2016 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 2016 under the Acid Rain Program (ARP) and the Cross-State Air Pollution Rule (CSAPR). This reporting year marks the second year of the CSAPR implementation and twenty-first year of the ARP.

Substantial reductions in power sector emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO_X), along with improvements in air quality and the environment, demonstrate the success of these programs. Transparency and data availability are a cornerstone of this success. This report highlights data that EPA systematically collects on emissions, compliance, and environmental effects.

Contents

2016 ARP and CSAPR at a Glance

- **Annual SO_2 emissions:**
  CSAPR - 1.2 million tons (87 percent below 2005)
  ARP - 1.5 million tons (91 percent below 1990)
- **Annual NO_x emissions**
  CSAPR - 0.8 million tons (69 percent below 2005)
  ARP - 1.2 million tons (81 percent below 1990)
- **CSAPR ozone season NO_x emissions:** 420,000 tons (53 percent below 2005)
- **Compliance:** 100 percent compliance for power plants in the ARP and CSAPR programs.
- **Ambient particulate sulfate concentrations:** The eastern United States has shown substantial improvement, decreasing 71 to 75 percent between 1989–1991 and 2014–2016.
- **Ozone NAAQS attainment:** Based on 2014-2016 data, all 92 areas in the East originally designated as nonattainment for the 1997 ozone NAAQS are now meeting the standard.
- **$PM_{2.5}$ NAAQS attainment:** Based on 2014-2016 data, 34 of the 39 areas in the East originally designated as 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 66 percent reduction in wet sulfate deposition from 1989–1991 to 2014–2016.
- **Levels of acid neutralizing capacity (ANC):** This indicator of recovery improved (i.e., increased) significantly from 1990 levels 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 covered power plants. The Acid Rain Program was the first nationwide cap and trade program, with a goal of reducing the emissions that cause acid rain under Title IV of the Clean Air Act. The undisputed success of the program in achieving significant emission reductions in a cost effective manner led to the deployment of the market-based cap and trade tool to additional environmental problems, namely interstate air pollution transport, or pollution from upwind emission sources that impact air quality in downwind areas. Interstate transport makes it difficult for downwind states to meet health-based air quality standards for $PM_{2.5}$ and ozone. EPA first deployed the NO_X Budget Trading Program (NBP) to help northeastern states address the interstate transport of NO_X emissions adversely impacting ozone air quality in northeastern states. Next, the NBP was effectively replaced by the ozone season NO_X program under the Clean Air Interstate Rule, which required further summertime NO_X emission reductions from the power sector, and also required annual reductions of NO_X as well as SO_2 to address $PM_{2.5}$ transport. The CSAPR replaced CAIR beginning in 2015 to continue reducing annual SO_2 and NO_X emissions, as well as seasonal NO_X emissions, to facilitate attainment of the ozone and fine particle NAAQS.

Highlights

Acid Rain Program (ARP): 1995 - present

- The ARP began in 1995 and covers fossil fuel-fired power plants across the contiguous United States. The ARP is designed to reduce SO_2 and NO_x emissions, the primary precursors of acid rain under Title IV of the Clean Air Act.
- 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): 2003 - 2008

- 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 (May 1 – September 30, the warm summer months when ozone formation is highest). The NBP was designed as a mechanism that states could use to address regional interstate transport for the 1979 ozone air quality standard (known as a National Ambient Air Quality Standard, or NAAQS).
- 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): 2009 - 2014

- 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 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): 2015 - present

- The CSAPR was developed in response to the 2008 court decisions on CAIR and replaced CAIR starting on January 1, 2015.
- The CSAPR addresses regional interstate transport of fine particle and ozone pollution for the 1997 ozone and $PM_{2.5}$ NAAQS and the 2006 $PM_{2.5}$ NAAQS. In 2015, the CSAPR required a total of 28 eastern states to reduce SO_2 emissions, annual NO_X emissions and/or ozone season NO_X emissions. Specifically, the 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.
- The CSAPR includes four separate cap and trade programs to achieve these reductions: the CSAPR SO_2 Group 1 and Group 2 trading programs, the CSAPR NO_x annual trading program, and the CSAPR NO_x ozone season trading program.
- The total CSAPR budget for each of the four trading programs equals the sum of the individual state budgets for those states affected by each program. In 2017, some original CSAPR budgets tighten, particularly in the SO_2 Group 1 program. Also, the CSAPR Update replaces the original CSAPR Ozone Season NO_X program for most states. The total CSAPR budget for each program is set at the following level in 2017:
    - SO_2 Group 1 – 1,372,631 tons
    - SO_2 Group 2 – 892,050 tons
    - Annual NO_X – 1,206,957 tons
    - Ozone Season NO_X – 316,464 tons

Cross-State Air Pollution Rule Update (CSAPR Update): 2017 - present

- The CSAPR Update was developed to address regional interstate transport for the 2008 ozone NAAQS and to respond to the July 2015 court remand of certain CSAPR ozone season requirements.
- Starting in May 2017, the CSAPR Update began further reducing ozone season NO_X emissions from power plants in 22 states in the eastern U.S.

