20th Anniversary of the Acid Rain Program

2015 PROGRAM PROGRESS

Cross-State Air Pollution Rule and Acid Rain Program

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

Executive Summary

This report summarizes annual progress through 2015 under the Acid Rain Program (ARP) and the first year of the Cross-State Air Pollution Rule (CSAPR). This reporting year marks the twentieth anniversary since the implementation of the ARP.

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

Contents

2015 ARP and CSAPR at a Glance

- **SO_2 emissions:**
  CSAPR - 1.8 million tons (77 percent below 2005)

  ARP - 2.2 million tons (86 percent below 1990)
- **Annual NO_x emissions:**
  CSAPR - 0.9 million tons (61 percent below 2005)

  ARP – 1.3 million tons (79 percent below 1990)
- **CSAPR ozone season NO_x emissions:**
  450,000 tons (48 percent below 2005)
- **Compliance:**
  100 percent compliance for power plants in the ARP and CSAPR SO_2 Group 2 programs. Over 99 percent compliance for power plants in CSAPR SO_2 Group 1, NO_X annual, and NO_X ozone season programs.
- **Ambient particulate sulfate concentrations:** decreased 66 to 70 percent in the East between 1989–1991 and 2013–2015.
- **Ozone NAAQS attainment**: Based on 2013-2015 data, all 92 areas in the East originally designated as in nonattainment for the 1997 ozone NAAQS are now meeting the standard.
- **$PM_{2.5}$ NAAQS attainment:** Based on 2013-2015 data, 34 of the 36 areas in the East originally designated as in nonattainment for the 1997 $PM_{2.5}$ NAAQS are now meeting the standard (two areas have incomplete data).
- **Wet sulfate deposition:** All areas of the eastern United States have shown significant improvement with an overall 64 percent reduction in wet sulfate deposition from 1989–1991 to 2013–2015.
- **Levels of acid neutralizing capacity (ANC):** This indicator of recovery improved (i.e., increased) significantly at lake and stream monitoring sites in the Adirondack region, New England and the Catskill mountains.

Chapter 1: Program Basics

The Acid Rain Program (ARP) and the Cross-State Air Pollution Rule (CSAPR) are cap and trade programs designed to reduce emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO_x) from power plants. The ARP covers power plants across the contiguous United States and CSAPR covers power plants in certain eastern states. The EPA is no longer implementing the NO_X Budget Trading Program (NBP) or the Clean Air Interstate Rule (CAIR).

Key Points

Acid Rain Program (ARP)

- The ARP began in 1995 and observed its twentieth anniversary during the 2015 reporting year.
- The ARP covers fossil fuel-fired power plants across the contiguous United States and is designed to reduce SO_2 and NO_x emissions, the primary precursors of acid rain.
- The ARP's market-based SO_2 cap and trade program sets an annual cap on the total amount of SO_2 that may be emitted by electricity generating units (EGUs). The final annual SO_2 emissions cap was set at 8.95 million tons in 2010, 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 jurisdictions (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 implementation began in 2009 (for the annual and ozone season NO_X programs) and 2010 (for the SO_2 program) and ended on December 31, 2014. CAIR required 28 eastern jurisdictions (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 air quality standards (known as the National Ambient Air Quality Standard, or NAAQS).
- 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.
- Two 2008 court decisions kept the requirements of CAIR in place temporarily but directed EPA to issue a new rule to replace it.

Cross-State Air Pollution Rule (CSAPR)

- CSAPR was developed in response to the 2008 court decisions on CAIR and replaced CAIR starting on January 1, 2015.
- 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. In 2015, CSAPR required a total of 28 eastern states to reduce SO_2 emissions, annual NO_x emissions and/or ozone season NO_x emissions. CSAPR requires reductions in annual emissions of SO_2 and NO_x from power plants in 23 eastern states and reductions of NO_x emissions during the ozone season from 25 eastern states.
- CSAPR includes four separate cap and trade programs to achieve these reductions: CSAPR SO_2 Group 1 and Group 2 trading programs, CSAPR NO_x annual trading program, and CSAPR NO_x ozone season trading program.
- A July 2015 court decision kept the requirements of CSAPR in place but remanded certain emission budgets to the EPA for reconsideration.
- In each of the four trading programs, the total emissions allowed in each compliance period under CSAPR equals the sum of the affected state emission budgets in program. The budgets for each program in 2015 were as follows:
    - SO_2 Group 1 – 2.55 million tons
    - SO_2 Group 2 – 917,787 tons
    - Annual NO_X – 1.27 million tons
    - Ozone Season NO_X – 628,392 tons

Cross-State Air Pollution Rule Update (CSAPR Update)

- The CSAPR Update was developed to address regional interstate transport for the 2008 ozone NAAQS.
- The Update replaces original reporting obligations under the CSAPR ozone season trading program for 22 states and responds to the July 2015 court remand of certain CSAPR ozone season budgets.
- Starting in May 2017, the CSAPR Update began reducing ozone season NO_X emissions further 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 total CSAPR Update budget equals the sum of the individual state budgets for those states included in the program. The combined state emission budgets in CSAPR Update program equal 316,464 tons of ozone season NO_X emissions in 2017 and 313,626 tons of emissions for 2018 and later years.

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 fossil fuel-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 economic 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 throughout the contiguous United States. 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 ozone in the eastern United States. The program, which operated during the ozone season from 2003 to 2008, was a central component of the NO_x State Implementation Plan (SIP) Call, promulgated in 1998, to help states meet the 1979 ozone NAAQS. All 21 jurisdictions (20 states plus Washington, D.C.) covered by the NO_x SIP Call participated in the NBP. 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 jurisdictions (27 states plus Washington, D.C.) to make reductions in SO_2 and NO_X emissions that cross state lines and contribute to unhealthy levels of fine particulate matter and ozone pollution in downwind areas. CAIR required 25 eastern jurisdictions (24 states plus Washington, D.C.) to limit annual power sector emissions of SO_2 and NO_x to address regional interstate transport of air pollution that contributes to the formation of fine particulates. It also required 26 jurisdictions (25 states plus Washington, D.C.) to limit power sector ozone season NO_x emissions to address regional interstate 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.

EPA issued CAIR on May 12, 2005 and the CAIR federal implementation plans (FIPs) on April 26, 2006. In 2008, the U.S. Court of Appeals for the DC Circuit remanded CAIR to the Agency, leaving existing CAIR programs in place while directing EPA to replace them as rapidly as possible with a new rule consistent with the Clean Air Act. The CAIR NO_x ozone season and NO_x annual programs began in 2009, while the CAIR SO_2 program began in 2010.

CSAPR replaced CAIR starting on January 1, 2015.

Cross-State Air Pollution Rule

EPA issued 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. CSAPR requires 23 states to reduce SO_2 and annual NO_X emissions to help downwind areas attain the 2006 24-hour and/or 1997 annual fine particle NAAQS. Twenty-five states were required to reduce ozone season NO_X emissions to help downwind areas attain the 1997 8-hour ozone NAAQS. 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.

CSAPR was scheduled to replace CAIR starting on January 1, 2012. However, the timing of CSAPR's implementation was affected by D.C. Circuit actions that stayed and then vacated 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 CSAPR compliance deadlines by three years. Accordingly, CSAPR Phase I implementation began January 1, 2015 and Phase II began January 1, 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 began reducing ozone season NO_X emissions further 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. However, the CSAPR Update only partially resolves covered states' interstate ozone transport obligations for the 2008 ozone NAAQS. States and EPA will need to determine whether additional actions are needed to fully address interstate ozone transport for this NAAQS. Additionally, states are required by the Clean Air Act to develop and submit interstate ozone transport SIPs by no later than three years after EPA promulgates a NAAQS. Pursuant to that statute, and because EPA promulgated a newer ozone NAAQS in October 2015, states would be expected to submit interstate ozone transport SIPs by October 2018.

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 be addressed in a timely fashion using the 4-step transport framework that has evolved through more than 20 years of state and federal regulatory actions and was applied most recently in the CSAPR Update. In December 2016, the agency provided preliminary air quality data and information regarding the early analytical steps of the transport framework for the 2015 NAAQS as part of a Notice of Data Availability (NODA).

More Information

- Acid Rain Program (ARP) https://www.epa.gov/airmarkets/acid-rain-program
- Cross-State Air Pollution Rule (CSAPR) https://www.epa.gov/csapr
- Cross-State Air Pollution Update Rule (CSAPR Update) https://www.epa.gov/airmarkets/final-cross-state-air-pollution-rule-update

- 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
- 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

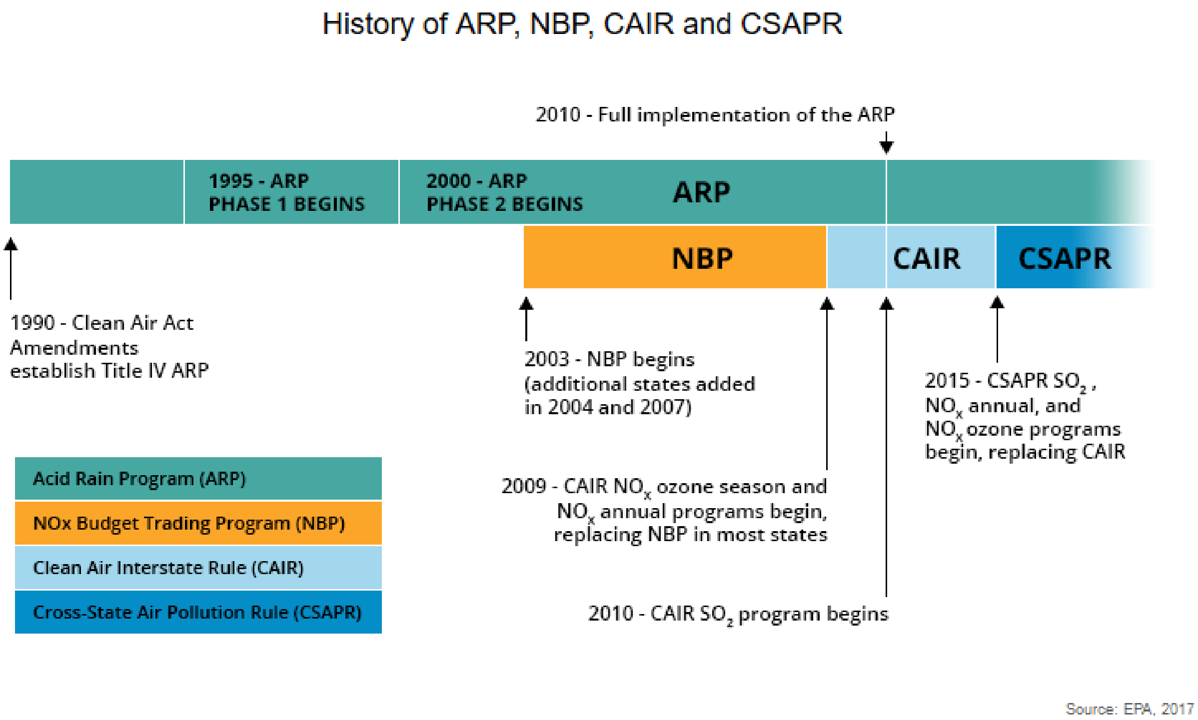


Figure 1. History of ARP, NBP, CAIR, and CSAPR

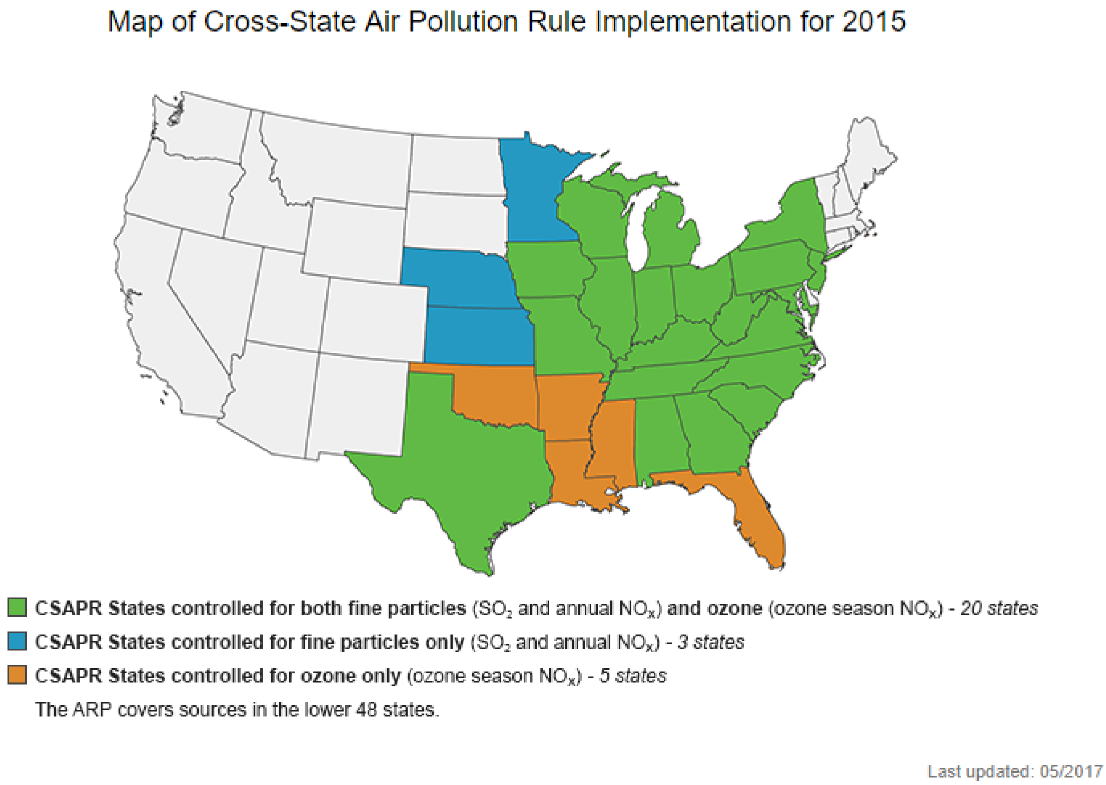


Figure 2. Map of Cross-State Air Pollution Rule Implementation for 2015

Chapter 2: Affected Units

The Acid Rain Program (ARP) and the Cross-State Air Pollution Rule's (CSAPR) sulfur dioxide (SO_2) and nitrogen oxides (NO_x) emission reduction programs generally apply to large electricity generating units (EGUs) that burn fossil fuels to generate electricity for sale. This section covers units affected in 2015, and does not include units from programs not being implemented in 2015 (like the NO_x Budget Trading Program [NBP] and Clean Air Interstate Rule [CAIR]).

Key Points

Acid Rain Program (ARP)

- In 2015, the ARP SO_2 requirements applied to 3,520 fossil fuel-fired combustion units at 1,226 facilities across the country; 795 units at 336 facilities were subject to the ARP NO_x program.

Cross-State Air Pollution Rule (CSAPR)

- In 2015, there were 2,820 affected EGUs at 864 facilities in the CSAPR SO_2 program. Of those, 2,225 (79 percent) were also covered by the ARP.
- In 2015, there were 2,820 affected EGUs at 864 facilities in the CSAPR NO_x annual program and 3,228 affected EGUs at 946 facilities in CSAPR NO_x ozone season program. Of those, 2,225 (79 percent) and 2,552 (79 percent), respectively, were also covered by the ARP.

Analysis and Background Information

In general, the ARP and CSAPR SO_2, NO_X annual, and NO_X ozone season trading programs apply to large EGUs—boilers, turbines, and combined cycle units– that burn fossil fuel, serve generators with nameplate capacity greater than 25 megawatts, and produce electricity for sale. These EGUs include 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. The ARP NO_X program applies to ARP-affected units that are older coal-fired boilers.

More Information

- Acid Rain Program (ARP) https://www.epa.gov/airmarkets/acid-rain-program
- Cross-State Air Pollution Rule (CSAPR) https://www.epa.gov/csapr

Figures

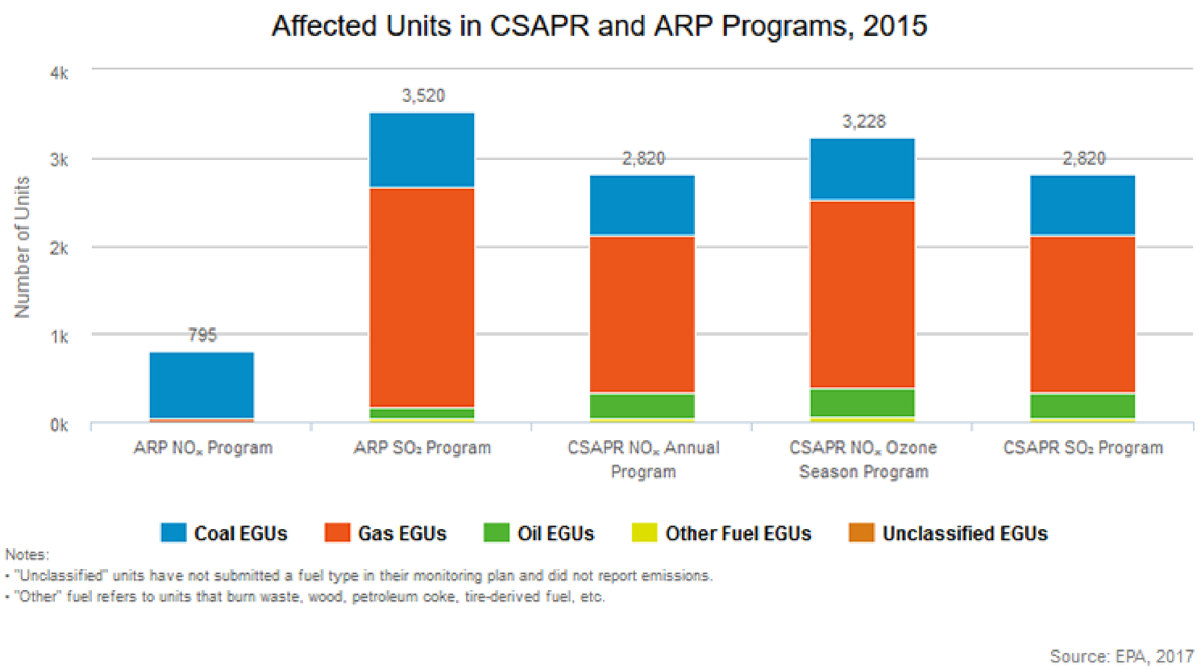


Figure 1. Affected Units in CSAPR and ARP Programs, 2015

Affected Units in CSAPR and ARP Programs, 2015

Fuel	ARP NO_x	ARP SO_2	CSAPR SO_2 and Annual NO_x	CSAPR Ozone Season NO_x
Coal	760	855	710	706
Gas	31	2,494	1,779	2,135
Oil	0	134	287	339
Other	4	28	37	40
Unclassified	0	9	7	8
Total Units	**795**	**3,520**	**2,820**	**3,228**

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, 2017

Figure 2. Affected Units in CSAPR and ARP Programs, 2015

Chapter 3: Emission Reductions

The Acid Rain Program (ARP) and Cross-State Air Pollution Rule (CSAPR) programs significantly reduced sulfur dioxide (SO_2), annual nitrogen oxides (NO_X), and ozone season NO_x emissions from power plants. Most of the emission reductions since 2005 occurred in response to the Clean Air Interstate Rule (CAIR), which was replaced by CSAPR in 2015. This section covers changes in emissions at units affected by CSAPR and ARP in 2015, and does not include programs not being implemented in 2015 (NBP and Clean Air Interstate Rule [CAIR]).

