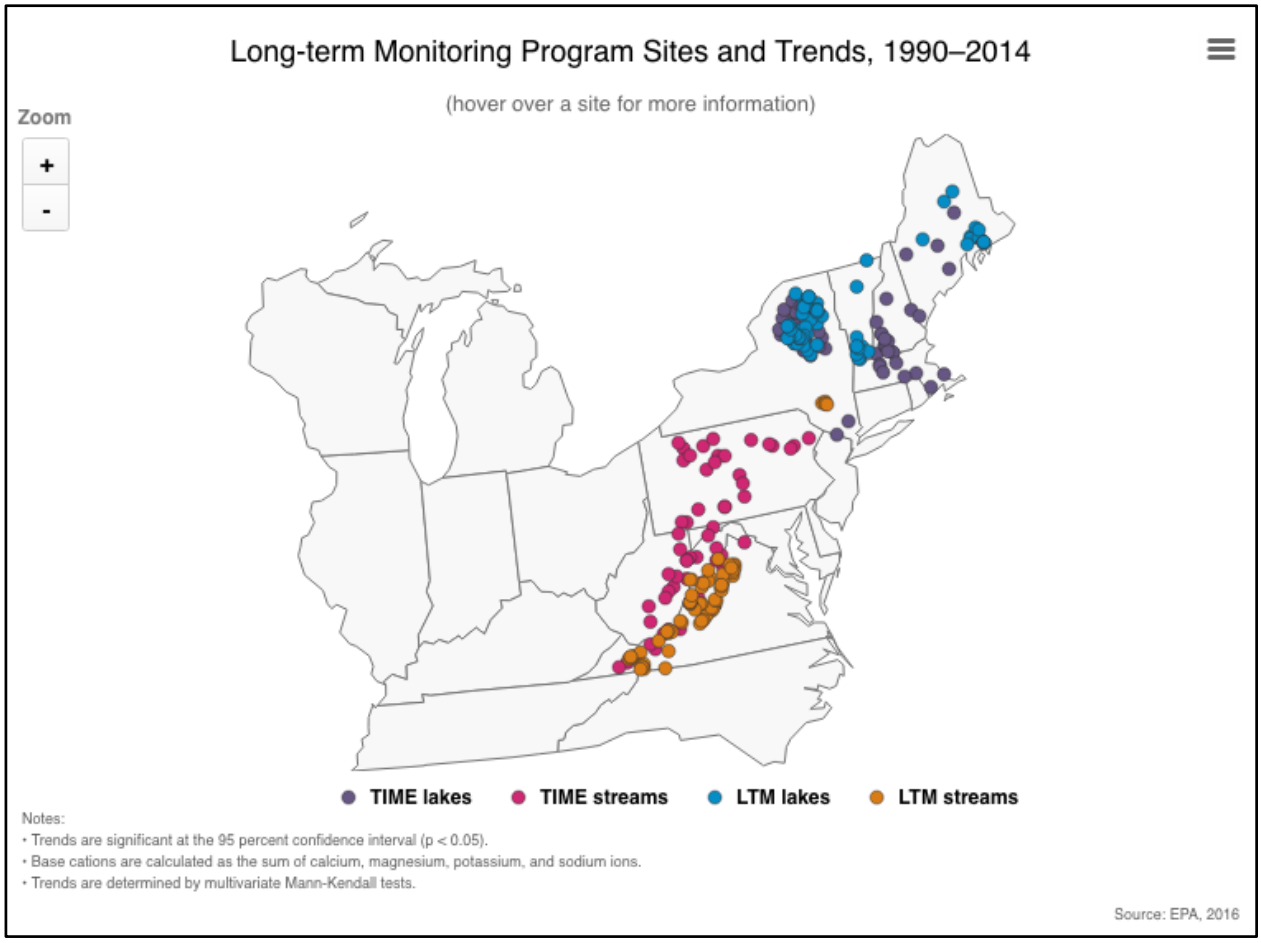
- Learn more about surface water monitoring at EPA http://www.epa.gov/airmarkets/monitoring-surface-water-chemistry
- Learn more about acid rain http://www.epa.gov/acidrain/

References

1. Burns, D.A., Lynch, J.A., Cosby, B.J., Fenn, M.E., & Baron, J.S. (2011). *National Acid Precipitation Assessment Program Report to Congress 2011: An Integrated Assessment.* U.S. EPA, National Science and Technology Council, Washington, D.C.: 114 p.

Figures

Subtopic: Ecosystem Health



Notes:

- Trends are significant at the 95 percent confidence interval ($p < 0.05$).
- Base cations are calculated as the sum of calcium, magnesium, potassium, and sodium ions.
- Trends are determined by multivariate Mann-Kendall tests.