- The CSAPR Update achieves these reductions through an ozone season NO_X cap and trade program. The total CSAPR Update budget equals the sum of the individual state budgets for those states included in the program. The CSAPR Update budget is set at 316,464 tons in 2017.[1]

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 annual SO_2 and 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. 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, 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. There is a degree of flexibility, however. Units under common control can comply through the use of emission rate averaging plans, subject to requirements ensuring that the total mass emissions from the units in an averaging plan do not exceed the total mass emissions the units would have emitted at their individual emission rate limits.

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 achieve the 1979 ozone NAAQS. All 21 jurisdictions (20 states plus Washington, D.C.) covered by the NO_x SIP Call opted to participate 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.

[1]Georgia's Ozone Season NO_X budget adds 24,041 tons of emissions to the total for states covered by CSAPR Update.

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.

The CSAPR replaced CAIR starting on January 1, 2015.

Cross-State Air Pollution Rule

EPA issued the CSAPR in July 2011, requiring 28 states in the eastern half of the United States to significantly improve air quality by reducing power plant emissions that cross state lines and contribute to fine particle and summertime ozone pollution in downwind states. The CSAPR requires 23 states to reduce annual SO_2 and NO_X emissions to help downwind areas attain the 2006 and/or 1997 annual $PM_{2.5}$ NAAQS. The CSAPR also requires 25 states to reduce ozone season NO_X emissions to help downwind areas attain the 1997 ozone NAAQS. The 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. All Group 1 states, as well as some Group 2 states, must make additional reductions in SO_2 emissions in Phase II in order to eliminate their significant contribution to air quality problems in downwind areas.

The CSAPR was scheduled to replace CAIR starting on January 1, 2012. However, the timing of the CSAPR's implementation was affected by D.C. Circuit actions that stayed and then vacated the CSAPR before implementation. On April 29, 2014, the U.S. Supreme Court reversed the D.C. Circuit's vacatur, and on October 23, 2014, the D.C. Circuit granted EPA's motion to lift the stay and shift the CSAPR compliance deadlines by three years. Accordingly, CSAPR Phase I implementation began January 1, 2015 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 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. In May 2017, the CSAPR Update began further reducing ozone season NO_X emissions from power plants in 22 states in the eastern U.S.

Next Steps to Address Interstate Air Pollution Transport

The CSAPR Update will result in meaningful, near-term reductions in ozone pollution that crosses state lines. However, the CSAPR Update may only partially resolve covered states' interstate ozone transport obligations for the 2008 ozone NAAQS. Under the Clean Air Act's "good neighbor" provisions (Section 110(a)(2)(D)(i)(I)), upwind states that contribute significantly to nonattainment or interfere with maintenance of the NAAQS in downwind areas must implement emission reductions through a state implementation plan (SIP), or in the absence of an approved SIP, a federal implementation plan (FIP). The CSAPR Update, however, may not be sufficient to fulfill this requirement. States and EPA will need to determine whether additional actions are needed to fully address regional ozone transport for this

NAAQS. In October 2017, EPA issued a memo with supplemental information intended to help states determine whether they have additional interstate transport obligations for the 2008 ozone NAAQS. For states that have not addressed this through their SIPs, EPA has committed to making this determination regarding remaining 2008 obligations by December, 2018.

Additionally, EPA promulgated a new, tighter ozone standard in 2015. Good neighbor SIPs for the 2015 ozone NAAQS are due in October 2018. EPA issued a Notice of Data Availability in December 2016, soliciting comments on preliminary interstate ozone transport modeling for the 2015 ozone NAAQS. In March 2018, EPA released a memo providing updated projected air quality modeling results for ozone, including projected ozone concentrations in 2023 at potential nonattainment and maintenance sites for the 2015 ozone NAAQS and projected upwind state contribution data. This memo also noted that the "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 previous state and federal regulatory actions, including the CSAPR and CSAPR Update.

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

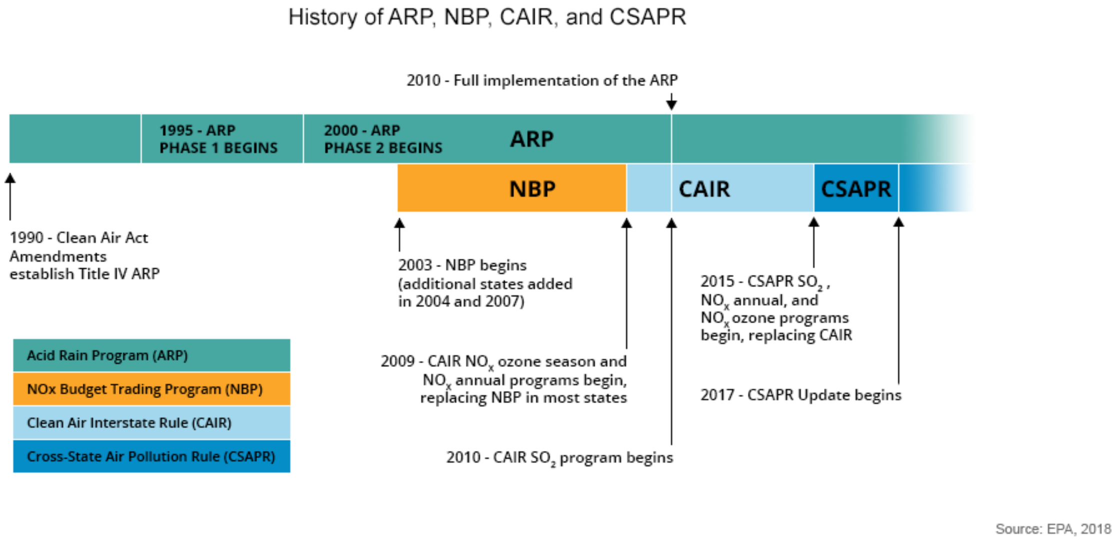
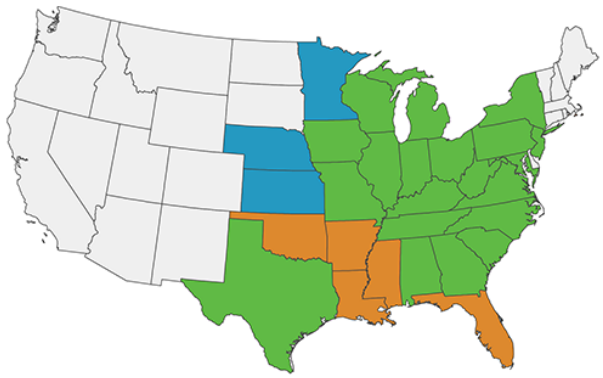