Sulfur Dioxide (SO_2)

Key Points

Overall Results

- Under the ARP, CAIR, and now CSAPR, power plants have significantly lowered SO_2 emissions while electricity demand (measured as heat input) remained relatively stable, indicating that the emission reductions were not driven by decreased total electric generation.
- These emission reductions are a result of an overall increase in the environmental efficiency at affected sources as power generators installed controls, switched to lower emitting fuels, or otherwise reduced their SO_2 emissions while meeting relatively steady electricity demand.

SO_2 Emission Trends

- **ARP:** Units in the ARP emitted 2.2 million tons of SO_2 in 2015, well below the ARP's statutory annual cap of 8.95 million tons. ARP sources reduced emissions by 13.5 million tons (86 percent) from 1990 levels and 15.1 million tons (87 percent) from 1980 levels.
- **CSAPR and ARP:** In 2015, the first year of operation of CSAPR SO_2 program, sources covered by both the CSAPR SO_2 annual program and the ARP reduced SO_2 emissions by 13.5 million tons (86 percent) from 1990 levels (before implementation of the ARP), 9.0 million tons (80 percent) from 2000 levels (ARP Phase II), and 8.0 million tons (78 percent) from 2005 levels (before implementation of CAIR and CSAPR). All ARP and CSAPR sources together emitted a total of 2.2 million tons of SO_2 in 2015.
- **CSAPR:** Annual SO_2 emissions from sources in the CSAPR SO_2 program alone fell from 7.7 million tons in 2005 to 1.8 million tons in 2015, a 77 percent reduction. In 2015, SO_2 emissions were about 1.7 million tons below the regional CSAPR emission budgets (1.3 million in Group 1 and 0.4 million in Group 2).

SO_2 State-by-State Emissions

- **CSAPR and ARP:** From 1990 to 2015, annual SO_2 emissions from sources in the ARP and CSAPR SO_2 program dropped in 45 states plus Washington, D.C. by a total of approximately 13.5 million tons. In contrast, annual SO_2 emissions increased in three states (Idaho, Nebraska, and Vermont) by a combined total of only 14,000 tons from 1990 to 2015.

- **CSAPR:** In 2015, each of the 23 states (16 states in Group 1 and 7 states in Group 2) had emissions below their CSAPR allowance budgets, collectively by about 1.7 million tons.

SO_2 Emission Rates

- In 2015, the average SO_2 emission rate for units in the ARP or CSAPR SO_2 program fell to 0.18 lb/mmBtu. This indicates a 76 percent reduction from 2005 rates, with the majority of reductions coming from coal-fired units.
- Although heat input has decreased slightly over the past 10 years, emissions have decreased dramatically since 2005, 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.

Analysis and Background Information

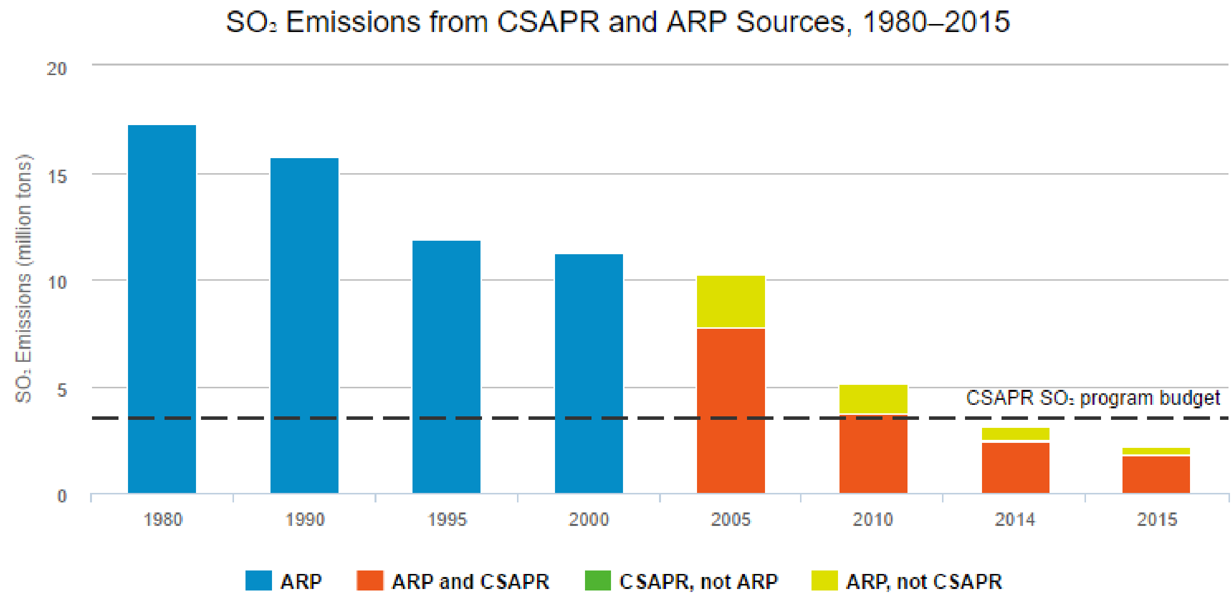
SO_2 is a highly reactive gas that is generated primarily from the burning of certain fossil fuels at power plants. In addition to contributing to the formation of fine particle pollution ($PM_{2.5}$), SO_2 emissions are linked with a number of adverse effects to human health and ecosystems.

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 and CSAPR. Most of these states are located in the Ohio River Valley and are upwind of the areas the ARP and CSAPR were designed to protect. Reductions under the ARP and CSAPR have provided important environmental and health benefits over a large region.

More Information

- Visit EPA's Power Plant Emission Trends site for the most up-to-date emissions and control data for sources in CSAPR 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
- Cross-State Air Pollution Rule (CSAPR) https://www.epa.gov/csapr
- 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



Notes:
• For CSAPR units not in the ARP, the 2015 annual SO_2 emissions were applied retroactively for each pre-CSAPR year following the year in which the unit began operating.
• There are a small number of sources in CSAPR 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 "CSAPR, not ARP" (to turn on and highlight emissions from these sources) and turn off the other categories of emissions.

Source: EPA, 2017

Figure 1. SO_2 Emissions from CSAPR and ARP Sources, 1980–2015

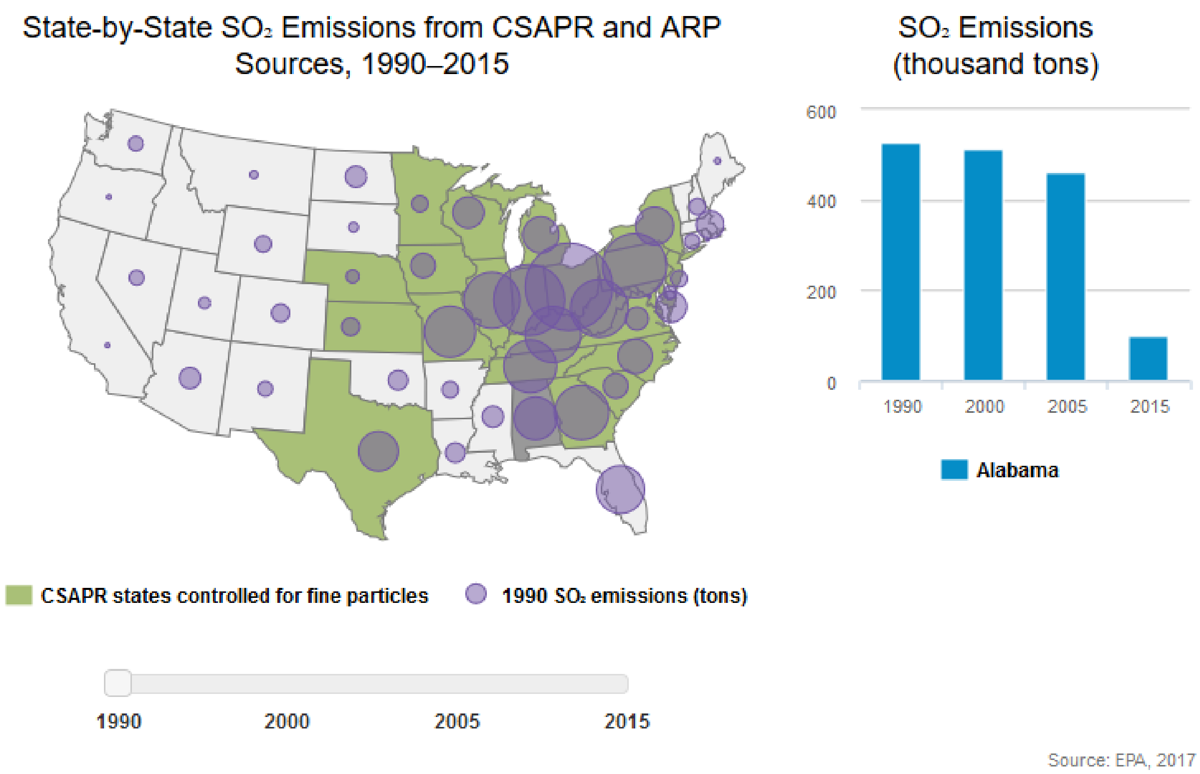
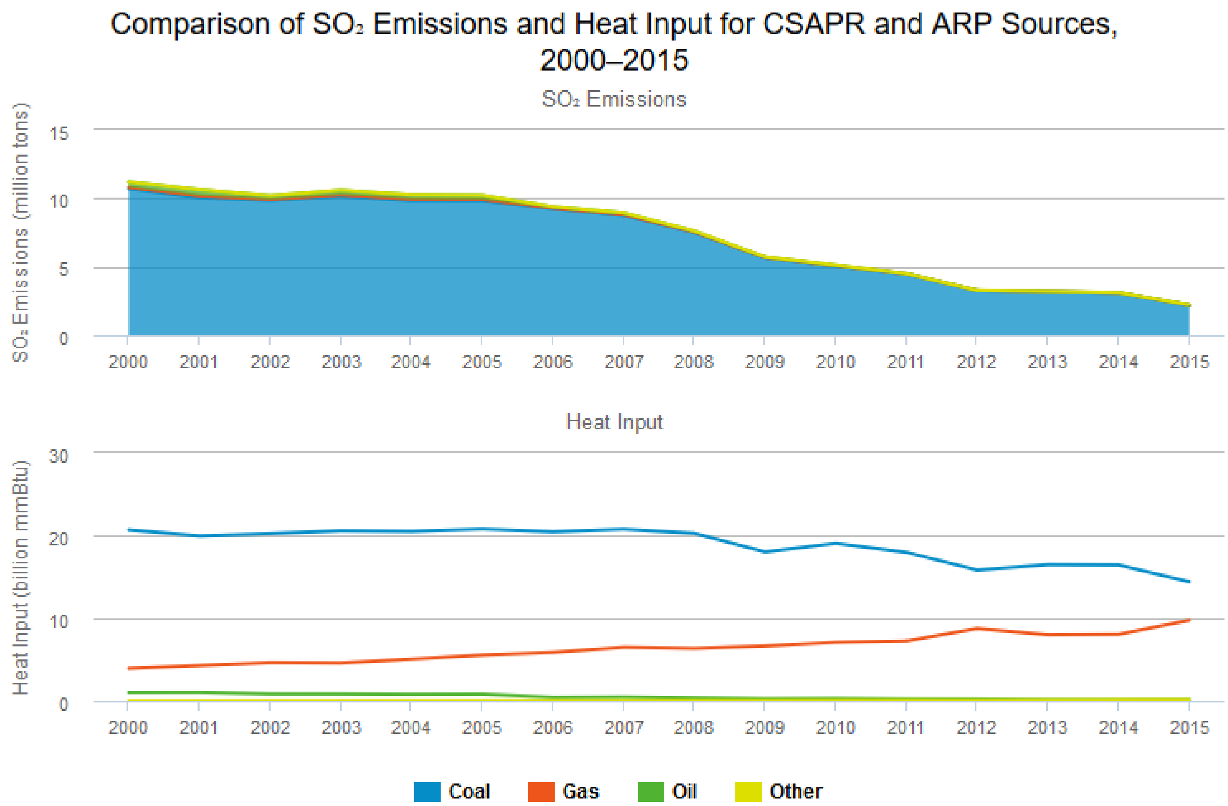


Figure 2. State-by-State SO_2 Emissions from CSAPR and ARP Sources, 1990–2015



Notes:
- The data shown here reflect totals for those facilities required to comply with each program in each respective year. This means that CSAPR-only SO_2 program facilities are not included in the SO_2 data prior to 2015.
- Fuel type represents primary fuel type; units might combust more than one fuel.
- Unless otherwise noted, EPA data are current as of January 2017, and may differ from past or future reports as a result of resubmissions by sources and ongoing data quality assurance activities.

Source: EPA, 2017

Figure 3. Comparison of SO_2 Emissions and Heat Input for CSAPR and ARP Sources, 2000–2015

CSAPR and ARP SO_2 Emissions Trends

	SO_2 Emissions (thousand tons)				SO_2 Rate (lb/mmBtu)				Heat Input (billion mmBtu)			
Primary Fuel	**2000**	**2005**	**2010**	**2015**	**2000**	**2005**	**2010**	**2015**	**2000**	**2005**	**2010**	**2015**
Coal	10,708	9,835	5,051	2,182	1.04	0.95	0.53	0.30	20.67	20.77	19.04	14.39
Gas	110	96	20	8	0.06	0.04	0.01	0.00	3.93	5.53	7.07	9.75
Oil	383	288	28	11	0.76	0.71	0.19	0.12	1.01	0.81	0.29	0.17
Other	1	4	22	12	0.22	0.27	0.57	0.17	0.01	0.03	0.08	0.14
Total	**11,201**	**10,223**	**5,120**	**2,213**	**0.88**	**0.75**	**0.39**	**0.18**	**25.61**	**27.13**	**26.48**	**24.45**

Notes:
- The data shown here reflect totals for those facilities required to comply with each program in each respective year. This means that CSAPR-only SO_2 program facilities are not included in the SO_2 emissions data prior to 2015.
- 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.
- The emission rate reflects the emissions (pounds) per unit of heat input (mmBtu) for each fuel category. The total SO_2 emission rate in each column of the table is not cumulative and does not equal the arithmetic mean of the four fuel-specific rates. The total for each year indicates the average rate across all units in the program because 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 January 2017, and may differ from past or future reports as a result of resubmissions by sources and ongoing data quality assurance activities.

Source: EPA, 2017

Figure 4. CSAPR and ARP SO_2 Emissions Trends

Annual Nitrogen Oxides (NO_X)

Key Points

Overall Results

- Annual NO_x emissions have declined dramatically under the ARP, NO_X Budget Trading Program (NBP), CAIR, and CSAPR programs, with the majority of reductions coming from coal-fired units.
- These reductions have 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 at affected sources as power generators installed controls, ran their controls year-round, switched to lower emitting fuels, or otherwise reduced their NO_x emissions while meeting relatively steady electricity demand.
- 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 2015.

Annual NO_x Emissions Trends

- **ARP:** Units in the ARP NO_x program emitted 1.3 million tons of NO_x emissions in 2015, indicating that ARP sources reduced emissions by 6.8 million tons from the projected level in 2000 without the ARP, and over three times the Title IV NO_x emission reduction objective.
- **CSAPR and ARP:** In 2015, the first year of operation of the CSAPR NO_x annual program, sources in both the CSAPR NO_x annual program and the ARP together emitted 1.4 million tons, a reduction of 5.0 million tons (79 percent reduction) from 1990 levels, 3.8 million tons (73 percent reduction) from 2000, and 2.3 million tons (63 percent reduction) from 2005 levels.
- **CSAPR:** Emissions from the CSAPR NO_x annual program sources alone were about 905,000 tons in 2015. This is about 1.4 million tons (61 percent) lower than in 2005 and 360,000 tons (29 percent) below the CSAPR NO_x annual program's 2015 regional budget of 1,269,837 tons.

Annual NO_x State-by-State Emissions

- **CSAPR and ARP**: From 1990 to 2015, annual NO_x emissions in the ARP and CSAPR NO_x program dropped in 46 states plus Washington, D.C. by a total of approximately 5.0 million tons. In contrast, annual emissions increased in two states (Idaho and Oregon) by a combined total of only 720 tons from 1990 to 2015.
- **CSAPR:** Twentytwo states had emissions below their CSAPR 2015 allowance budgets, collectively by about 370,000 tons. A single state (West Virginia) exceeded its 2015 budget by about 1,700 tons through use of excess allowances from EGUs in other states.

Annual NO_x Emission Rates

- In 2015, the CSAPR and ARP average annual NO_x emission rate was 0.11 lb/mmBtu, a 58 percent reduction from 2005.

- Although heat input has decreased slightly over the past 10 years, emissions have decreased dramatically since 2005, indicating an improvement in NO_X emission rates. 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 emissions than coal-fired units.

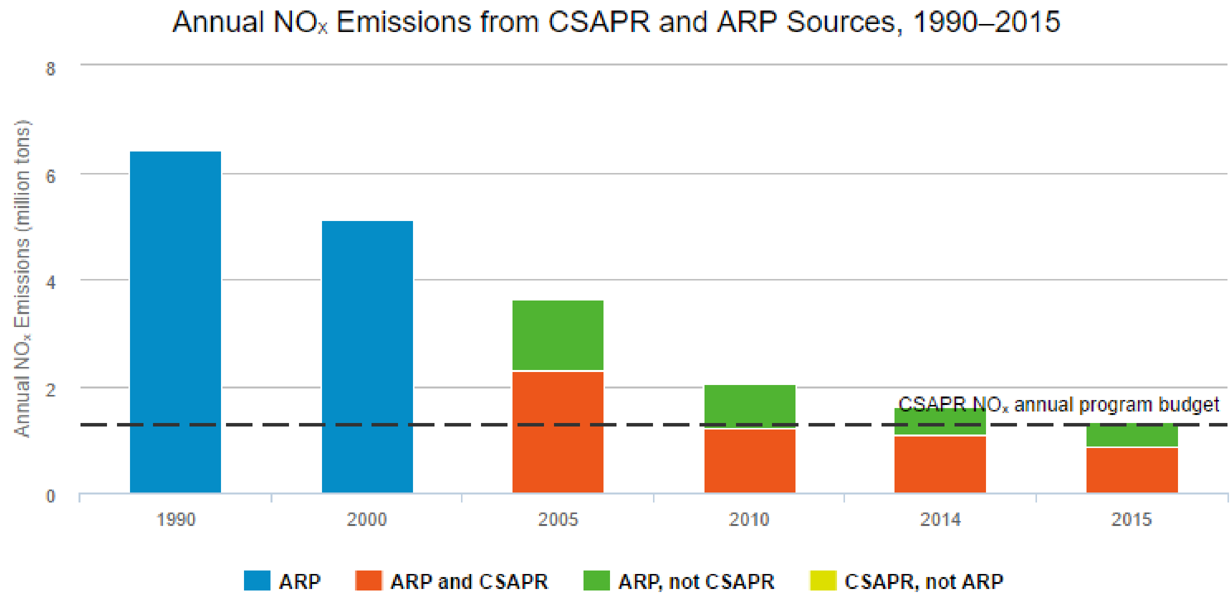
Analysis and Background Information

Nitrogen oxides, or 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 emissions contribute to the formation of ground-level ozone and fine particle pollution, which cause a variety of adverse health effects. NO_2, one form of NO_X, is specifically linked to adverse health effects on the human respiratory system.