Figure 1. Long-term Monitoring Program Sites and Trends, 1990–2014

Regional Trends in Sulfate, Nitrate, ANC, and Base Cations at Long-term Monitoring Sites, 1990–2014

Region	Water Bodies Covered	% of Sites with Improving Sulfate Trend	% of Sites with Improving Nitrate Trend	% of Sites with Improving ANC Trend	% of Sites with Improving Base Cations Trend
Adirondack Mountains	38 lakes in NY*	100%	42%	87%	92%
New England	26 lakes in ME and VT	100%	21%	58%	67%
Catskills*	4 streams in NY	100%	0%	50%	100%
Central Appalachians	66 streams in VA	26%	52%	14%	23%

Notes:
- Trends are statistically significant at the 95 percent confidence interval ($p < 0.05$).
- Base cations are calculated as the sum of calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na) ions.
- Trends are determined by multivariate Mann-Kendall tests.
- *Trends are based on a different subset of 38 lakes in New York than the results presented in previous reports.

Source EPA, 2016

Notes:
- Trends are statistically significant at the 95 percent confidence interval ($p < 0.05$).
- Base cations are calculated as the sum of calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na) ions.
- Trends are determined by multivariate Mann-Kendall tests.
- *Trends are based on a different subset of 38 lakes in New York than the results presented in previous reports.

Figure 2. Regional Trends in Sulfate, Nitrate, ANC, and Base Cations at Long-term Monitoring Sites, 1990–2014

Critical Loads Analysis

Analysis and Background Information

A critical loads analysis is an assessment tool used to provide a quantitative estimate of whether acid deposition levels resulting from SO_2 and NO_x emission reductions are sufficient to protect aquatic biological resources. If acidic deposition is less than the calculated critical load, harmful ecological effects (e.g., reduced reproductive success, stunted growth, loss of biological diversity) are not expected to occur, and ecosystems damaged by past exposure are expected to eventually recover.[1]

Lake and stream waters having an ANC value greater than 50 µeq/L are classified as having a moderately healthy aquatic biological community; therefore, this ANC concentration is often used as a goal for ecological protection of surface waters affected by acidic deposition. In this analysis, the critical load represents the amount of sulfur and nitrogen that could be deposited annually to a lake or stream and its watershed and still support a moderately healthy ecosystem (i.e., having an ANC greater than 50 µeq/L). Surface water samples from 6,001 lakes and streams along acid-sensitive regions of the Appalachian Mountains and some adjoining northern coastal plain regions were collected through a number of water quality monitoring programs. Critical load exceedances were calculated using the Steady-State Water Chemistry model.[2,3]

Key Points

Critical Loads and Exceedances

- For the period from 2012 to 2014, 16 percent of all studied lakes and streams were shown to still receive levels of combined total sulfur and nitrogen deposition exceeding their calculated critical load. This is a 52 percent improvement over the period from 2000 to 2002 when 34 percent of all studied lakes and streams exceeded their calculated critical load.
- Emission reductions achieved between 2000 and 2014 are anticipated to contribute to broad surface water improvements and increased aquatic ecosystem protection across the five regions along the Appalachian Mountains.
- Based on this modeled approach, in 2014, current sulfur and nitrogen deposition loadings still exceed levels required for recovery of many lakes and streams, indicating that additional emission reductions would be necessary for some acid-sensitive aquatic ecosystems along the Appalachian Mountains to recover and be protected from acid deposition.

More Information

- Learn more about surface water monitoring at EPA http://www.epa.gov/airmarkets/monitoring-surface-water-chemistry
- National Acid Precipitation Assessment Program (NAPAP) Report to Congress http://ny.water.usgs.gov/projects/NAPAP/