Figure 1. History of ARP, NBP, CAIR, and CSAPR

Map of Cross-State Air Pollution Rule Implementation for 2016



- **CSAPR States controlled for both fine particles** (SO_2 and annual NO_X) **and ozone** (ozone season NO_X) - *20 states*
- **CSAPR States controlled for fine particles only** (SO_2 and annual NO_X) - *3 states*
- **CSAPR States controlled for ozone only** (ozone season NO_X) - *5 states*

The ARP covers sources in the lower 48 states.

Source: EPA, 2018

Figure 2. Map of Cross-State Air Pollution Rule States

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 2016.

Highlights

Acid Rain Program (ARP)

- In 2016, the ARP SO_2 requirements applied to 3,446 fossil fuel-fired combustion units at 1,216 facilities across the country; 710 units at 314 facilities were subject to the ARP NO_x program.

Cross-State Air Pollution Rule (CSAPR)

- In 2016, there were 2,708 affected EGUs at 846 facilities in the CSAPR SO_2 program. Of those, 2,160 (80 percent) were also covered by the ARP.
- In 2016, there were 2,708 affected EGUs at 846 facilities in the CSAPR NO_x annual program and 3,106 affected EGUs at 929 facilities in the CSAPR NO_x ozone season program. Of those, 2,160 (80 percent) and 2,474 (80 percent), respectively, were also covered by the ARP.

Analysis and Background Information

In general, the ARP and the 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 that 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, historically 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

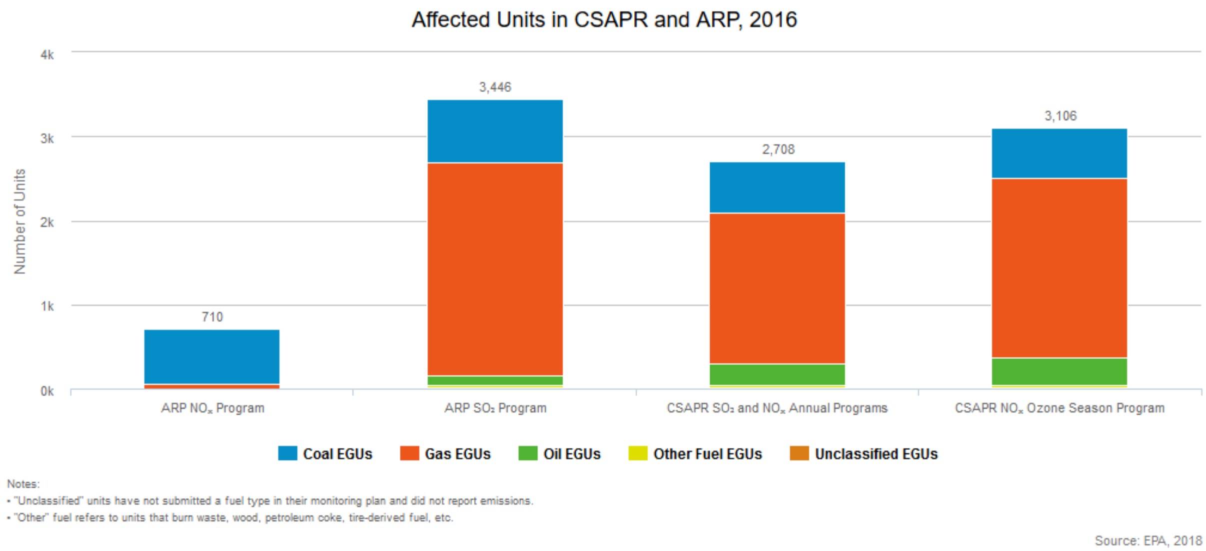


Figure 1. Affected Units in CSAPR and ARP, 2016

Affected Units in CSAPR and ARP, 2016

Fuel	ARP NO_x	ARP SO_2	CSAPR SO_2 and Annual NO_x	CSAPR Ozone Season NO_x
Coal	655	749	612	598
Gas	53	2,537	1,790	2,145
Oil	0	123	261	314
Other	2	28	37	40
Unclassified	0	9	8	9
Total Units	710	3,446	2,708	3,106

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, 2018

Figure 2. Affected Units in CSAPR and ARP, 2016

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 the CSAPR and ARP in 2016.