More Information

- Visit EPA's Power Plant Emission Trends site for the most up-to-date emissions and control data for sources in CSAPR 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
- Cross-State Air Pollution Rule (CSAPR) https://www.epa.gov/csapr
- Learn more about nitrogen oxides (NO_x) https://www.epa.gov/no2-pollution
- Learn more about particulate matter (PM) https://www.epa.gov/pm-pollution

Figures



Notes:
- For CSAPR units not in the ARP the 2015 annual NO_x emissions were applied retroactively for each pre-CSAPR year following the year in which the unit began operating.
- There are a small number of sources in CSAPR 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 "CSAPR, not ARP" (to turn on and highlight emissions from these sources) and turn off the other categories of emissions.

Source: EPA, 2017

Figure 1. Annual NO_x Emissions from CSAPR and ARP Sources, 1990–2015

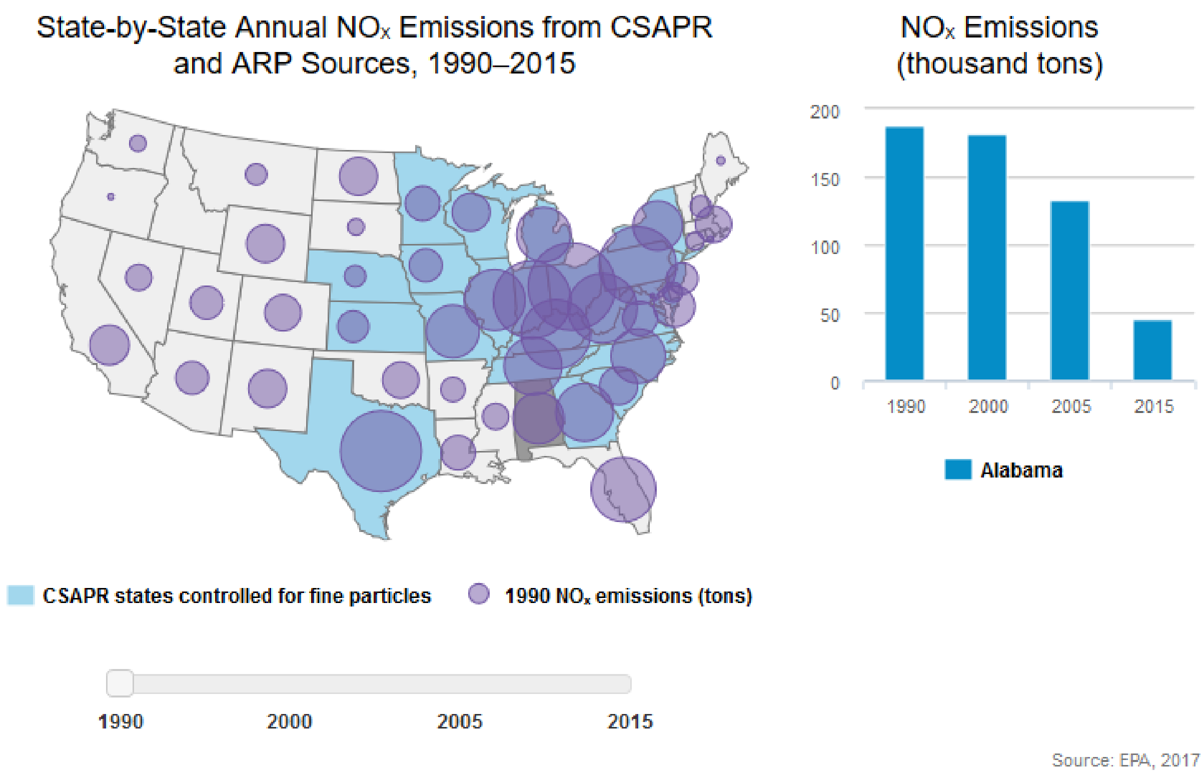
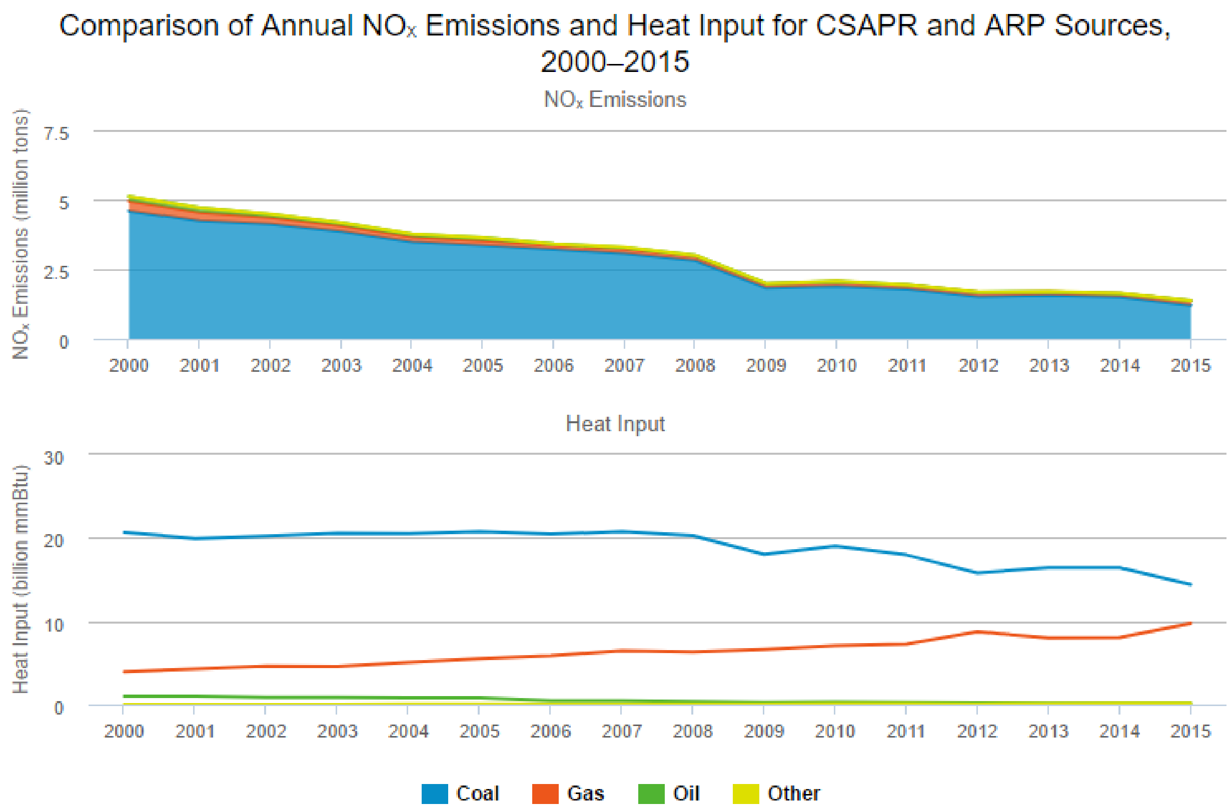


Figure 2. State-by-State Annual NO_x Emissions from CSAPR and ARP Sources, 1990-2015



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 CSAPR NO_x annual program facilities are not included in the annual NO_x emissions data prior to 2015.
• Fuel type represents primary fuel type; units might combust more than one fuel.
• Unless otherwise noted, EPA data are current as of January 2017, and may differ from past or future reports as a result of resubmissions by sources and ongoing data quality assurance activities.

Source: EPA, 2017

Figure 3. Comparison of Annual NO_X Emissions and Heat Input for CSAPR and ARP Sources, 2000–2015

CSAPR and ARP Annual NO_x Emissions Trends

	NO_x Emissions (thousand tons)				NO_x Rate (lb/mmBtu)				Heat Input (billion mmBtu)			
Primary Fuel	**2000**	**2005**	**2010**	**2015**	**2000**	**2005**	**2010**	**2015**	**2000**	**2005**	**2010**	**2015**
Coal	4,587	3,356	1,896	1,208	0.44	0.32	0.20	0.17	20.67	20.77	19.04	14.39
Gas	357	170	143	146	0.18	0.06	0.04	0.03	3.93	5.53	7.07	9.75
Oil	159	101	19	11	0.32	0.25	0.13	0.13	1.01	0.81	0.29	0.17
Other	2	6	5	7	0.25	0.42	0.13	0.10	0.01	0.03	0.08	0.14
Total	**5,104**	**3,633**	**2,063**	**1,373**	**0.40**	**0.27**	**0.16**	**0.11**	**25.61**	**27.13**	**26.48**	**24.45**

Notes:
- The data shown here reflect totals for those facilities required to comply with each program in each respective year. This means that CSAPR-only annual NO_x program facilities are not included in the NO_x emissions data prior to 2015.
- 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.
- The emission rate reflects the emissions (pounds) per unit of heat input (mmBtu) for each fuel category. The total NO_x emission rate in each column of the table is not cumulative and does not equal the arithmetic mean of the four fuel-specific rates. The total for each year indicates the average rate across all units in the program because 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 January 2017, and may differ from past or future reports as a result of resubmissions by sources and ongoing data quality assurance activities.

Source: EPA, 2017

Figure 4. CSAPR and ARP Annual NO_x Emissions Trends

Ozone Season Nitrogen Oxides (NO_x)

Key Points

Overall Results

- Ozone season NO_x emissions have declined dramatically under the ARP, NBP, CAIR, and CSAPR programs.
- These reductions have 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 at affected sources as power generators installed controls, switched to lower emitting fuels, or otherwise reduced their ozone season NO_x emissions while meeting relatively steady electricity demand.
- Other programs—such as regional and state NO_x emission control programs—also contributed significantly to the ozone season NO_x emission reductions achieved by sources in 2015.

Ozone Season NO_x Emissions Trends

- Units in the CSAPR NO_x ozone season program emitted 450,000 tons in 2015, a reduction of 1.8 million tons (80 percent) from 1990, 1.1 million tons lower (70 percent reduction) than in 2000 (before implementation of the NBP), 330,000 tons lower (42 percent reduction) than in 2005 (before implementation of CAIR), and 58,000 tons lower (11 percent reduction) than in 2014 (before implementation of CSAPR).
- In 2015, CSAPR NO_x ozone season program emissions were 28 percent below the regional emission budget of 628,392 tons.

Ozone Season NO_x State-by-State Emissions

- Between 2005 and 2015, ozone season NO_x emissions from CSAPR sources fell in every state participating in the CSAPR NO_x ozone season program.
- Twenty-three states had emissions below their CSAPR 2015 allowance budgets, collectively by about 180,000 tons. Two states (Louisiana and West Virginia) exceeded their 2015 budgets by about 2,800 tons combined through use of excess allowances in other states.

Ozone Season NO_x Emission Rates

- In 2015, the average NO_x ozone season emission rate fell to 0.10 lb/mmBtu. This indicates a 40 percent reduction from 2005 emission rates, with the majority of reductions coming from coal-fired units.
- Although heat input has decreased slightly over the past 10 years, emissions have decreased dramatically since 2005, 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.

Analysis and Background Information

Nitrogen oxides, or 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 emissions contribute to the formation of ground-level ozone and fine particle pollution, which cause a variety of adverse human health effects. NO_2, one form of NO_X, is specifically linked to adverse health effects on the human respiratory system.

The CSAPR NO_x ozone season program was established to reduce interstate transport of pollution 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 emissions in 2000 have seen the greatest emission reductions under the CSAPR NO_x ozone season program. Most of these states are in the Ohio River Valley and are upwind of the areas CSAPR was designed to protect. Reductions by sources in these states have resulted in important environmental and human health benefits over a large region.

More Information

- Visit EPA's Power Plant Emission Trends site for the most up-to-date emissions and control data for sources in CSAPR and the ARP https://www3.epa.gov/airmarkets/progress/datatrends/index.html
- Air Markets Program Data (AMPD) https://ampd.epa.gov/ampd/
- Cross-State Air Pollution Rule (CSAPR) https://www.epa.gov/csapr
- Learn more about nitrogen oxides (NO_x) https://www.epa.gov/no2-pollution
- Learn more about ozone https://www.epa.gov/ozone-pollution

Figures

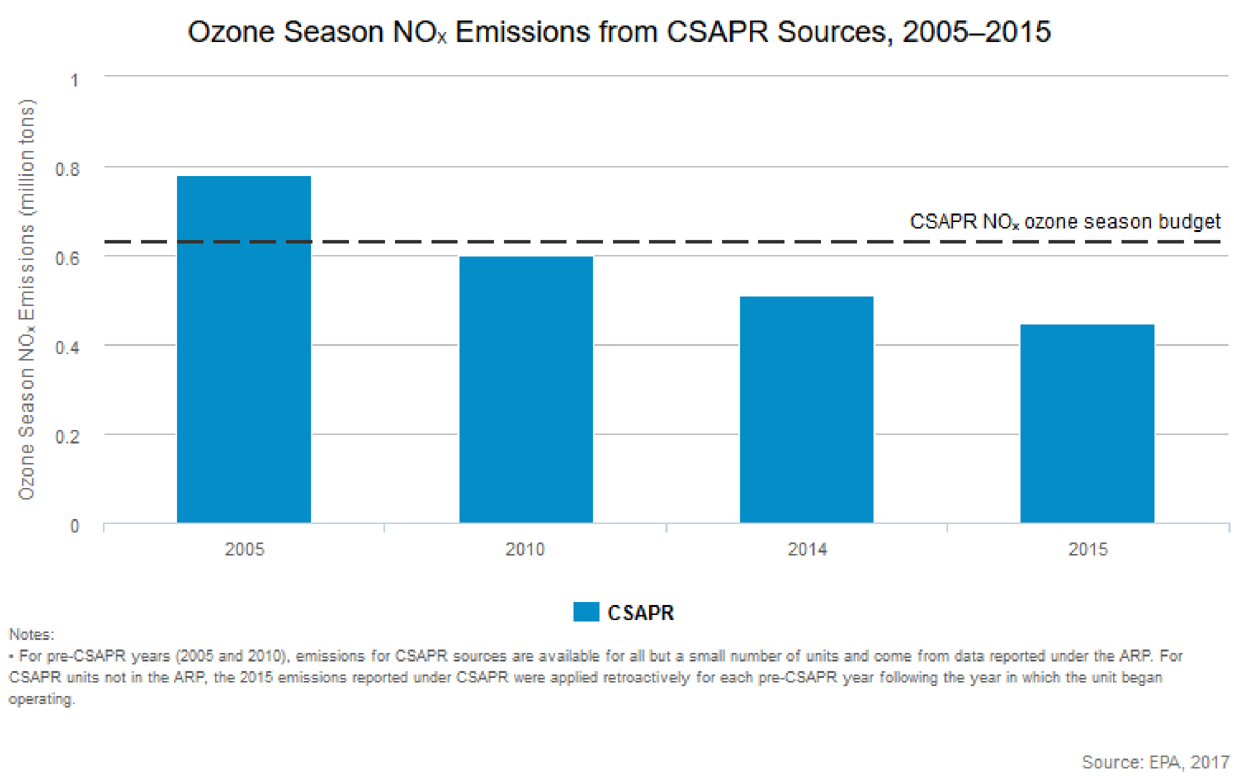


Figure 1. Ozone Season NO_x Emissions from CSAPR Sources, 2005–2015

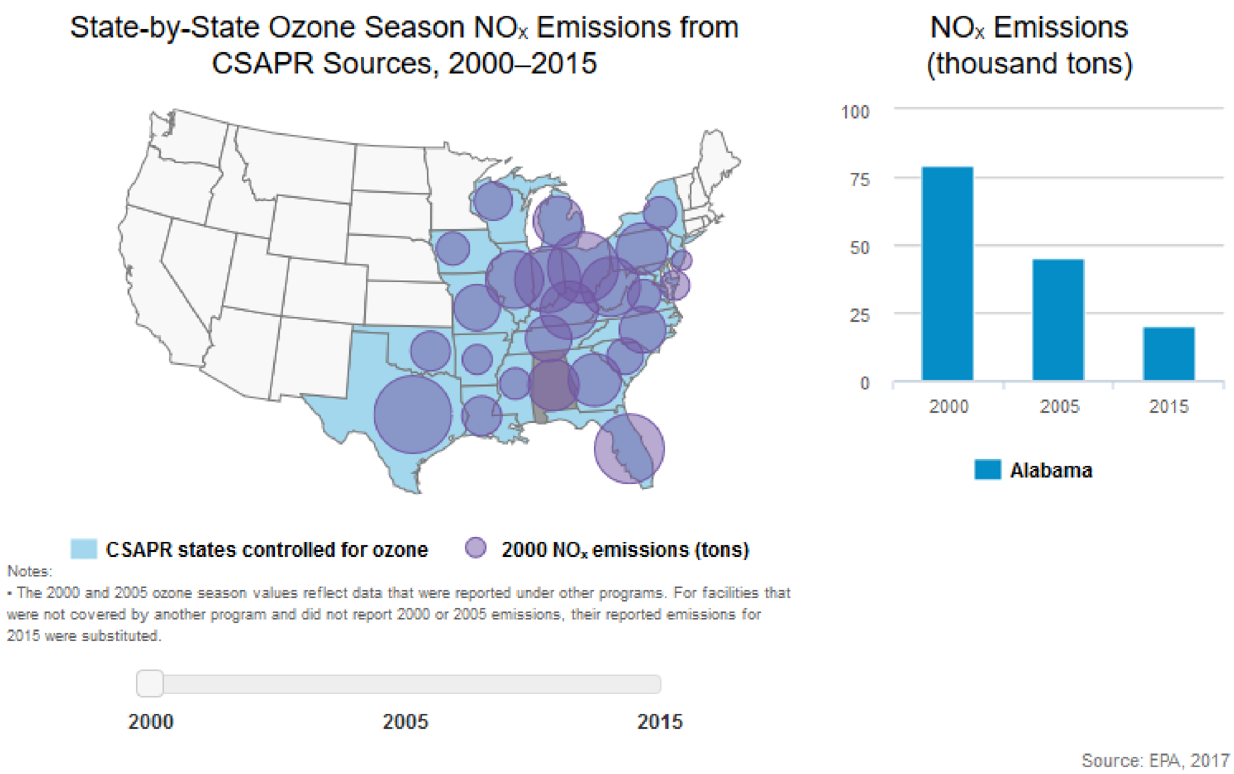
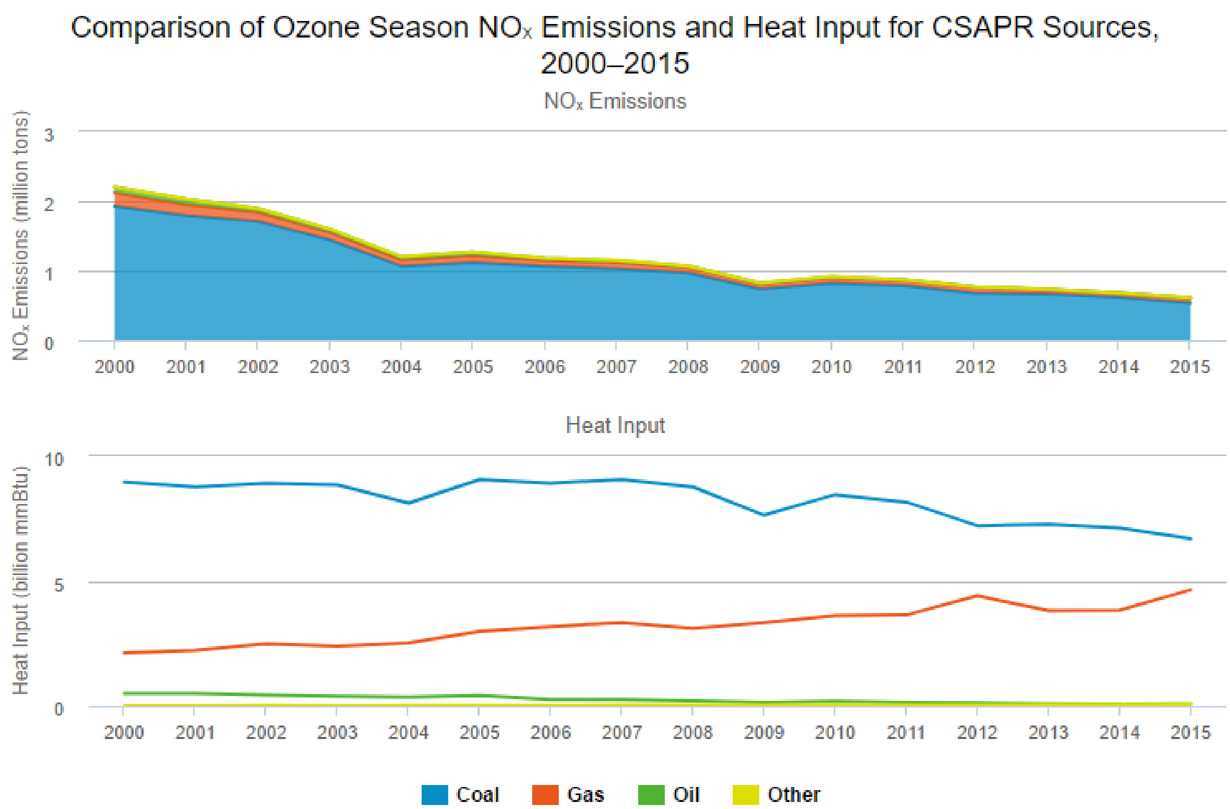


Figure 2. State-by-State Ozone Season NO_x Emissions from CSAPR Sources, 2000–2015



Notes:

- The data shown here for the the ozone season program reflect totals for those facilities required to comply with each program in each respective year. This means that CSAPR NO_x ozone season only program facilities are not included in the ozone season NO_x emissions data prior to 2015.
- Fuel type represents primary fuel type; units might combust more than one fuel.
- Unless otherwise noted, EPA data are current as of January 2017, and may differ from past or future reports as a result of resubmissions by sources and ongoing data quality assurance activities.