References

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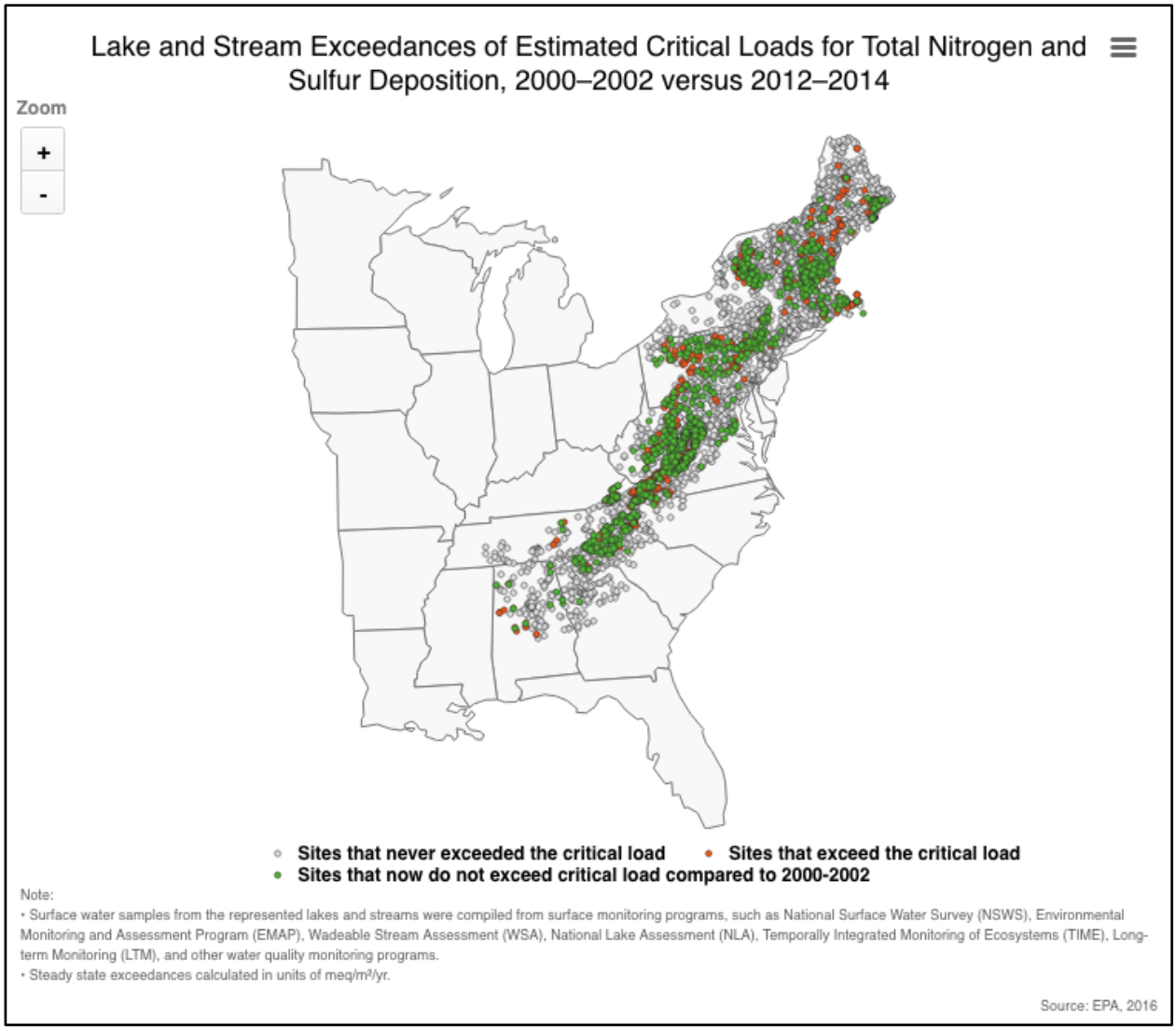
2. Sullivan, T.J., Cosby, B.J., Webb, J.R., Dennis, R.L., Bulger, A.J., & Deviney, Jr. F.A. (2007). Streamwater acid-base chemistry and critical loads of atmospheric sulfur deposition in Shenandoah National Park, Virginia. *Environmental Monitoring and Assessment,* 137: 85–99.

3. Nilsson, J. & Grennfelt, P. (Eds) (1988). Critical loads for sulphur and nitrogen. UNECE/Nordic Council workshop report, Skokloster, Sweden. Nordic Council of Ministers: Copenhagen.

Figures

Subtopic: Critical Loads Analysis



Notes:

- Surface water samples from the represented lakes and streams were compiled from surface monitoring programs, such as National Surface Water Survey (NSWS), Environmental Monitoring and Assessment Program (EMAP), Wadeable Stream Assessment (WSA), National Lake Assessment (NLA), Temporally Integrated Monitoring of Ecosystems (TIME), Long-term Monitoring (LTM), and other water quality monitoring programs.
- Steady state exceedances calculated in units of meq/m^2/yr.

Figure 1. Lake and Stream Exceedances of Estimated Critical Loads for Total Nitrogen and Sulfur Deposition, 2000–2002 versus 2012–2014

Critical Load Exceedances by Region

Region	Number of Water Bodies Modeled	Water Bodies in Exceedance of Critical Load				Percent Reduction
		2000-2002		2012-2014		
		Number of Sites	Percent of Sites	Number of Sites	Percent of Sites	
New England (ME, NH, VT, RI, CT)	2,027	461	23%	214	11%	54%
Adirondack Mountains (NY)	315	144	46%	67	21%	53%
Northern Mid-Atlantic (PA, NY, NJ)	1,166	279	24%	116	10%	58%
Southern Mid-Atlantic (VA, WV, MD)	1,597	856	54%	447	28%	48%
Southern Appalachian Mountains (NC, TN, SC, GA, AL)	896	286	32%	133	15%	53%
Total Units	**6,001**	**2,026**	**34%**	**977**	**16%**	**52%**

Notes:
- Surface water samples from the represented lakes and streams were compiled from surface monitoring programs, such as National Surface Water Survey (NSWS), Environmental Monitoring and Assessment Program (EMAP), Wadeable Stream Assessment (WSA), National Lake Assessment (NLA), Temporally Integrated Monitoring of Ecosystems (TIME), Long-term Monitoring (LTM), and other water quality monitoring programs.
- Steady state exceedances calculated in units of meq/m^2/yr.

Source EPA, 2016

Notes:

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- Steady state exceedances calculated in units of meq/m^2/yr.

Figure 2. Critical Load Exceedances by Region