Sulfur Dioxide (SO_2)

Highlights

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 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 1.5 million tons of SO_2 in 2016, well below the ARP's statutory annual cap of 8.95 million tons. ARP sources reduced emissions by 14.3 million tons (91 percent) from 1990 levels and 15.8 million tons (91 percent) from 1980 levels.
- **CSAPR and ARP:** In 2016, the second year of operation of the CSAPR SO_2 program, sources in both the CSAPR SO_2 annual program and the ARP together reduced SO_2 emissions by 14.2 million tons (91 percent) from 1990 levels (before implementation of the ARP), 9.7 million tons (87 percent) from 2000 levels (ARP Phase II), and 8.8 million tons (85 percent) from 2005 levels (before implementation of CAIR and CSAPR). All ARP and CSAPR sources together emitted a total of 1.5 million tons of SO_2 in 2016.
- **CSAPR:** Annual SO_2 emissions from sources in the CSAPR SO_2 program alone fell from 8.8 million tons in 2005 to 1.2 million tons in 2016, a 87 percent reduction. In 2016, SO_2 emissions were about 2.3 million tons below the regional CSAPR emission budgets (1.8 million in Group 1 and 0.5 million in Group 2); the CSAPR SO_2 annual program's 2016 regional budget are 2,551,802 and 917,787 tons for Group 1 and Group 2, respectively.

SO_2 State-by-State Emissions

- **CSAPR and ARP:** From 1990 to 2016, annual SO_2 emissions from sources in the ARP and the CSAPR SO_2 program dropped in 45 states plus Washington, D.C. by a total of approximately 14.2 million tons. In contrast, annual SO_2 emissions increased in three states (Idaho, Nebraska, and Vermont) by a combined total of 550 tons from 1990 to 2016.

- **CSAPR:** All 23 states (16 states in Group 1 and 7 states in Group 2) had emissions below their CSAPR allowance budgets, collectively by about 2.3 million tons.

SO_2 Emission Rates

- The average SO_2 emission rate for units in the ARP or CSAPR SO_2 program fell to 0.13 lb/mmBtu. This indicates an 81 percent reduction from 2005 rates, with the majority of reductions coming from coal-fired units.
- Although heat input has decreased slightly over the past 11 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 emissions.

Analysis and Background Information

SO_2 is a highly reactive gas that is generated primarily from the burning of fossil fuels at power plants. In addition to contributing to the formation of fine particle pollution ($PM_{2.5}$), SO_2 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 these programs 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