Source: EPA, 2017

Figure 3. Comparison of Ozone Season NO_X Emissions and Heat Input for CSAPR Sources, 2000–2015

CSAPR Ozone Season NO_x Emissions Trends

	Ozone Emissions (thousand tons)				Ozone Rate (lb/mmBtu)				Heat Input (billion mmBtu)			
Primary Fuel	**2000**	**2005**	**2010**	**2015**	**2000**	**2005**	**2010**	**2015**	**2000**	**2005**	**2010**	**2015**
Coal	1,926	1,117	821	533	0.43	0.25	0.19	0.16	8.96	9.06	8.45	6.68
Gas	196	96	79	72	0.19	0.07	0.04	0.03	2.12	2.98	3.61	4.64
Oil	78	51	13	5	0.32	0.25	0.13	0.11	0.49	0.41	0.19	0.08
Other	1	2	2	4	0.24	0.39	0.11	0.10	0.01	0.01	0.04	0.07
Total	**2,201**	**1,266**	**915**	**614**	**1.31**	**0.77**	**0.15**	**0.11**	**11.58**	**12.45**	**12.28**	**11.47**

Notes:
- The data shown here for the ozone season program reflect totals for those facilities required to comply with each program in each respective year. This means that CSAPR NO_x ozone season only program facilities are not included in the ozone season NO_x emissions data prior to 2015.
- 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.
- The emission rate reflects the emissions (pounds) per unit of heat input (mmBtu) for each fuel category. The total NO_x ozone season emission rate in each column of the table is not cumulative and does not equal the arithmetic mean of the four fuel-specific rates. The total for each year indicates the average rate across all units in the program because 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 January 2017, and may differ from past or future reports as a result of resubmissions by sources and ongoing data quality assurance activities.

Source: EPA, 2017

Figure 4. CSAPR Ozone Season NO_x Emissions 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 market-based Acid Rain Program (ARP) and Cross-State Air Pollution Rule (CSAPR) 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 necessary to ensure program compliance and is achieved through the use of continuous emission monitoring systems (CEMS).

Key Points

ARP and CSAPR SO_2 Program Controls and Monitoring

- Of all coal-fired generation (measured in gross megawatt hours, or MWh) in 2015 from sources participating in the ARP and CSAPR SO_2 program, 78 percent was produced by units with controls.
- Units with advanced flue gas desulfurization technologies (FGDs), also known as scrubbers, accounted for 55 percent of coal-fired units and 76 percent of coal-fired generation in 2015.
- In 2015, 32 percent of CSAPR units (including 100 percent of coal-fired units) monitored SO_2 emissions using CEMS while the vast majority (99 percent) of SO_2 emissions were measured by CEMS.

CSAPR NO_x Annual Program Controls and Monitoring

- Of all the fossil fuel-fired generation (as measured in gross megawatt hours, or MWh) from sources participating in CSAPR NO_x annual program, 70 percent was produced in 2015 by units with advanced pollution controls (either selective catalytic reduction [SCR] or selective non-catalytic reduction [SNCR]).
- In 2015, the 346 coal-fired units with advanced pollution controls (either SCRs or SNCRs) accounted for 70 percent of coal-fired generation. At oil- and natural gas-fired units, SCR- and SNCR- controlled units produced 72 percent of generation.
- In 2015, 72 percent of CSAPR units (including 100 percent of coal-fired units) monitored NO_X emissions using CEMS while the vast majority (99 percent) of NO_X emissions were measured by CEMS.

CSAPR NO_x Ozone Season Program Controls and Monitoring

- Of all the fossil fuel-fired generation (as measured in gross megawatt hours, or MWh) from sources participating in CSAPR NO_x ozone season program, 69 percent was produced in 2015 by units with advanced pollution controls (either SCRs or SNCRs).
- In 2015, units with advanced pollution controls (either SCR or SNCR) accounted for 69 percent of coal-fired generation. At oil- and natural gas-fired units, SCR- and SNCR- controlled units produced 69 percent of generation.

- In 2015, 73 percent of CSAPR units (including 100 percent of coal-fired units) monitored ozone season NO_X emissions using CEMS while the vast majority (99 percent) of ozone season NO_X emissions were measured by CEMS.

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, reliability, accessibility, and timeliness. 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.

While some units with low levels of SO_2 and NO_X emissions were allowed to use other approved monitoring methods, the vast majority of SO_2 and NO_X emissions were measured by CEMS.

SO_2 Emission Controls

Sources in the ARP and CSAPR SO_2 program have a number of SO_2 emission control options available. These include switching to low sulfur coal, installing and operating various types of FGDs, or injecting limestone in fluidized bed boilers. FGDs – also known as scrubbers – on coal-fired generators are the principal means of controlling SO_2 emissions and tend to be present on the highest generating coal-fired units.

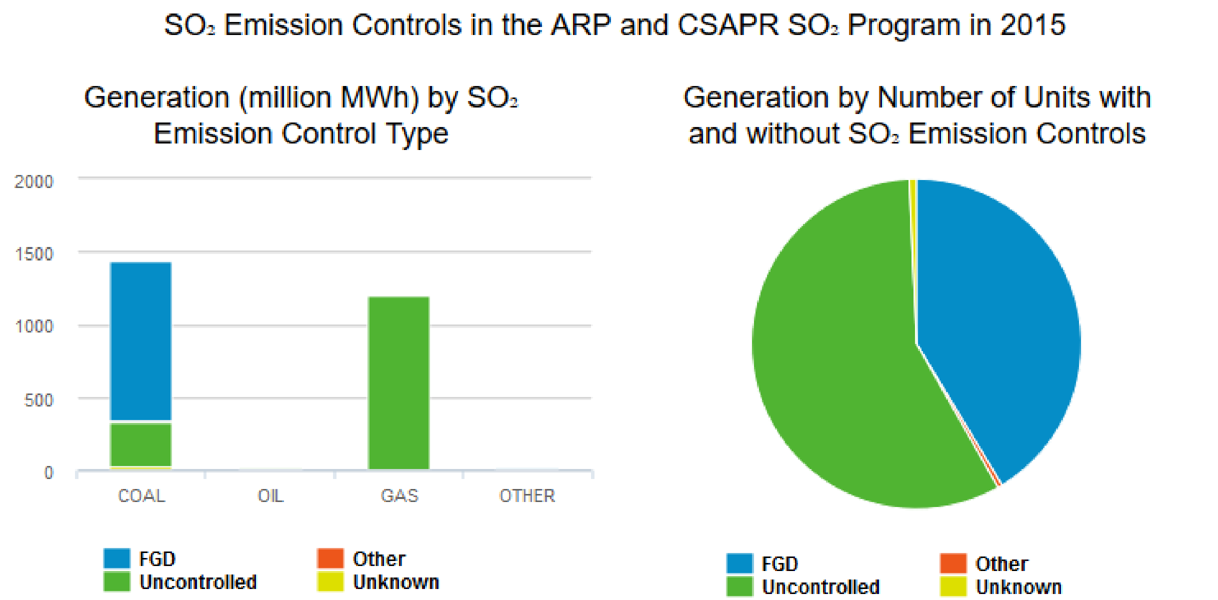
NO_x Emission Controls

Sources in the ARP and CSAPR NO_X annual and ozone season programs have a variety of options by which to reduce NO_x emissions, including advanced controls such as SCR or SNCR, combustion controls, and others.

More Information

- Visit EPA's Power Plant Emission Trends site for the most up-to-date emissions and control data for sources in CSAPR 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
- Plain English guide to 40 CRF Part 75 https://www.epa.gov/airmarkets/plain-english-guide-part-75-rule
- Continuous emission monitoring systems (CEMS) https://www.epa.gov/emc/emc-continuous-emission-monitoring-systems

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 January 2017, and may differ from past or future reports as a result of resubmissions by sources and ongoing data quality assurance activities.
- There is a small amount of generation from units with "Other" controls or "Unknown" controls. The data for these units is not easily visible on the full chart. To more clearly see the generation data for these units, especially for Oil and Other fuel types, use the interactive features of the figure: click on the boxes in the legend to turn off the blue and green categories of control types (labeled "FGD" and "Uncontrolled") and turn on the orange and yellow categories of control types (labeled "Other" and "Unknown").

Source: EPA, 2017

Figure 1. SO_2 Emission Controls in the ARP and CSAPR SO_2 Program in 2015

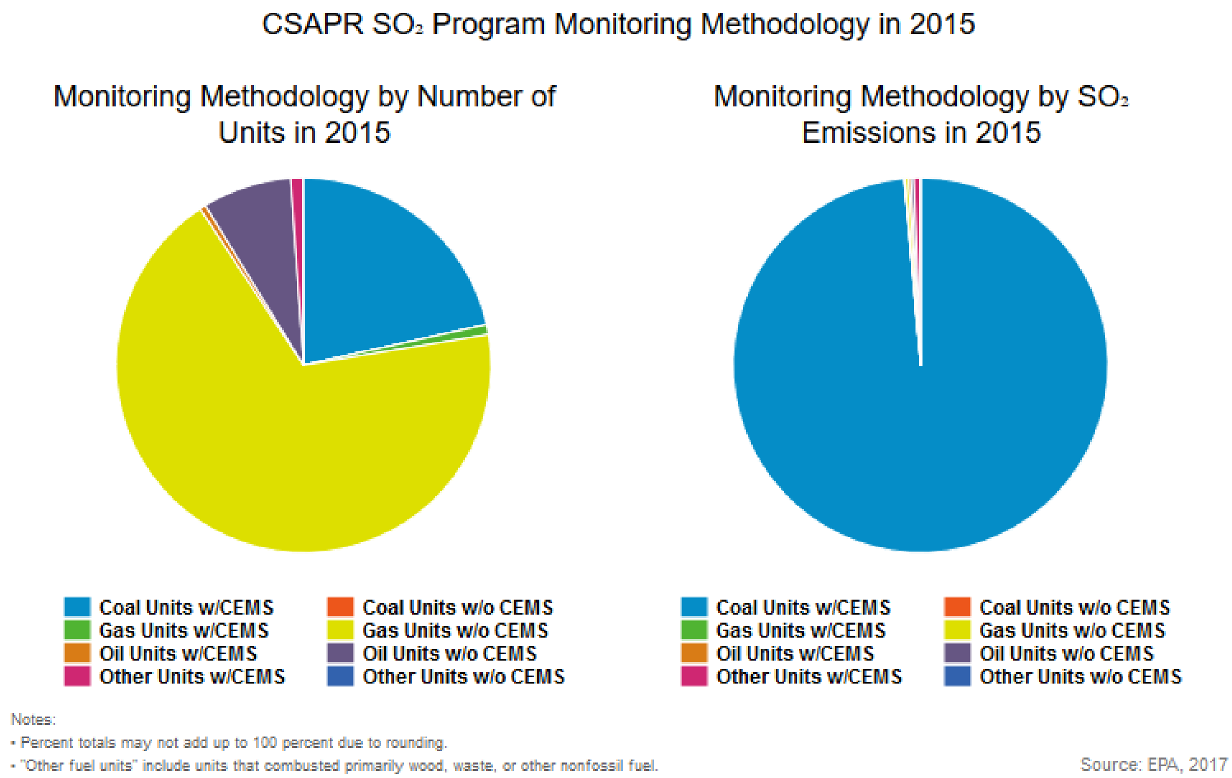
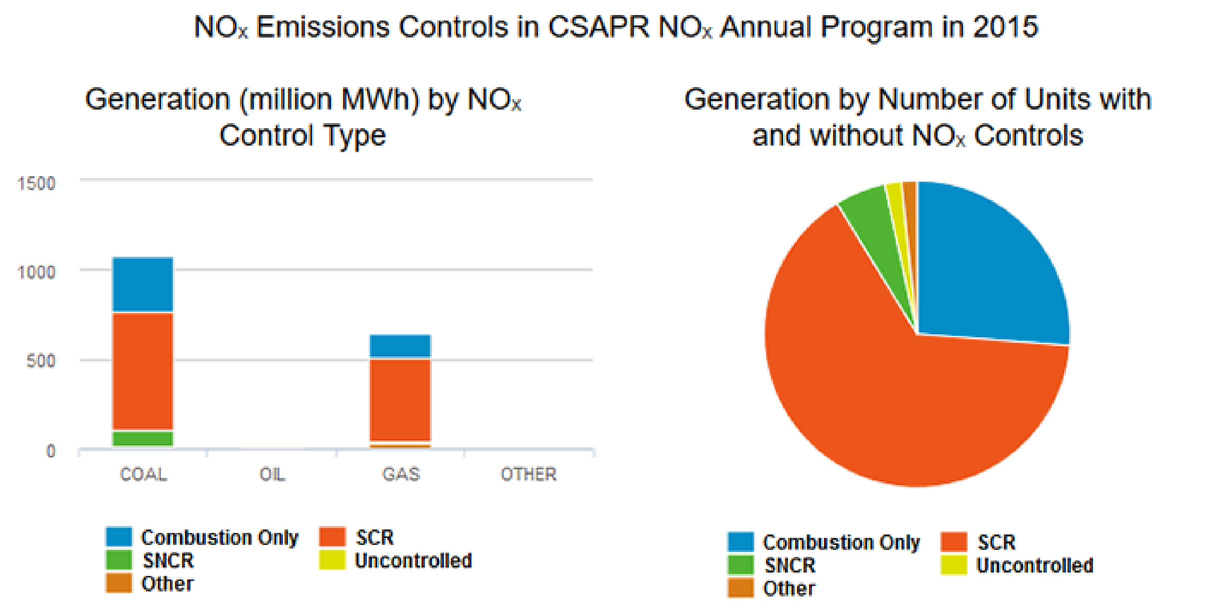


Figure 2. CSAPR SO_2 Program Monitoring Methodology in 2015



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 Only" 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 January 2017, and may differ from past or future reports as a result of resubmissions by sources and ongoing data quality assurance activities.
- There is a small amount of generation from units with "Other" controls and from "Uncontrolled" units. The data for these units is not easily visible on the full chart. To more clearly see the generation data for these units, especially for Oil and Other fuel types, use the interactive features of the figure: click on the boxes in the legend to turn off the blue, dark orange, and green categories of control types (labeled "Combustion Only," "SCR," and "SNCR") and turn on the yellow and light orange categories of control types (labeled "Uncontrolled" "Other").

Source: EPA, 2017

Figure 3. NO_x Emissions Controls in CSAPR NO_x Annual Program in 2015

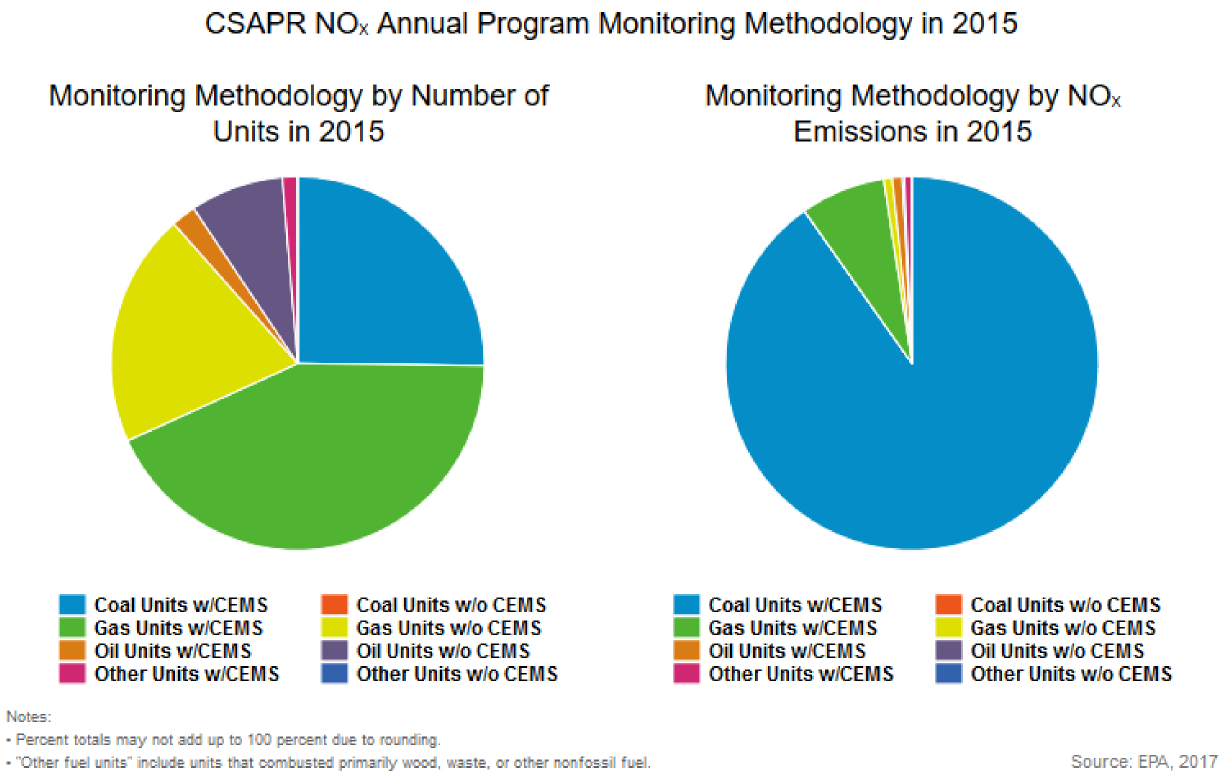
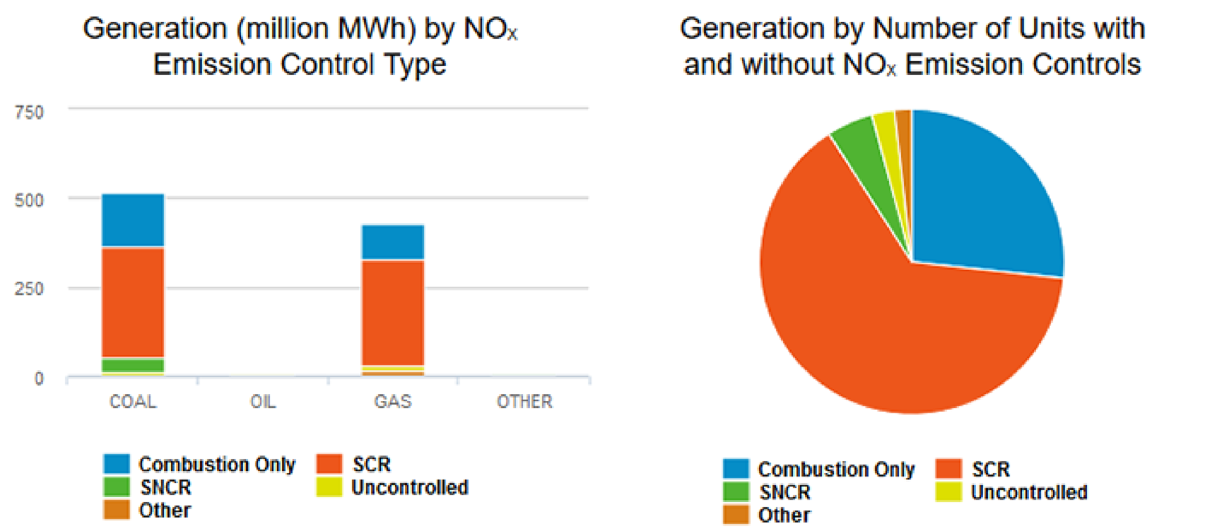


Figure 4. CSAPR NO_X Annual Program Monitoring Methodology in 2015

NOx Emissions Controls in CSAPR NOx Ozone Season Program in 2015



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 Only" 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 January 2017, and may differ from past or future reports as a result of resubmissions by sources and ongoing data quality assurance activities.
- There is a small amount of generation from units with "Other" controls and from "Uncontrolled" units. The data for these units is not easily visible on the full chart. To more clearly see the generation data for these units, especially for Oil and Other fuel types, use the interactive features of the figure: click on the boxes in the legend to turn off the blue, dark orange, and green categories of control types (labeled "Combustion Only," "SCR," and "SNCR") and turn on the yellow and light orange categories of control types (labeled "Uncontrolled" "Other").