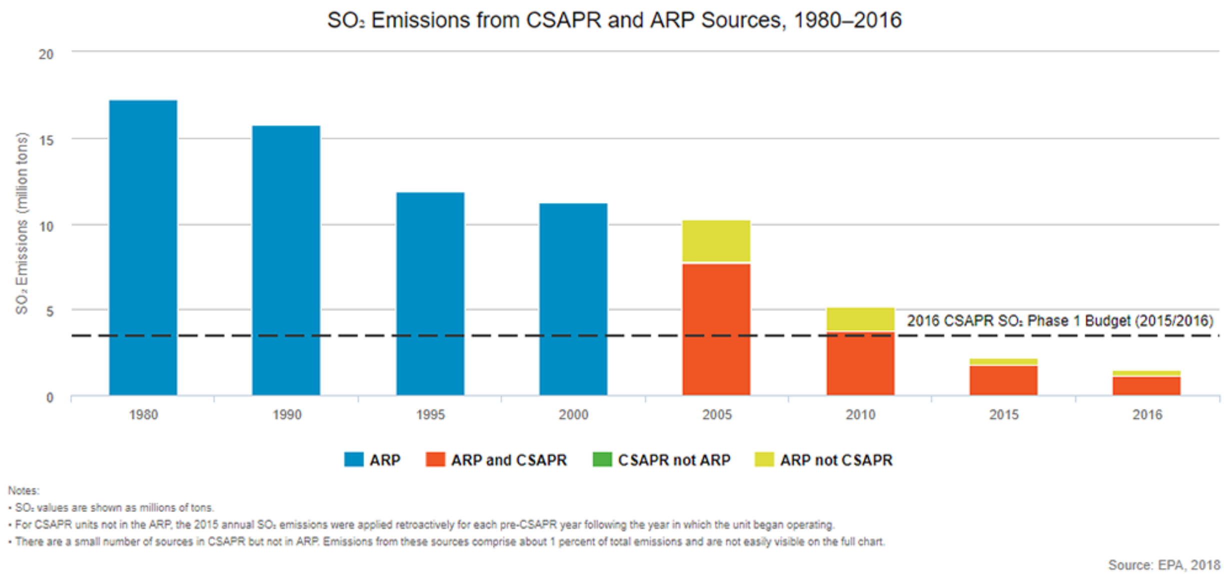


Figure 1. SO_2 Emissions from CSAPR and ARP Sources, 1980–2016

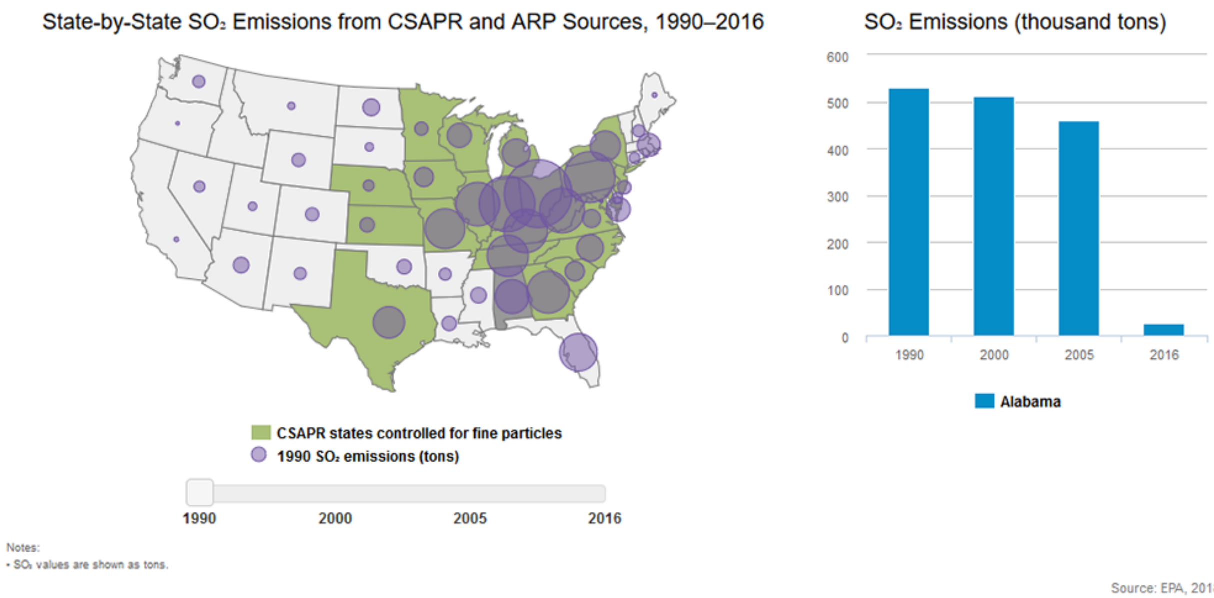


Figure 2. State-by-State SO_2 Emissions from CSAPR and ARP Sources, 1990–2016

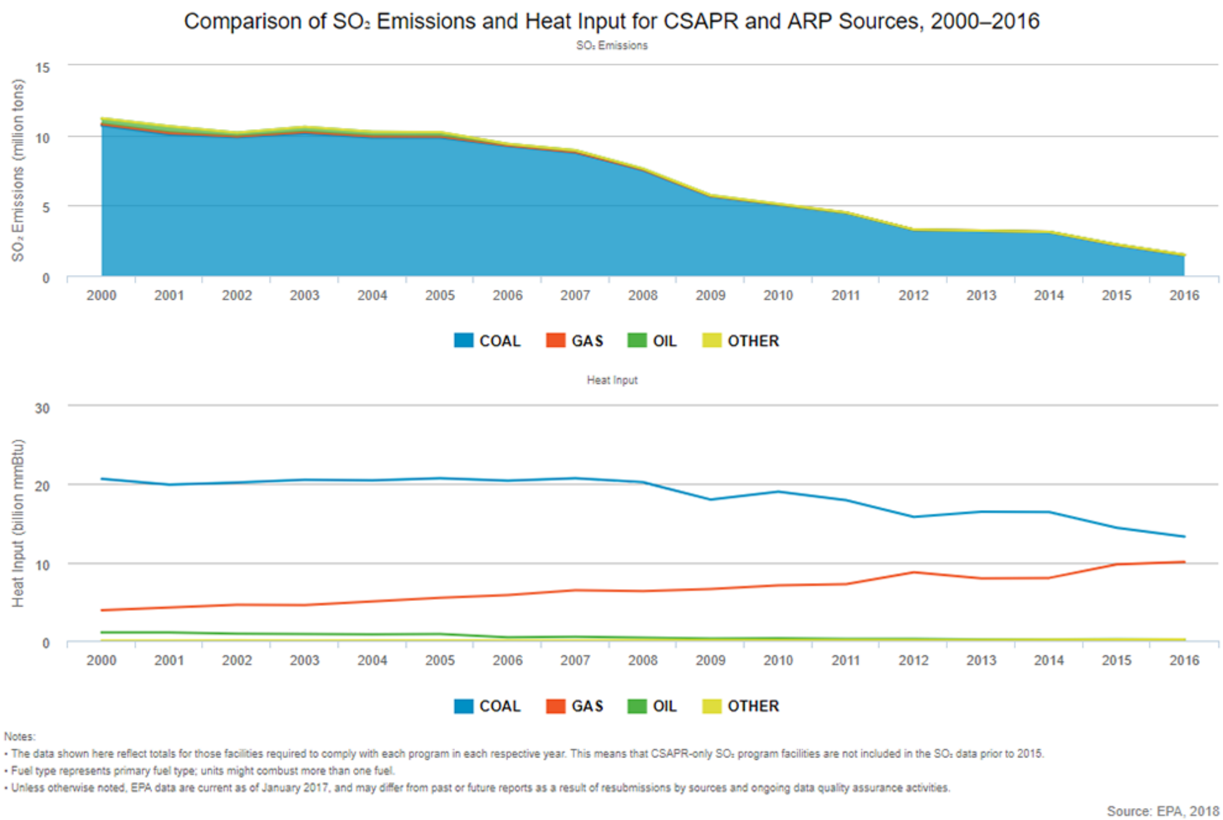


Figure 3. Comparison of SO_2 Emissions and Heat Input for CSAPR and ARP Sources, 2000–2016