Source: EPA, 2017

Figure 5. NO_x Emissions Controls in CSAPR NO_x Ozone Season Program in 2015

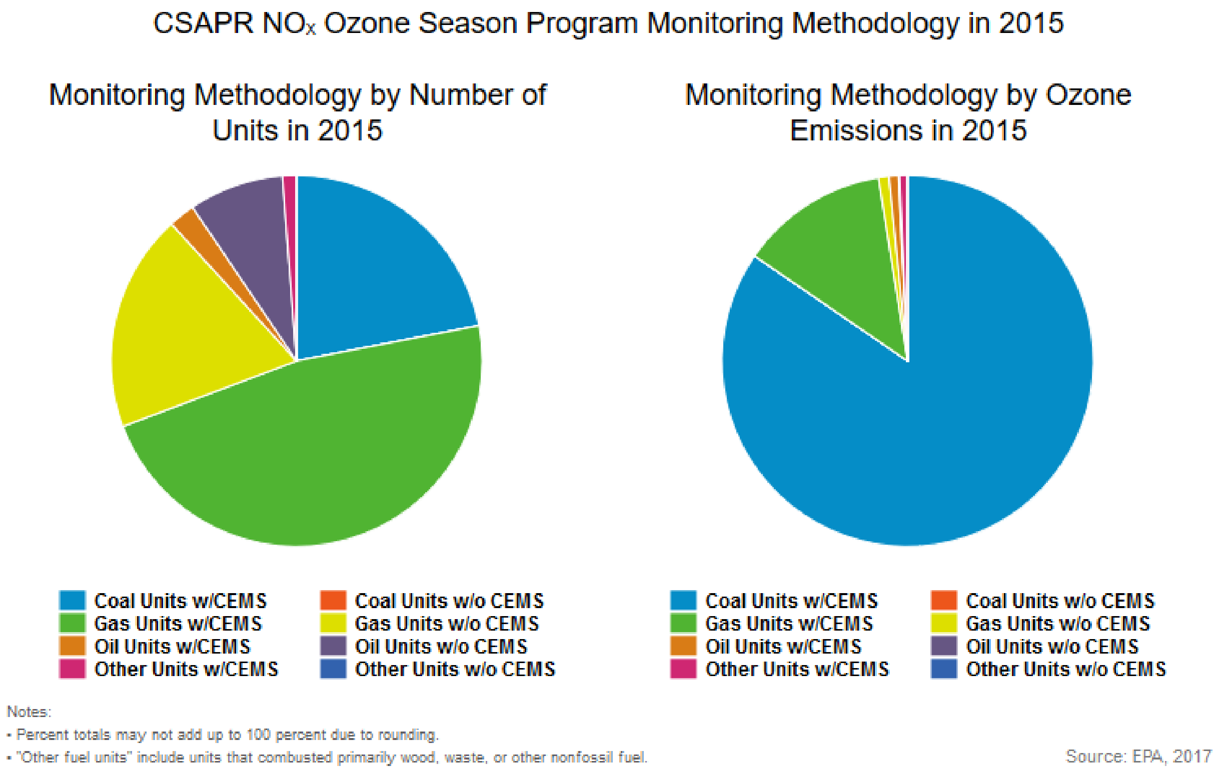


Figure 6. CSAPR NO_X Ozone Season Program Monitoring Methodology in 2015

Chapter 5: Program Compliance

This analysis shows how the Acid Rain Program (ARP) and Cross-State Air Pollution Rule (CSAPR) allowances were used for compliance under the trading programs in 2015.

Key Points

ARP SO_2 Programs

- The reported 2015 SO_2 emissions by ARP sources totaled 2,189,307 tons.
- Almost 36 million SO_2 allowances were available for compliance (9 million vintage 2015 and over 27 million banked from prior years).
- Just under 2.2 million allowances were deducted for ARP compliance. After reconciliation, over 33.7 million ARP SO_2 allowances were banked and carried forward to the 2016 ARP compliance year.
- All ARP SO_2 facilities were in compliance in 2015 and held enough allowances to cover their SO_2 emissions.

CSAPR SO_2 Group 1 Program

- The reported 2015 SO_2 emissions by CSAPR Group 1 sources totaled 1,279,747 tons.
- Over 2.5 million SO_2 Group 1 allowances were available for compliance (all were vintage 2015 - there were no banked allowances since this was the first year for the program).
- Just under 1.3 million allowances were deducted for CSAPR SO_2 Group 1 compliance. After reconciliation, over 1.2 million CSAPR SO_2 Group 1 allowances were banked and carried forward to the 2016 compliance year.
- One facility was out of compliance with the CSAPR SO_2 Group 1 Program and had 5 tons of excess emissions.

CSAPR SO_2 Group 2 Program

- The reported 2015 SO_2 emissions by CSAPR Group 2 sources totaled 497,820 tons.
- Just over 916,000 SO_2 Group 2 allowances were available for compliance (all were vintage 2015 - there were no banked allowances since this was the first year for the program).
- Over 497,000 allowances were deducted for CSAPR SO_2 Group 2 compliance. After reconciliation, over 419,000 CSAPR SO_2 Group 2 allowances were banked and carried forward to the 2016 compliance year.
- All CSAPR SO_2 Group 2 facilities were in compliance in 2015 and held enough allowances to cover their SO_2 emissions.

CSAPR NO_X Annual Program

- The reported 2015 annual NO_X emissions by CSAPR sources totaled 905,439 tons.
- Just over 1.26 million NO_X annual allowances were available for compliance (all were vintage 2015 - there were no banked allowances since this was the first year for the program).
- Over 905,000 allowances were deducted for CSAPR NO_X annual compliance. After reconciliation, over 356,000 CSAPR NO_X annual allowances were banked and carried forward to the 2016 compliance year.
- Two facilities were out of compliance with the CSAPR NO_X annual Program and had 9 total tons of excess emissions.

CSAPR NO_X Ozone Season Program

- The reported 2015 ozone season NO_X emissions by CSAPR sources totaled 452,239 tons.
- Just over 626,000 NO_X ozone season allowances were available for compliance (all were vintage 2015 - there were no banked allowances since this was the first year for the program).
- Over 452,000 allowances were deducted for CSAPR NO_X ozone season compliance. After reconciliation, almost 174,000 CSAPR NO_X ozone season allowances were banked and carried forward to the 2016 compliance year.
- Three facilities were out of compliance with the CSAPR NO_X ozone season program and had 15 total tons of excess emissions.

Analysis and Background Information

The year 2015 was the first year of compliance for the CSAPR SO_2 (Group 1 and Group 2), annual NO_X and ozone season NO_X programs. Each program has its own distinct set of allowances, which cannot be used for compliance with the other programs (e.g., CSAPR SO_2 Group 1 allowances cannot be used to comply with the CSAPR SO_2 Group 2 Program).

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

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

Acid Rain Program SO_2 Program Allowance Reconciliation Summary, 2015

Total Allowances Held (1995 - 2015 Vintage)	**35,892,022**	Held by Affected Facility Accounts	**23,510,854**
		Held by Other Accounts (General and Non-Affected Facility Accounts)	**12,381,168**
Allowances Deducted for Acid Rain Compliance	2,190,248		
Penalty Allowance Deductions	0		
Banked Allowances	**33,701,774**	Held by Affected Facility Accounts	**21,320,606**
		Held by Other Accounts (General and Non-Affected Facility Accounts)	**12,381,168**

ARP SO_2 Program Compliance Results

Reported Emissions (tons)	**2,189,307**
Compliance issues, rounding, and report resubmission adjustments (tons)	**941**
Emissions not covered by allowances (tons)	**0**
Total allowances deducted for emissions	**2,190,248**

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 January 2017 and subsequent adjustments of penalties are not reflected.

Source: EPA, 2017

Figure 1. ARP SO_2 Program Allowance Reconciliation Summary, 2015

Cross-State Air Pollution Rule SO_2 Annual Group 1 Program Allowance Reconciliation Summary, 2015

Total Allowances Held (2015 Vintage)	**2,547,354**	Held by Affected Facility Accounts	**2,383,376**
		Held by Other Accounts (General, State Holding and Non-Affected Facility Accounts)	**163,978**
Allowances Deducted for Cross-State Air Pollution Rule SO_2 Annual Group 1 Program	1,280,617		
Penalty Allowance Deductions	10		
Banked Allowances	**1,266,737**	Held by Affected Facility Accounts	**1,102,759**
		Held by Other Accounts (General, State Holding and Non-Affected Facility Accounts)	**163,978**

CSAPR SO_2 Group 1 Program Compliance Results

Reported Emissions (tons)	**1,279,747**
Compliance issues, rounding, and report resubmission adjustments (tons)	**865**
Emissions not covered by allowances (tons)	**5**
Total allowances deducted for emissions	**1,280,617**

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 January 2017 and subsequent adjustments of penalties are not reflected.

Source: EPA, 2017

Figure 2. CSAPR SO_2 Group 1 Program Allowance Reconciliation Summary, 2015

Cross-State Air Pollution Rule SO_2 Annual Group 2 Program Allowance Reconciliation Summary, 2015

Total Allowances Held (2015 Vintage)	**916,324**	Held by Affected Facility Accounts	**860,279**
		Held by Other Accounts (General, State Holding and Non-Affected Facility Accounts)	**56,045**
Allowances Deducted for Cross-State Air Pollution Rule SO_2 Annual Group 2 Program	497,790		
Penalty Allowance Deductions	0		
Banked Allowances	**418,534**	Held by Affected Facility Accounts	**362,489**
		Held by Other Accounts (General, State Holding and Non-Affected Facility Accounts)	**56,045**

CSAPR SO_2 Group 2 Program Compliance Results

Reported Emissions (tons)	**497,820**
Compliance issues, rounding, and report resubmission adjustments (tons)	**-30**
Emissions not covered by allowances (tons)	**0**
Total allowances deducted for emissions	**497,790**

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 January 2017 and subsequent adjustments of penalties are not reflected.

Source EPA, 2017

Figure 3. CSAPR SO_2 Group 2 Program Allowance Reconciliation Summary, 2015

Cross-State Air Pollution Rule NO_x Annual Program Allowance Reconciliation Summary, 2015

Total Allowances Held (2015 Vintage)	**1,261,855**	Held by Affected Facility Accounts	**1,200,906**
		Held by Other Accounts (General, State Holding and Non-Affected Facility Accounts)	**60,949**
Allowances Deducted for Cross-State Air Pollution Rule NO_x Annual Program	905,218		
Penalty Allowance Deductions	18		
Banked Allowances	**356,637**	Held by Affected Facility Accounts	**295,688**
		Held by Other Accounts (General, State Holding and Non-Affected Facility Accounts)	**60,949**

CSAPR NO_x Annual Program Compliance Results

Reported Emissions (tons)	**905,439**
Compliance issues, rounding, and report resubmission adjustments (tons)	**-230**
Emissions not covered by allowances (tons)	**9**
Total allowances deducted for emissions	**905,218**

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 January 2017 and subsequent adjustments of penalties are not reflected.

Source EPA, 2017

Figure 4. CSAPR NO_X Annual Program Allowance Reconciliation Summary, 2015

Cross-State Air Pollution Rule NO_x Ozone Season Program Allowance Reconciliation Summary, 2015

Total Allowances Held (2015 Vintage)	**626,125**	Held by Affected Facility Accounts	**601,962**
		Held by Other Accounts (General, State Holding and Non-Affected Facility Accounts)	**24,163**
Allowances Deducted for Cross-State Air Pollution Rule NO_x Ozone Season Program	452,249		
Penalty Allowance Deductions	30		
Banked Allowances	**173,876**	Held by Affected Facility Accounts	**149,713**
		Held by Other Accounts (General, State Holding and Non-Affected Facility Accounts)	**24,163**

CSAPR NO_x Ozone Season Program Compliance Results

Reported Emissions (tons)	**452,239**
Compliance issues, rounding, and report resubmission adjustments (tons)	**-5**
Emissions not covered by allowances (tons)	**15**
Total allowances deducted for emissions	**452,249**

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 January 2017 and subsequent adjustments of penalties are not reflected.

Source EPA, 2017

Figure 5. CSAPR NO_X Ozone Season Program Allowance Reconciliation Summary, 2015

Chapter 6: Market Activity

Allowance trading allows participants in cap and trade programs to adopt the most cost-effective strategy to reduce emissions. Participants that reduce their emissions below the number of allowances they hold may trade allowances, sell them, 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 not only among their own generating assets, but across the entire marketplace of power generators.

Key Points

Transaction Types and Volumes

- In 2015, over 900,000 allowances were traded across all four of CSAPR trading programs. More than half of the transactions within the CSAPR Group 1 sulfur dioxide (SO_2) program and nitrogen oxides (NO_X) annual program were between unrelated parties (distinct organizations). A little more than one-third of CSAPR Group 2 SO_2 program and NO_X ozone season program allowance transactions were between distinct organizations.
- In 2015, over 5 million ARP allowances were traded, the majority (81 percent) between related organizations.

2015 Allowance Prices[1]

- ARP SO_2 allowance prices averaged less than $1 per ton.
- CSAPR SO_2 Group 1 allowance prices started 2015 at $250 per ton and ended 2015 at $3 per ton.
- CSAPR SO_2 Group 2 allowance prices started 2015 at $450 per ton and ended 2015 at $5 per ton.
- CSAPR NO_X annual program allowances started 2015 at $250 per ton and ended 2015 at $99 per ton.
- CSAPR NO_X ozone season program allowances started 2015 at $250 per ton and ended 2015 at $175 per ton.

[1] Allowance prices as reported by SNL Finance, 2017. Prices rounded to the nearest dollar.

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 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 2015 emissions were below emission budgets for the Acid Rain Program (ARP) and for all four Cross-State Air Pollution Rule (CSAPR) programs. As a result, CSAPR 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.

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

2015 Allowance Transfers under CSAPR and ARP

	Transactions conducted	Allowances Transferred	Share of Program's Allowances Transferred	
			Related (%)	Distinct (%)
ARP SO_2	1,155	5,375,846	81%	19%
CSAPR SO_2 Group 1	109	273,441	45%	55%
CSAPR SO_2 Group 2	53	237,776	62%	38%
CSAPR NO_x Annual	307	189,407	46%	54%
CSAPR NO_x Ozone Season	1,032	199,688	64%	36%

Notes:
• The breakout between distinct and related organizations is not an exact value as relationships are often difficult to categorize in a simple bifurcated manner. EPA's analysis is conservative and the "Distinct Organizations" percentage is likely higher.
• Percentages may not add up to 100% due to rounding.

Source: EPA, 2017

Figure 1. 2015 Allowance Transfers under CSAPR and ARP

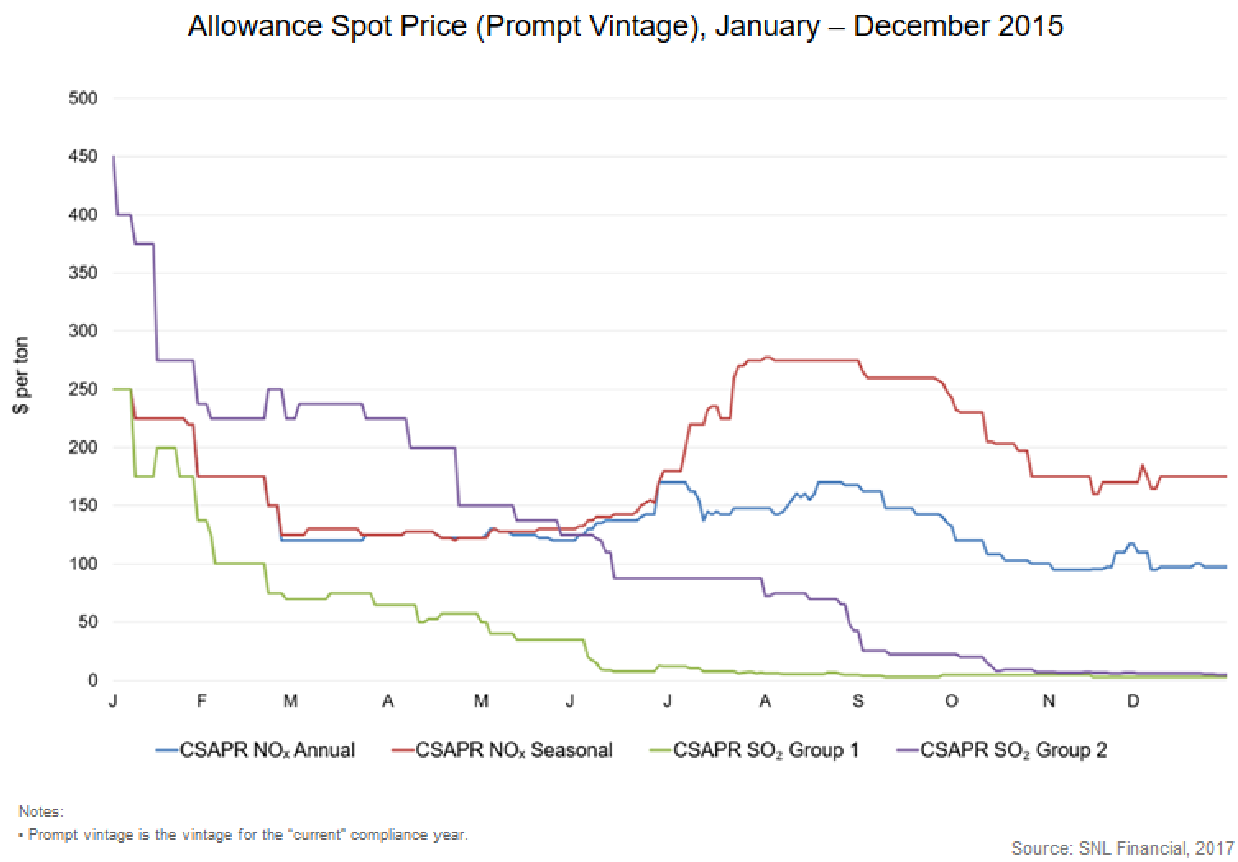


Figure 2. Allowance Spot Price (Prompt Vintage), January–December 2015

Chapter 7: Air Quality

The Acid Rain Program (ARP) and Cross-State Air Pollution Rule (CSAPR) 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 and particulate matter, which cause a range of serious health effects and degrade visibility in many American cities and scenic areas, including 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

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 12.2 parts per billion (ppb) to 1.3 ppb (90 percent) between 1980 and 2015.
- 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 2013–2015 observation periods.
- Ambient particulate sulfate concentrations have decreased since the ARP was implemented, with average concentrations decreasing by 66 to 70 percent in observed regions from 1989–1991 to 2013–2015.
- Average annual ambient total nitrate concentrations declined 50 percent from 1989–1991 to 2013–2015 in the eastern United States, with the largest reductions in the Mid-Atlantic and Northeast.