CSAPR and ARP SO_2 Emissions Trends, 2016

	SO_2 Emissions (thousand tons)				SO_2 Rate (lb/mmBtu)				Heat Input (billion mmBtu)			
Primary Fuel	**2000**	**2005**	**2010**	**2016**	**2000**	**2005**	**2010**	**2016**	**2000**	**2005**	**2010**	**2016**
Coal	10,708	9,835	5,051	1,466	1.04	0.95	0.53	0.22	20.67	20.77	19.04	13.30
Gas	108	91	19	9	0.06	0.03	0.01	0.00	3.88	5.49	7.06	10.07
Oil	384	292	28	3	0.73	0.70	0.19	0.03	1.05	0.84	0.30	0.16
Other	1	4	22	12	0.20	0.27	0.57	0.17	0.01	0.03	0.08	0.14
Total	**11,201**	**10,222**	**5,120**	**1,490**	**0.88**	**0.75**	**0.39**	**0.11**	**25.61**	**27.13**	**26.48**	**23.67**

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 2018, and may differ from past or future reports as a result of resubmissions by sources and ongoing data quality assurance activities.

Source: EPA, 2018

Figure 4. CSAPR and ARP SO_2 Emissions Trends, 2016

Annual Nitrogen Oxides

Highlights

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 2016.

Annual NO_x Emissions Trends

- **ARP:** Units in the ARP NO_x program emitted 1.2 million tons of NO_x emissions in 2016. Sources reduced emissions by 6.9 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 2016, the second year of operation of the CSAPR NO_x annual program, sources in both the CSAPR NO_x annual program and the ARP together emitted 1.2 million tons, a reduction of 5.2 million tons (81 percent reduction) from 1990 levels, 3.9 million tons (77 percent reduction) from 2000, and 2.5 million tons (67 percent reduction) from 2005 levels.
- **CSAPR:** Emissions from CSAPR NO_x annual program sources alone were about 802,000 tons in 2016. This is about 1.8 million tons (69 percent) lower than in 2005 and 470,000 tons (37 percent) below the CSAPR NO_x annual program's 2016 regional budget of 1,269,837 tons.

Annual NO_x State-by-State Emissions

- **CSAPR and ARP**: From 1990 to 2016, annual NO_x emissions in the ARP and the CSAPR NO_x program dropped in 47 states plus Washington, D.C. by a total of approximately 5.2 million tons. In contrast, annual emissions increased in one state (Idaho) by 200 tons from 1990 to 2016.
- **CSAPR:** Twenty-two states had emissions below their CSAPR 2016 allowance budgets, collectively by about 470,000 tons. A single state (Missouri) exceeded its 2016 budget by about 7,800 tons.

Annual NO_x Emission Rates

- In 2016, the CSAPR and ARP average annual NO_x emission rate was 0.10 lb/mmBtu, a 63 percent reduction from 2005.
- Although heat input has decreased slightly over the past 11 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 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.