Analysis and Background Information

Sulfur Dioxide

Sulfur oxides are a group of highly reactive gases that can travel long distances in the upper atmosphere and predominantly exist as sulfur dioxide (SO_2). 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 emissions contribute to the formation of fine particle pollution ($PM_{2.5}$) and are linked with a number of adverse health effects on the respiratory system.[1] In addition, particulate sulfate degrades visibility and, because sulfate compounds are typically acidic, they 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 emissions are 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 and CSAPR 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.

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://www.epa.gov/no2-pollution
- Learn more about EPA's Clean Air Market Programs https://www.epa.gov/airmarkets/programs

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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.

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Figures

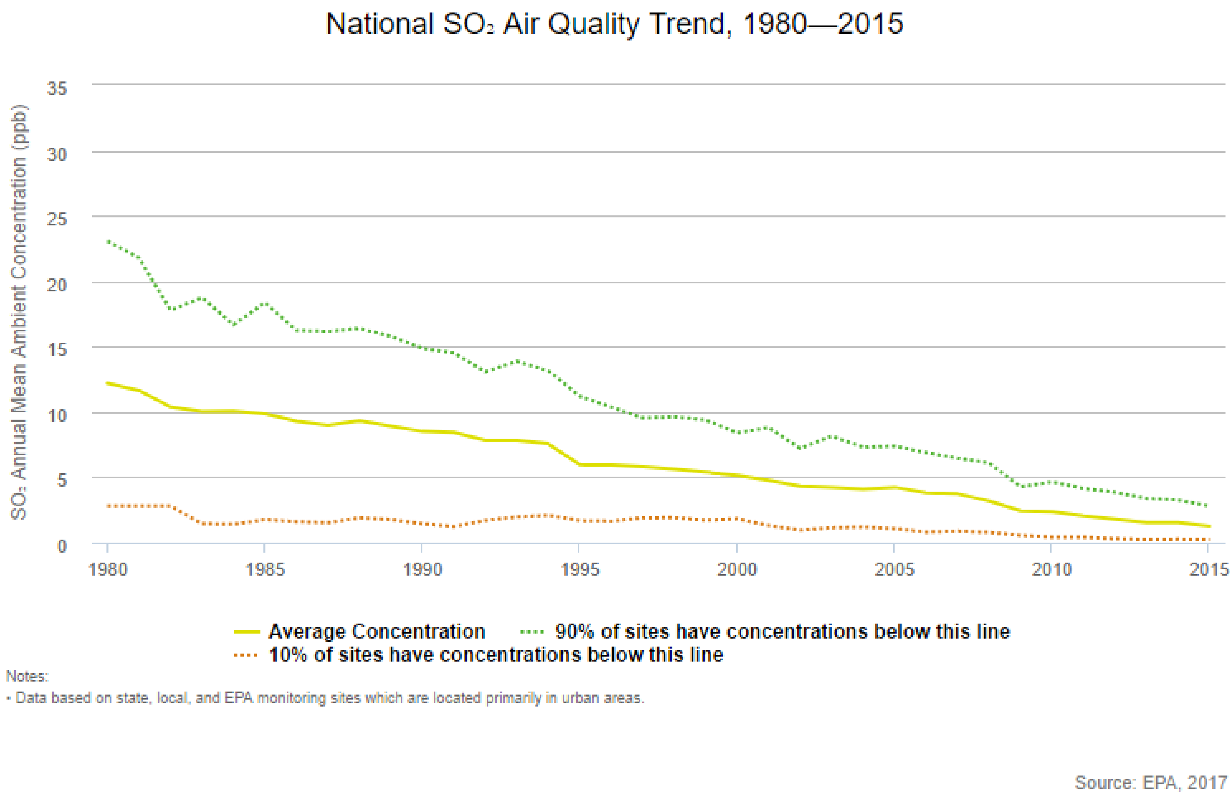

Figure 1. National SO_2 Air Quality Trend, 1980–2015

Regional Changes in Air Quality

Measurment	Region	Annual Average, 1989-1991	Annual Average, 2013-2015	Percent Change	Number of Sites	Statistical Significance
Ambient particulate sulfate concentration (µg/m³)	Mid-Atlantic	6.3	1.9	-70	12	***
	Midwest	5.8	2.0	-66	9	***
	Northeast	3.4	1.1	-68	4	
	Southeast	5.5	1.7	-69	8	***
Ambient sulfur dioxide concentration (µg/m³)	Mid-Atlantic	13.0	2.0	-85	12	***
	Midwest	11.0	1.0	-83	9	***
	Northeast	5.2	0.7	-87	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	2.5	-46	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, 2017

Figure 2. Regional Changes in Air Quality

Ozone

Key Points

Changes in 1-Hour Ozone during Ozone Season

- An overall regional reduction in ozone levels was observed between 2000–2002 and 2013–2015, with a 22 percent reduction in the highest (99th percentile) ozone concentrations in CSAPR states.
- Results demonstrate how NO_X emission reduction policies have affected 1-hour ozone concentrations in the eastern United States – the region that the policies were designed to target.

Trends in Rural 8-Hour Ozone

- From 2013 to 2015, rural ozone concentrations averaged 65 ppb in CSAPR states, a decrease of 25 ppb (27 percent) from the 1990 to 2002 period.
- The Autoregressive Integrated Moving Average (ARIMA) model shows how the reductions in rural ozone concentrations follow the implementation of the NBP in 2003 (two-year 14 ppb reduction from 2002) and the start of the CAIR NO_X ozone season program in 2009 (two-year 7 ppb reduction from 2007).
- Three of the four lowest observed ozone concentrations were between 2013 and 2015. Ozone season NO_X emissions fell steadily under CAIR and continued to drop after implementation of CSAPR in 2015. In addition, implementation of the mercury and air toxics standards (MATS), which began in 2015, achieves co-benefit reductions of NO_X emissions.

Changes in 8-Hour Ozone Concentrations

- The average reduction in ozone concentrations not adjusted for weather in the CSAPR NO_X ozone season program region from 2000–2002 to 2013–2015 was about 10 ppb (18 percent).
- The average reduction in the meteorologically-adjusted ozone concentrations in the CSAPR NO_X ozone season program region from 2000–2002 to 2013–2015 was about 11 ppb (19 percent).

Changes in Ozone Nonattainment Areas

- Ninety-two of the 113 areas originally designated as nonattainment for the 1997 8-hour ozone National Ambient Air Quality Standard (NAAQS) (0.08 ppm) are in the eastern United States and are home to about 122 million people.[1] These nonattainment areas were designated in 2004 using air quality data from 2001 to 2003.[2]
- Based on data from 2013 to 2015, all 92 of the eastern ozone nonattainment areas now show concentrations below the level of the 1997 standard.
- Twenty-two of the 46 areas originally designated as nonattainment for the 2008 8-hour ozone NAAQS (0.075 ppm) are in the eastern United States and are home to about 80 million people. These nonattainment areas were designated in 2012 using air quality data from 2008 to 2010 or 2009 to 2011.

- Based on data from 2013-2015, 82 percent (18 areas) of the eastern ozone nonattainment areas now show concentrations below the level of the 2008 standard, while four areas continue to show concentrations above the 2008 standard. While four areas continue to show concentrations above the 2008 standard, three of those areas made progress toward meeting the standard in the 2013-2015 period. Given that the majority of ozone season NO_X emission reductions in the power sector that occurred after 2003 are attributable to the NBP, CAIR, and CSAPR, it is reasonable to conclude that ozone season NO_X emission reduction programs have significantly contributed to these improvements in ozone air quality.

Analysis and Background Information

Ozone pollution – also known as smog – 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 formation and hot, sunny days are most favorable for ozone production. For ozone, EPA and states typically regulate NO_X emissions during the summer when sunlight intensity and temperatures are highest.

Ozone Standards

In 1979, EPA established NAAQS for 1-hour ozone at 0.12 parts per million (ppm, or 124 parts per billion). In 1997, a more stringent 8-hour ozone standard of 0.08 ppm (84 ppb) was finalized, revising the 1979 standard. CSAPR was designed to help downwind states in the eastern United States achieve the 1997 ozone NAAQS. Based on extensive scientific evidence about ozone's effects on public health and welfare, EPA strengthened the 8-hour ozone standard to 0.075 ppm (75 ppb) in 2008, and further strengthened the 8-hour NAAQS for ground-level ozone to 0.070 ppm (70 ppb) in October 2015. EPA revoked the 1-hour ozone standard in 2005 and also recently revoked the 1997 8-hour ozone standard in April 2015.

Regional Trends in Ozone

EPA investigated trends in daily maximum 8-hour ozone concentrations measured at rural Clean Air Status and Trends Network (CASTNET) monitoring sites within the CSAPR 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 emissions (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 in 2011 is likely due to actions taken for CAIR compliance, although other factors contributing to the decline 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 CSAPR 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 78 urban areas and 39 rural CASTNET monitoring sites located in the CSAPR 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.[3, 4]

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, CAIR, and CSAPR. As power sector emissions are an important component of the NO_X emission inventory, it is reasonable to conclude that the reduction in ozone season NO_X emissions from these programs have significantly contributed to improvements in ozone air quality and attainment of the 1997 ozone health-based air quality standard. In fact, all areas originally designated as nonattainment for the 1997 ozone NAAQS are now meeting the standard.

Emission reductions under these power sector programs also have helped many areas in the eastern United States reach attainment for the 2008 ozone NAAQS. However, several areas continue to be out of compliance with the 2008 ozone NAAQS, and additional NO_X ozone season emission reductions are needed to attain that standard as well as the strengthened ozone standard that was finalized in October 2015.

In order to help downwind states and communities meet and maintain the 2008 ozone standard, EPA finalized the CSAPR Update in September 2016 to address the transport of ozone pollution that crosses state lines in the eastern United States. Implementation began in May 2017 to further reduce ozone season NO_X emissions from power plants in 22 states in the East.

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://www.epa.gov/no2-pollution
- Learn more about Nonattainment Areas https://www.epa.gov/green-book
- Learn more about EPA's Clean Air Market Programs https://www.epa.gov/airmarkets/programs

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Figures

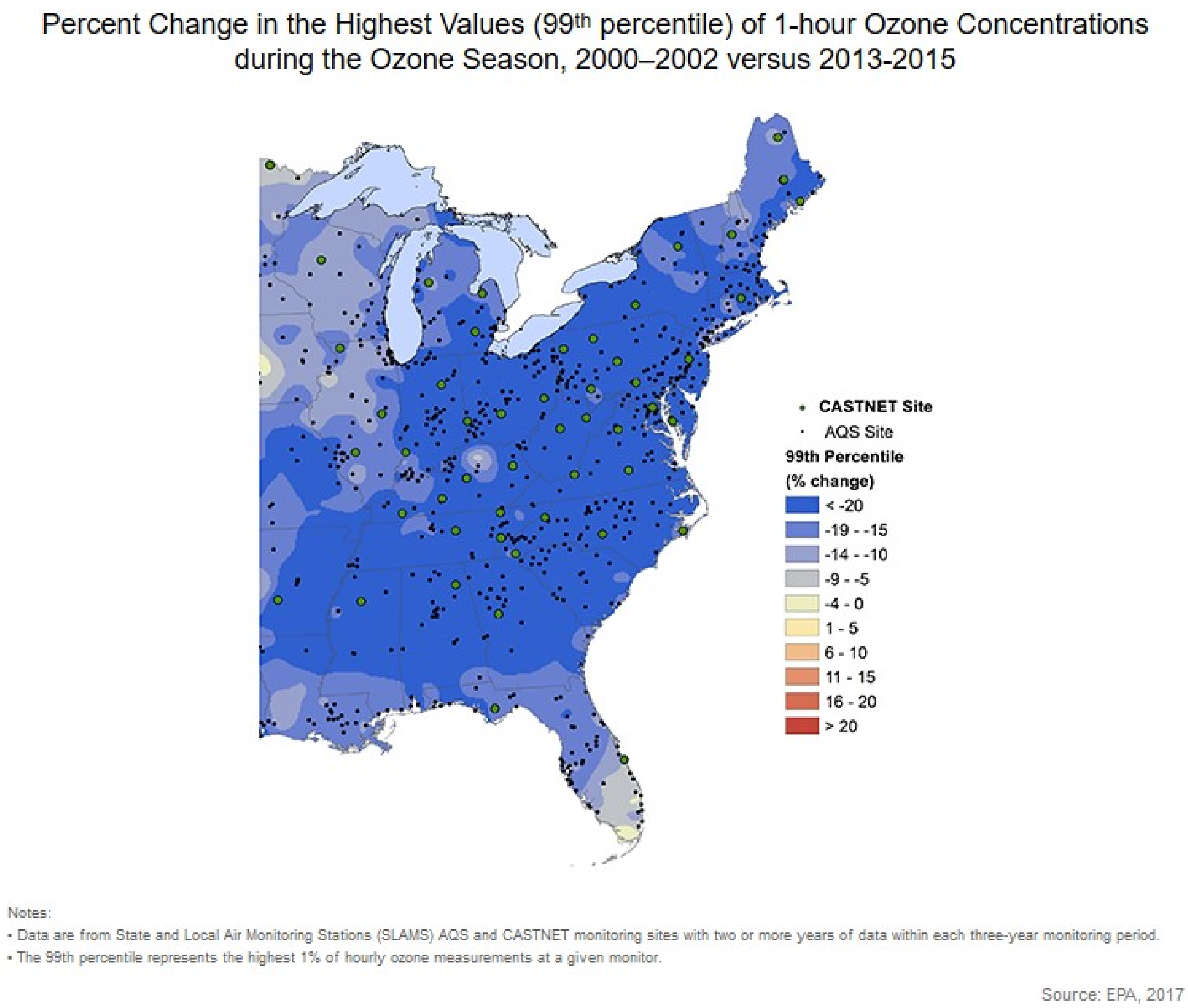
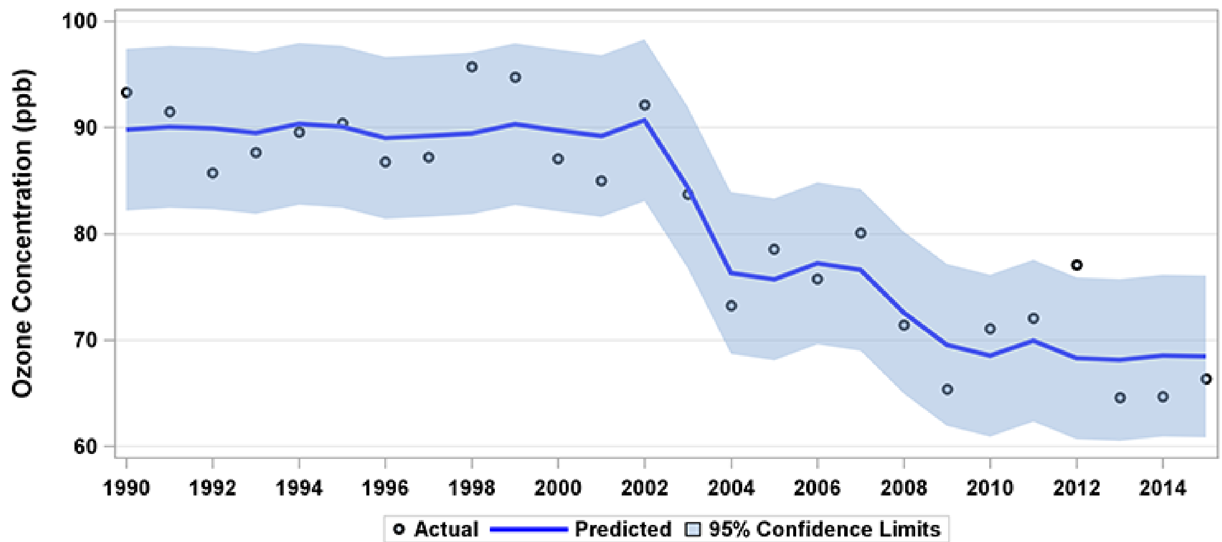


Figure 1. Percent Change in the Highest Values (99th percentile) of 1-hour Ozone Concentrations during the Ozone Season, 2000–2002 versus 2013-2015

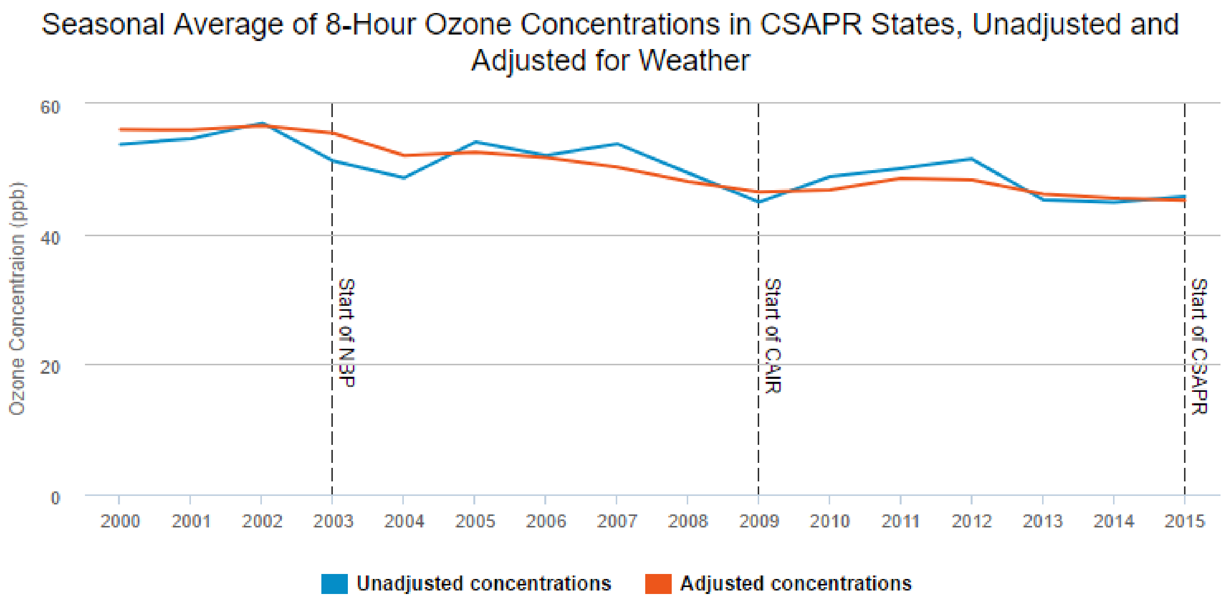
Shifts in 8-hour Seasonal Rural Ozone Concentrations in the CSAPR NO_x Ozone Season Region, 1990–2015



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 CSAPR NO_x ozone season program region.

Source: EPA, 2017

Figure 2. Shifts in 8-hour Seasonal Rural Ozone Concentrations in CSAPR NO_X Ozone Season Region, 1990–2015



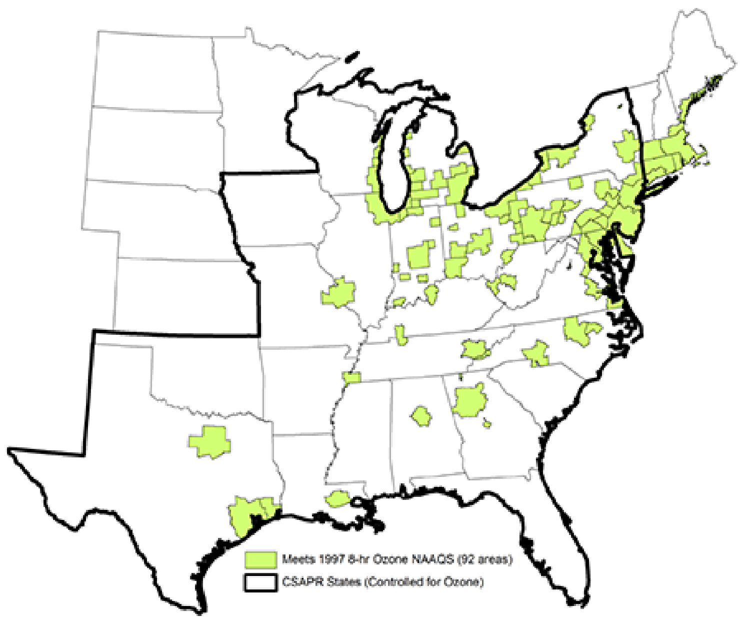
Notes:

- 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 CSAPR 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 2015. In urban areas with more than one monitoring site, the highest observed ozone concentration in the area was used for each day.

Source: EPA, 2017

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

Changes in 1997 Ozone NAAQS Nonattainment Areas in the CSAPR Region, 2001–2003 (Original Designations) versus 2013-2015



Source: EPA, 2017

Figure 4. Changes in 1997 Ozone NAAQS Nonattainment Areas in CSAPR Region, 2001–2003 (Original Designations) versus 2013-2015

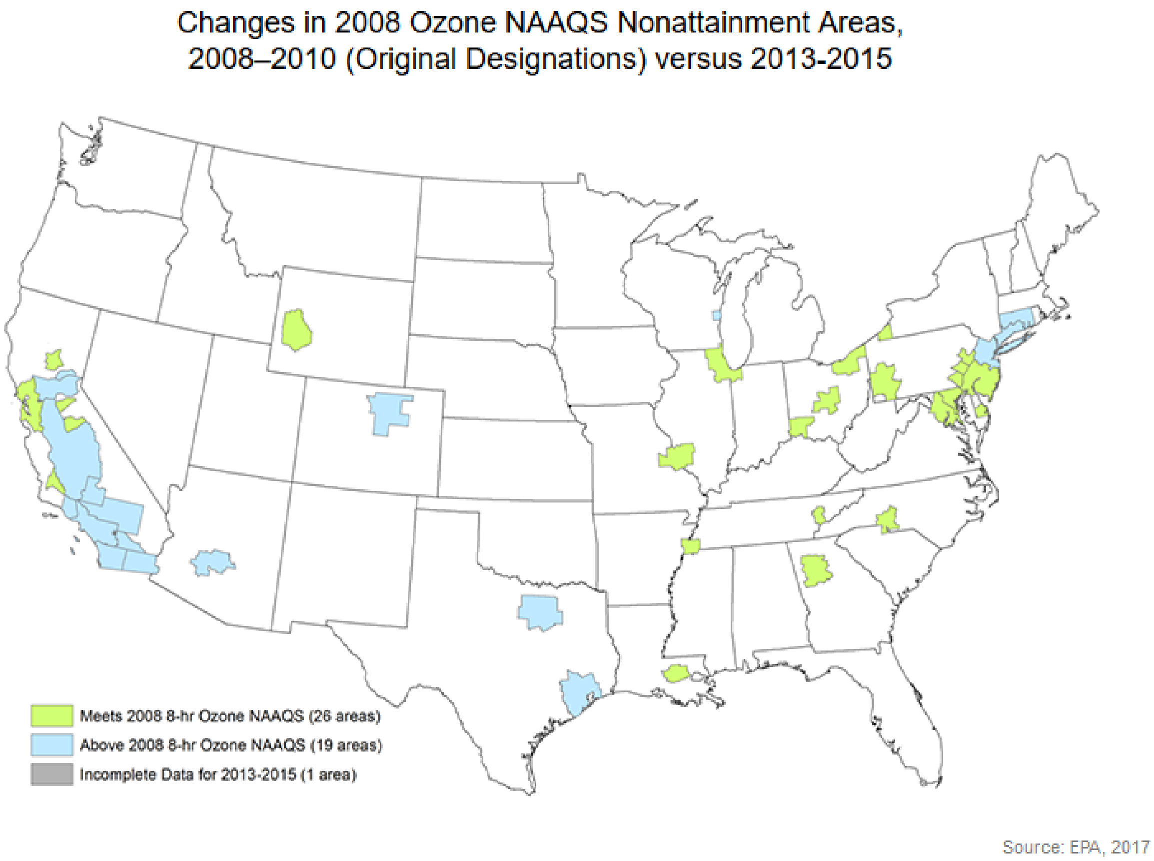


Figure 5. Changes in 2008 Ozone NAAQS Nonattainment Areas, 2008–2010 (Original Designations) versus 2013-2015

Particulate Matter

Key Points

PM Seasonal Trends

- Average $PM_{2.5}$ concentration data were downloaded from the Air Quality System (AQS) for 173 sites located in the CSAPR 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 seasonal average $PM_{2.5}$ concentrations have decreased by about 38 and 42 percent in the warm and cool season months, respectively, between 2000 and 2015.

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.[1,2] The nonattainment areas were set in January 2005 using 2001 to 2003 data.
- Based on data gathered from 2013 to 2015, 34 of these eastern areas originally designated nonattainment show concentrations below the level of the 1997 $PM_{2.5}$ standard (15 $\mu g/m^3$), indicating improvements in $PM_{2.5}$ air quality. Two areas have incomplete data.
- Given that the majority of power sector SO_2 and annual NO_X emission reductions occurring after 2003 are attributable in part to the ARP, NBP, CAIR, and CSAPR, it is reasonable to conclude that these emission reduction programs have significantly contributed to these improvements in $PM_{2.5}$ air quality.

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: premature death; increased respiratory symptoms, such as irritation of the airways, coughing, or difficulty breathing; decreased lung function; aggravated asthma; development of chronic bronchitis; irregular heartbeat; and nonfatal heart attacks.[3,4,5]

Particulate Matter Standards

The CAA requires EPA to set NAAQS for particle pollution. In 1997, EPA set the first standards 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 $\mu g/m^3$.

CSAPR was promulgated to help downwind states in the eastern United States achieve the 1997 annual average $PM_{2.5}$ NAAQS and the 2006 24-hour $PM_{2.5}$ NAAQS; therefore, analyses in this report focus on those standards.

Changes in $PM_{2.5}$ Nonattainment Areas

In the eastern US, recent data indicate that no areas are violating the 1997 or 2006 $PM_{2.5}$ NAAQS. 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, CAIR, and CSAPR. 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.

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://www.epa.gov/no2-pollution
- Learn more about Nonattainment Areas https://www.epa.gov/green-book
- Learn more about EPA's Clean Air Market Programs https://www.epa.gov/airmarkets/programs

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Figures

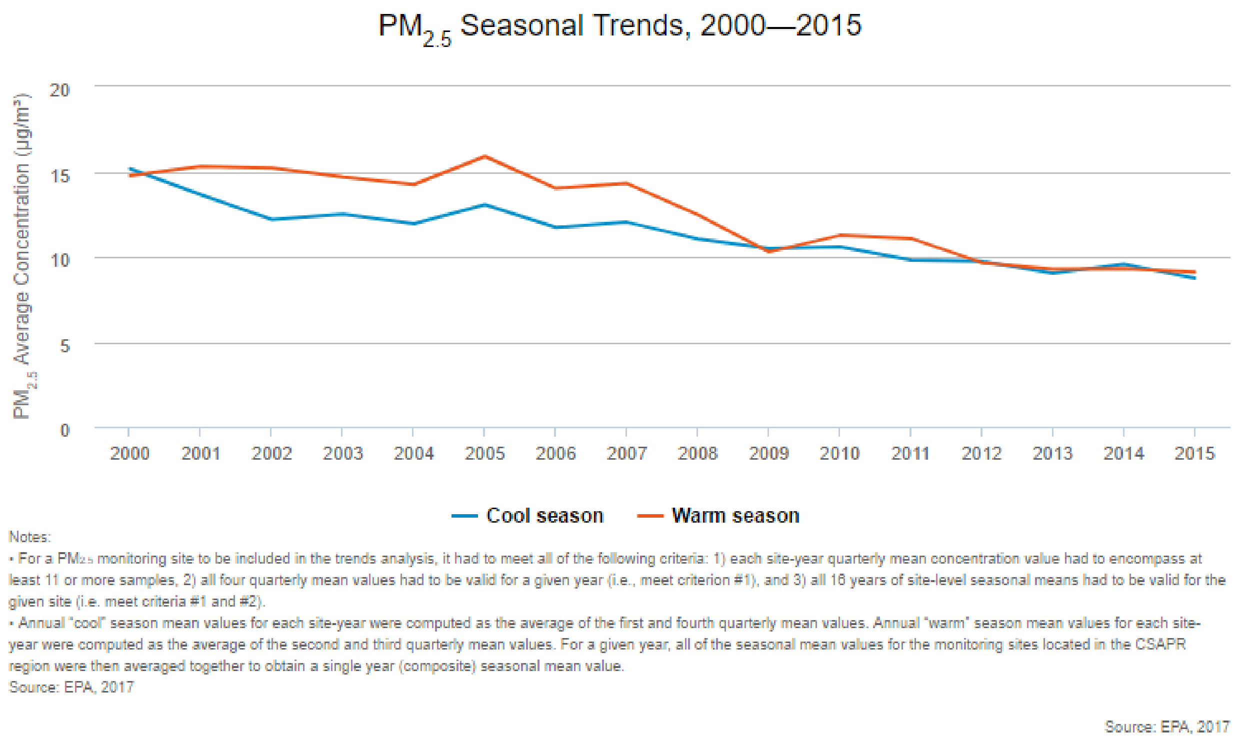

Figure 1. $PM_{2.5}$ Seasonal Trends, 2000–2015

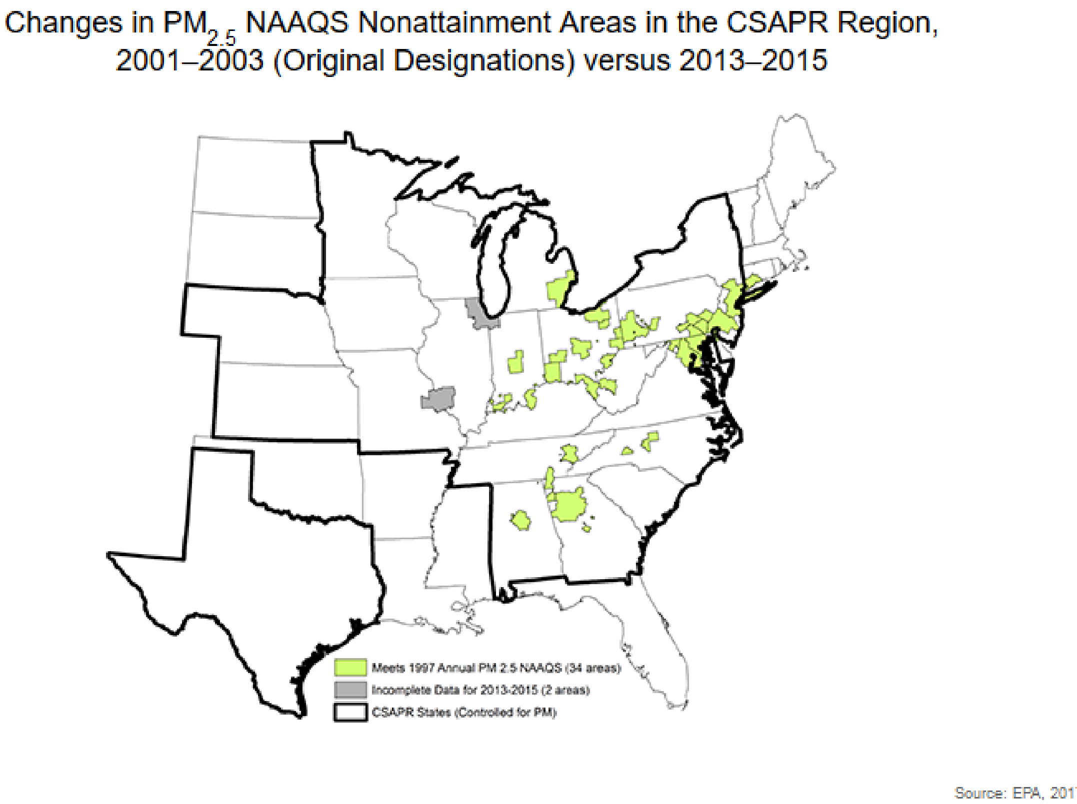

Figure 2. Changes in $PM_{2.5}$ NAAQS Nonattainment Areas in CSAPR Region, 2001–2003 (Original Designations) versus 2013–2015

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 sulfur and nitrogen-containing acidic pollutants. 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.

Key Points

Wet Sulfate Deposition

- All areas of the eastern United States have shown significant improvement with an overall 64 percent reduction in wet sulfate deposition from 1989–1991 to 2013–2015.
- Between 1989–1991 and 2013–2015, the Northeast and Mid-Atlantic experienced the largest reductions in wet sulfate deposition, 68 percent and 71 percent, respectively.
- 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 9 percent in the Midwest from 1989–1991 to 2013–2015. Smaller reductions in wet deposition of inorganic nitrogen deposition in the Midwest are attributed to a 22 percent increase in wet deposition of reduced nitrogen (NH_4^+) over the same time period.
- 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, agriculture, and manufacturing) contribute to changes in air concentrations and deposition of nitrogen.

Regional Trends in Total Deposition

- 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 79 percent from 1989–1991 to 2013–2015.
- Decreases in dry and total inorganic nitrogen deposition have generally been greater than that of wet deposition, with average reductions of 59 percent and 52 percent, respectively. In contrast, wet deposition from inorganic nitrogen reduced by an average of 20 percent from 1989–1991 to 2013–2015.

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 are deposited to the surface in the form of wet and dry acid deposition.

Long-term monitoring network data show significant improvements in the primary indicators of acid deposition. 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^+ or pH) 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 Cross-State Air Pollution (CSAPR) 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.

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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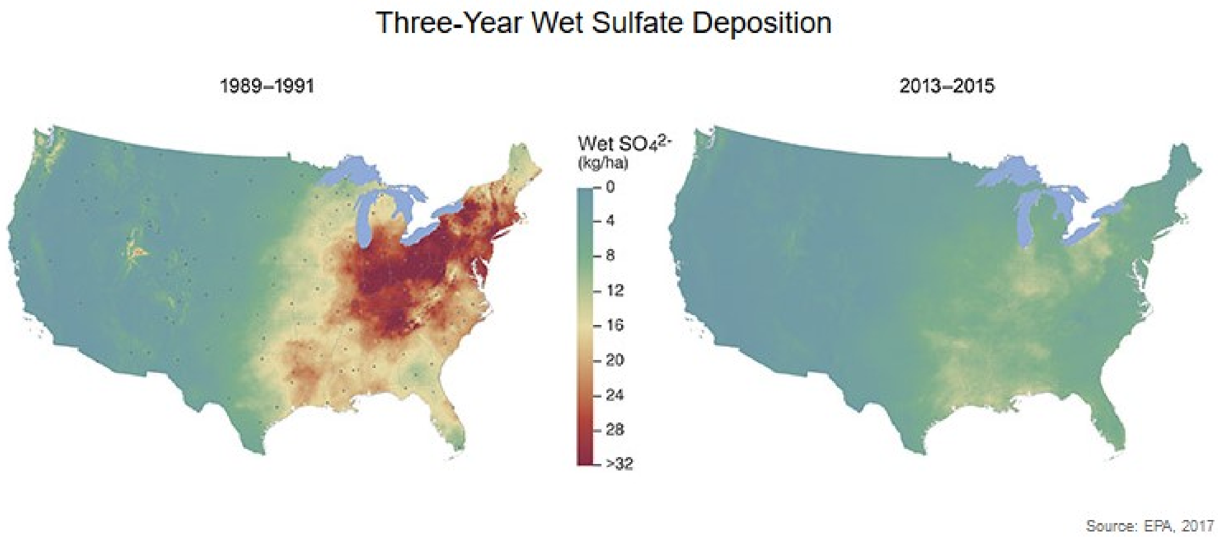

Figure 1. Three-Year Wet Sulfate Deposition

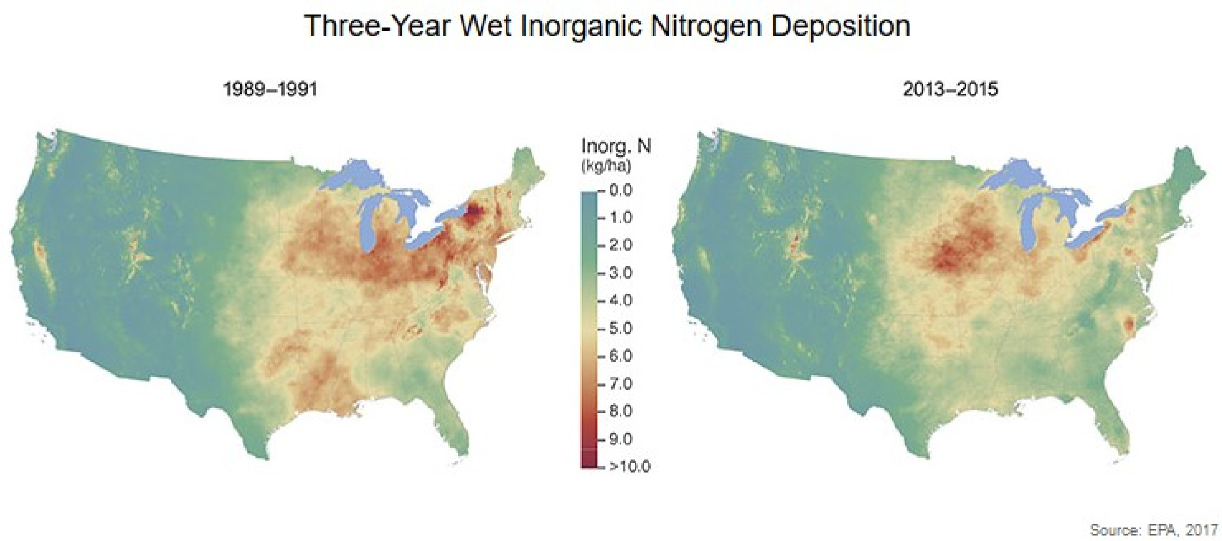

Figure 2. Three-Year Wet Inorganic Nitrogen Deposition

Regional Trends in Deposition

Measurment	Region	Annual Average, 1989–1991	Annual Average, 2013–2015	Percent Change	Number of Sites	Statistical Significance
Dry inorganic nitrogen deposition (kg-N/ha)	Mid-Atlantic	2.5	0.9	-64	12	***
	Midwest	2.4	1.2	-50	9	***
	Northeast	1.3	0.4	-69	4	
	Southeast	1.7	0.7	-59	8	***
Dry sulfur deposition (kg-S/ha)	Mid-Atlantic	7.0	1.2	-83	12	***
	Midwest	6.6	1.4	-79	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	3.8	-57	12	***
	Midwest	8.6	4.8	-44	9	***
	Northeast	6.6	2.9	-56	4	
	Southeast	6.4	3.1	-52	8	***
Total sulfur deposition (kg-S/ha)	Mid-Atlantic	16.0	4.0	-75	12	***
	Midwest	15.0	5.0	-67	9	***
	Northeast	9.5	2.5	-74	4	
	Southeast	10.4	3.3	-68	8	***
Wet nitrogen deposition from inorganic nitrogen (kg-N/ha)	Mid-Atlantic	6.2	3.9	-37	11	***
	Midwest	5.8	5.3	-9	27	***
	Northeast	5.7	4.0	-30	16	***
	Southeast	4.3	3.5	-19	22	***
Wet sulfur deposition from sulfate (kg-S/ha)	Mid-Atlantic	9.2	2.7	-71	11	***
	Midwest	7.1	2.9	-59	27	***
	Northeast	7.5	2.4	-68	16	***
	Southeast	5.9	2.4	-59	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, 2017

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, forest, grasslands, 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.