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

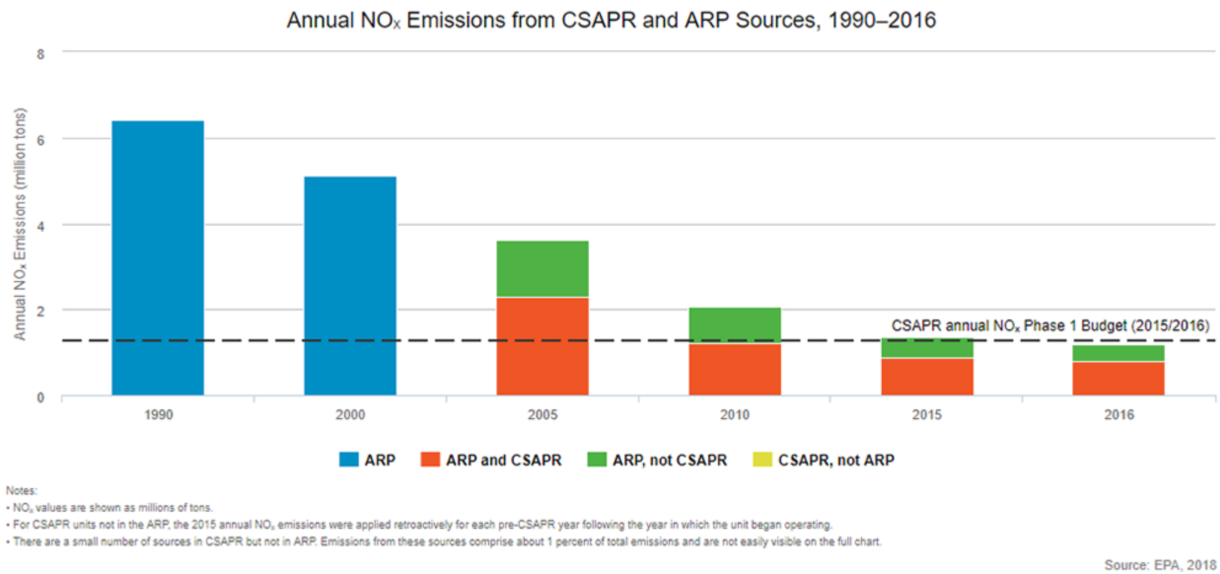


Figure 1. Annual NO_X Emissions from CSAPR and ARP Sources, 1990–2016

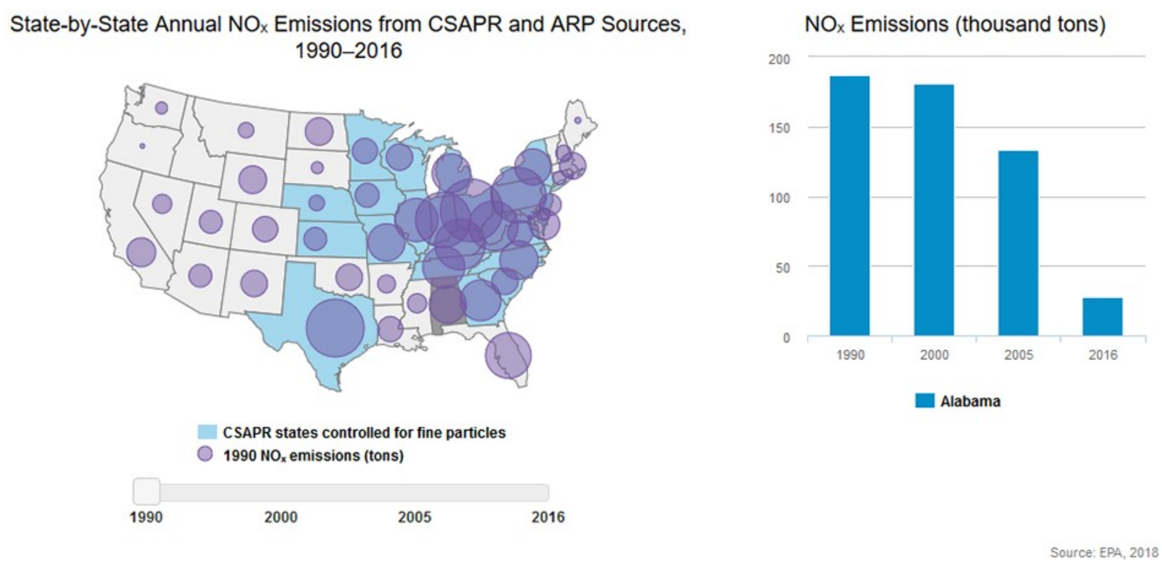
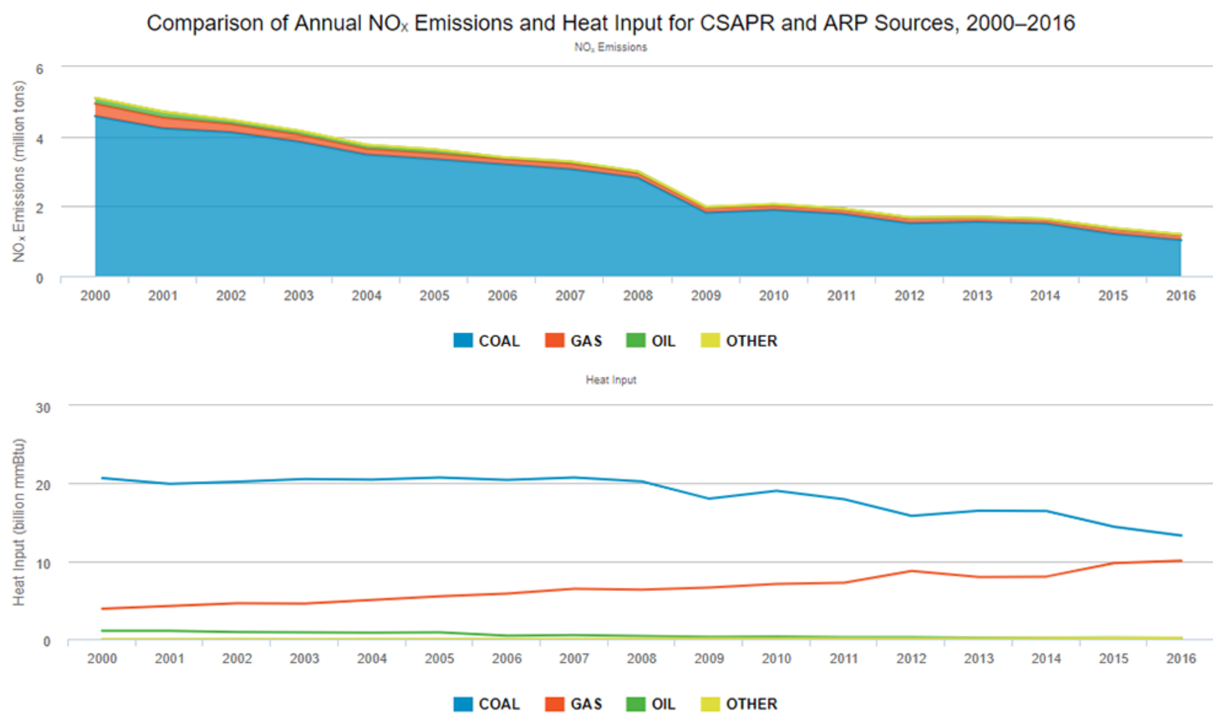