Ground-level ozone is an air pollutant that can impact ecological systems like forests, altering a plant's health and leading to changes in individual tree growth (e.g., biomass loss) and to the biological community. Analyzing the biomass loss of certain trees before and after implementation of NO_X emission reduction programs provides information about the effect of reduced NO_X emissions and ozone concentrations on forested areas.

Ecosystem Health

Key Points

Regional Trends in Water Quality

- Between 1990 and 2015, significant decreasing trends in sulfate concentrations, demonstrating improved lake and stream health, are found at all long-term monitoring (LTM) program lake and stream monitoring sites in New England, the Adirondacks, and the Catskill mountains.
- On the other hand, between 1990 and 2015, streams in the central Appalachian region have experienced mixed results due in part to their soils and geology. Only 27 percent of monitored streams show lower sulfate concentrations (and statistically significant trends), while 17 percent show increased sulfate concentrations.
- Nitrate concentrations and trends are highly variable and many sites do not show improving trends between 1990 and 2015, despite reductions in NO_X emissions and inorganic nitrogen deposition.
- In 2015, levels of acid neutralizing capacity (ANC), a key indicator of aquatic ecosystem recovery, have increased significantly from 1990 in lake and stream sites in the Adirondack Mountains, New England, and the Catskill mountains.

Ozone Impacts on Forest

- Between 2000-2002 and 2013-2015, the area in the eastern United States with significant forest biomass loss (> 2 % biomass loss) decreased from 33 percent to 5 percent for seven tree species – black cherry, yellow-poplar, sugar maple, eastern white pine, Virginia pine, red maple, and quaking aspen.
- For black cherry and yellow poplar (the tree species most sensitive to ground-level ozone), the total land area in the eastern United States with significant biomass loss decreased from 15 percent to 5

percent for black cherry, and from 3 percent to 0 percent for yellow poplar between 2000-2002 and 2013-2015.

- For the period 2013-2015, total land area in the eastern United States with significant biomass loss for the remaining five species (red maple, sugar maple, quaking aspen, Virginia pine, and eastern white pine) is now zero. This is in contrast to 34% for the period of 2000-2002.

- While this change in biomass loss cannot be exclusively attributed to the implementation of the NBP, CAIR, and CSAPR, it is likely that NO_X emission reductions achieved under these programs, and the corresponding decreases in ozone concentration, contributed to this environmental improvement.

Analysis and Background Information

Acidified Surface Water Trends

Acidified precipitation and surface water mobilizes toxic forms of aluminum from soils, particularly in clay rich soils, harming fish and other aquatic 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. Improvement in surface water status is generally indicated by decreasing concentration of sulfate and nitrate anions, decreasing base cations, and increasing ANC. 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 toxic forms of aluminum and base cations from soils, leaving soils depleted of buffering cations.
- **Nitrate** has the potential 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]

Surface Water 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 geologic provinces). As of the end of 2015, the TIME program is no longer operating. All data and trends presented here reflect the results of LTM program monitoring activities.

Forest Health

Ground-level ozone is one of many air pollutants that can alter a plant's health and ability to reproduce and can make the plant more susceptible to disease, insects, fungus, harsh weather, etc. These impacts can lead to changes in the biological community, both in the diversity of species and in the health, vigor, and growth of individual species. As an example, many studies have shown that ground-level ozone reduces the health of many commercial and ecologically important forest tree species throughout the United States[2, 3]. By looking at the distribution and abundance of seven sensitive tree species and the level of ozone at particular locations, it is possible to estimate reduction in growth – or biomass loss – for each species. The EPA evaluated biomass loss for seven common tree species in the eastern United States that have a higher sensitivity to ozone (black cherry, yellow-poplar, sugar maple, eastern white pine, Virginia pine, red maple, and quaking aspen) to determine whether decreasing ozone concentrations are reducing biomass loss in forest ecosystems.

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/

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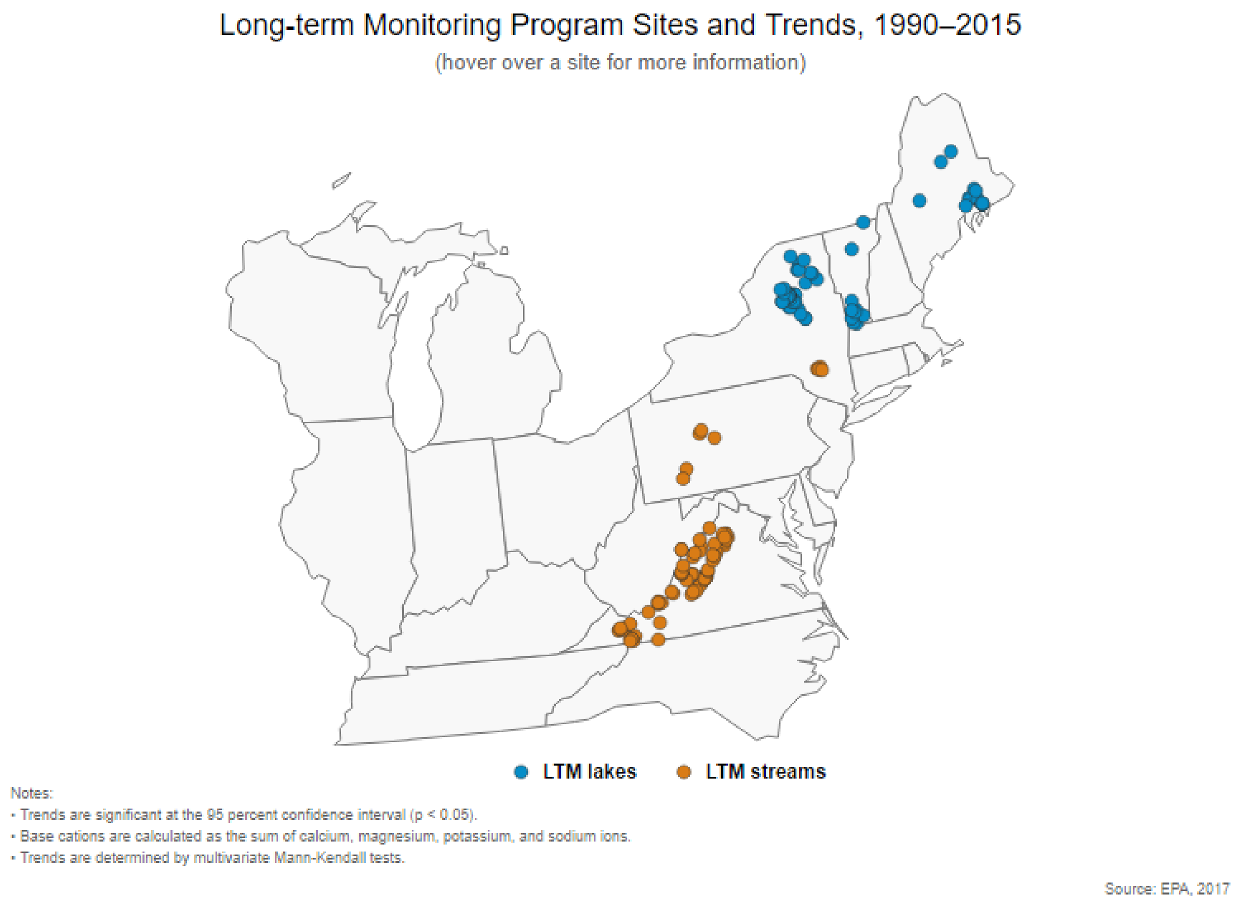

Figure 1. Long-term Monitoring Program Sites and Trends, 1990–2015

Regional Trends in Sulfate, Nitrate, ANC, and Base Cations at Long-term Monitoring Sites, 1990–2015

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	44 lakes in NY*	100%	57%	91%	89%
New England	26 lakes in ME and VT	100%	25%	67%	60%
Catskills/ N. Appalachian Plateau	9 streams in NY and PA	80%	40%	58%	90%
Central Appalachians	66 streams in VA	27%	74%	11%	23%

Notes:
- Trends are determined by multivariate Mann-Kendall tests
- Trends are significant at the 95 percent confidence interval ($p < 0.05$)
- Sum of Base Cations calculated as (Ca+Mg+K+Na)

*Trends are based on a new subsite of 38 lakes in NY where 26 of the lakes have ANC less than 25 μeq/L

Source: EPA, 2017

Figure 2. Regional Trends in Sulfate, Nitrate, ANC, and Base Cations at Long-term Monitoring Sites, 1990–2015

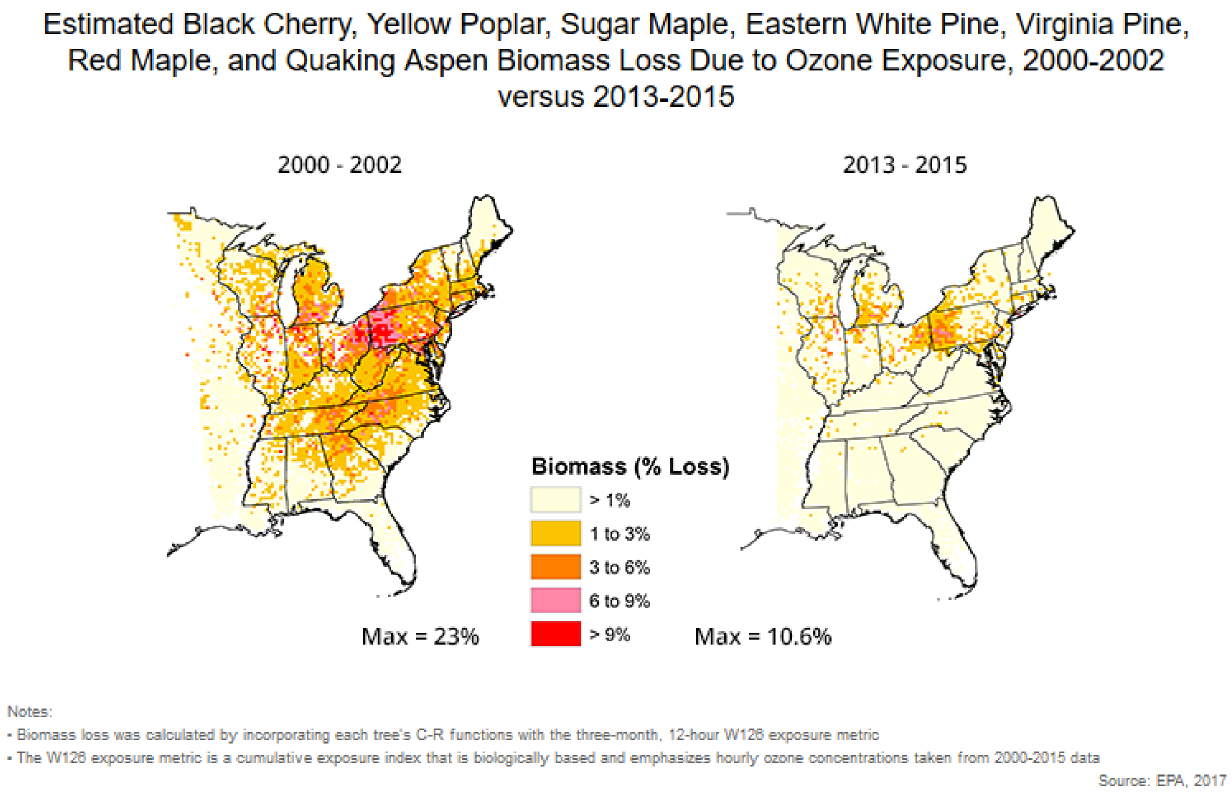

Figure 3. Estimated Black Cherry, Yellow Poplar, Sugar Maple, Eastern White Pine, Virginia Pine, Red Maple, and Quaking Aspen Biomass Loss Due to Ozone Exposure, 2000-2002 versus 2013-2015

Critical Loads Analysis

Key Points

Critical Loads and Exceedances

- For the period from 2013 to 2015, 13 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 60 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 2015 have contributed and will continue to contribute to broad surface water improvements and increased aquatic ecosystem protection across the five regions along the Appalachian Mountains.
- Based on this analysis, current sulfur and nitrogen deposition loadings in 2015 still exceed levels required for recovery of some 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.

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 emissions 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 aquatic 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]

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/

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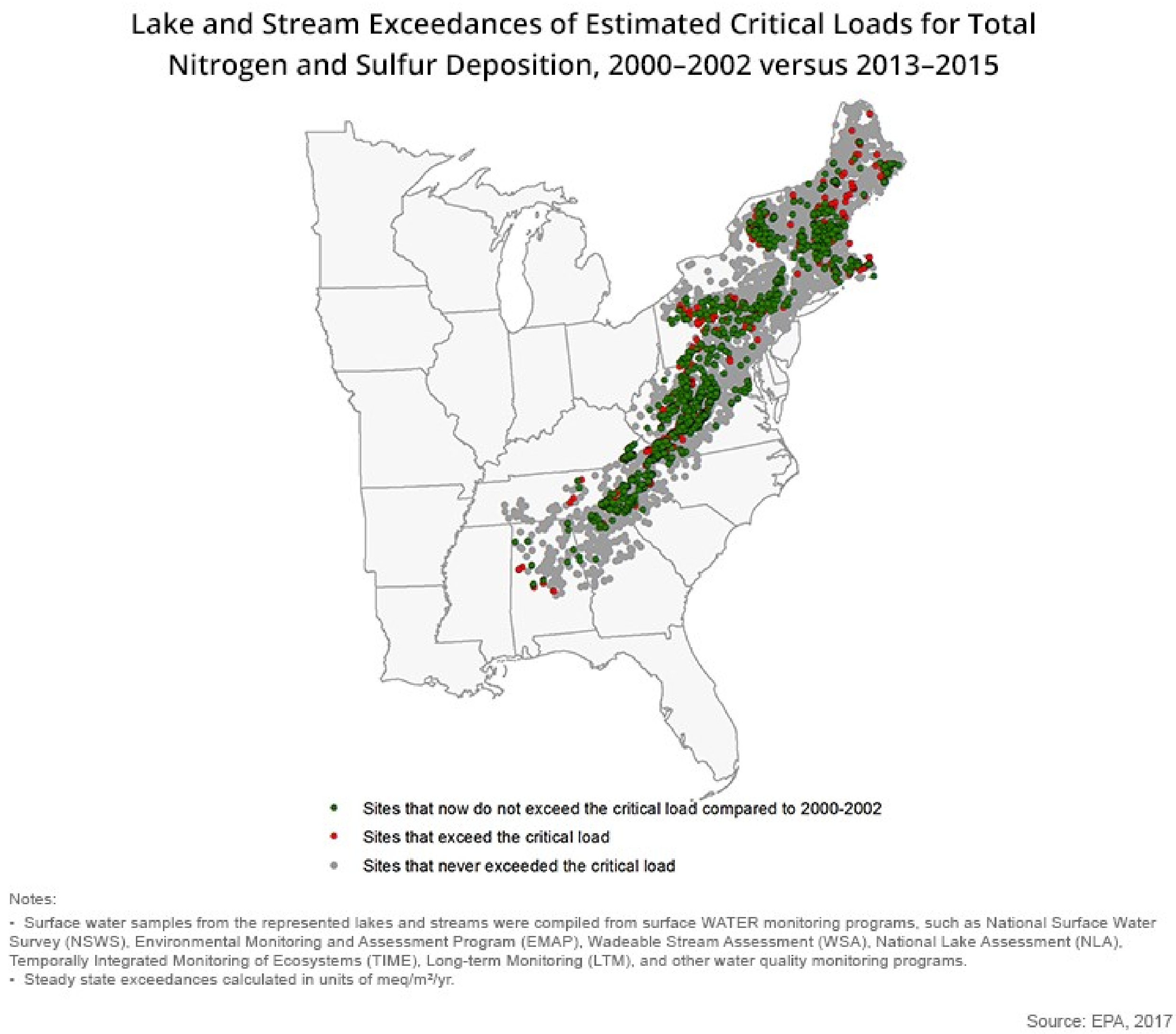

Figure 1. Lake and Stream Exceedances of Estimated Critical Loads for Total Nitrogen and Sulfur Deposition, 2000–2002 versus 2013–2015

Critical Load Exceedances by Region, 2000-2002 versus 2013-2015

Region	Number of Water Bodies Modeled	Water Bodies in Exceedance of Critical Load				Percent Reduction
		2000–2002		2013–2015		
		Number of Sites	Percent of Sites	Number of Sites	Percent of Sites	
New England (CT, MA, ME, NH, RI, VT)	2,027	461	23%	185	9%	60%
Adirondacks (NY)	315	144	46%	58	18%	60%
Northern Mid-Atlantic (NY, NJ, PA)	1,166	279	24%	95	8%	66%
Southern Mid-Atlantic (MD, VA, WV)	1,597	856	54%	356	22%	58%
Southern Appalachian Mountains (AL, GA, NC, SC, TN,)	896	286	32%	115	13%	60%
Total Units	**6,001**	**2,026**	**34%**	**809**	**13%**	**60%**

Notes:
• Surface water samples from the represented lakes and streams were compiled from surface WATER 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, 2017

Figure 2. Critical Load Exceedances by Region, 2000-2002 versus 2013-2015