Figure 2. State-by-State Annual NO_X Emissions from CSAPR and ARP Sources, 1990-2016



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, 2018

Figure 3. Comparison of Annual NO_X Emissions and Heat Input for CSAPR and ARP Sources, 2000–2016

CSAPR and ARP Annual NO_x Emissions Trends, 2016

	NO_x Emissions (thousand tons)				NO_x Rate (lb/mmBtu)				Heat Input (billion mmBtu)			
Primary Fuel	**2000**	**2005**	**2010**	**2016**	**2000**	**2005**	**2010**	**2016**	**2000**	**2005**	**2010**	**2016**
Coal	4,587	3,356	1,896	1,029	0.44	0.32	0.20	0.16	20.67	20.77	19.04	13.30
Gas	355	167	143	155	0.18	0.06	0.04	0.03	3.88	5.50	7.06	10.08
Oil	162	104	19	9	0.31	0.25	0.13	0.10	1.05	0.84	0.30	0.16
Other	2	6	5	7	0.24	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**	**0.10**	**25.61**	**27.14**	**26.48**	**23.68**

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 annual 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 2018, and may differ from past or future reports as a result of resubmissions by sources and ongoing data quality assurance activities.

Source: EPA, 2018

Figure 4. CSAPR and ARP Annual NO_X Emissions Trends, 2016

Ozone Season Nitrogen Oxides

Highlights

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 2016.

Ozone Season NO_x Emissions Trends

- Units in the CSAPR NO_x ozone season program emitted 420,000 tons in 2016,
    - a reduction of 1.8 million tons (81 percent) from 1990,
    - 1.4 million tons lower (77 percent reduction) than in 2000 (before implementation of the NBP),
    - 480,000 tons lower (53 percent reduction) than in 2005 (before implementation of CAIR), and
    - 30,000 tons lower (7 percent reduction) than in 2015.
- In 2016, CSAPR NO_x ozone season program emissions were 33 percent below the regional emission budget of 628,392 tons.

Ozone Season NO_x State-by-State Emissions

- Between 2005 and 2016, 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 2016 allowance budgets, collectively by about 210,000 tons. Two states (Louisiana and Missouri) exceeded their 2016 budgets by about 3,900 tons combined.

Ozone Season NO_x Emission Rates

- In 2016, the average NO_x ozone season emission rate fell to 0.09 lb/mmBtu for CSAPR ozone season program states and 0.10 lb/mmBtu nationally. This represents a 50 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 11 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 emissions than coal-fired units.

Analysis and Background Information

Nitrogen oxides 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.

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

In general, the states with the highest emitting sources of ozone season NO_x emissions in 2000 have seen the greatest 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

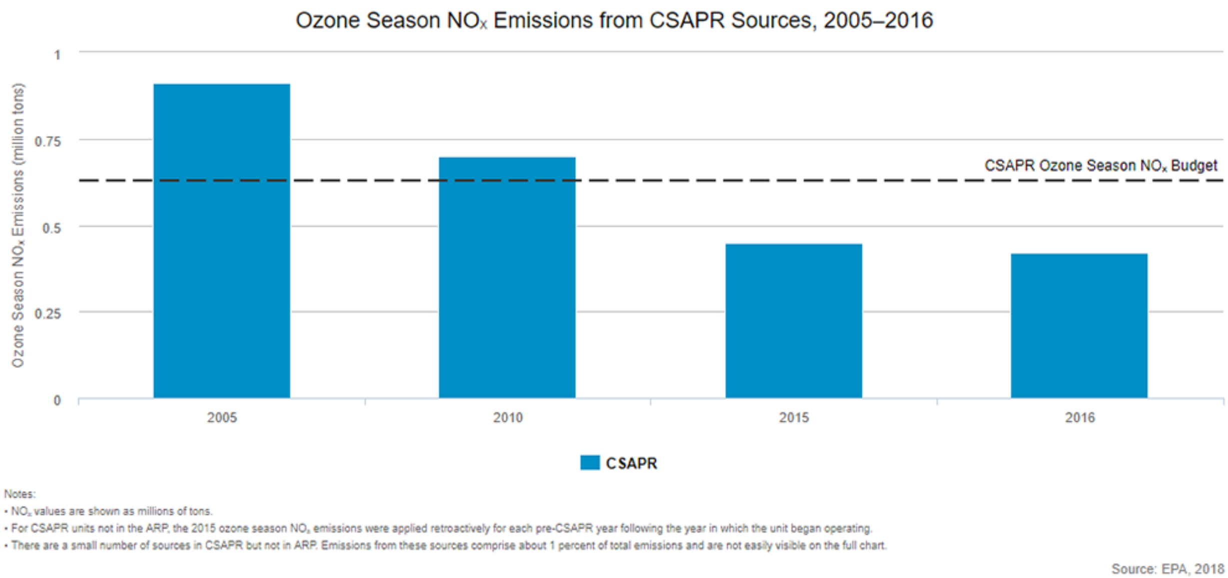
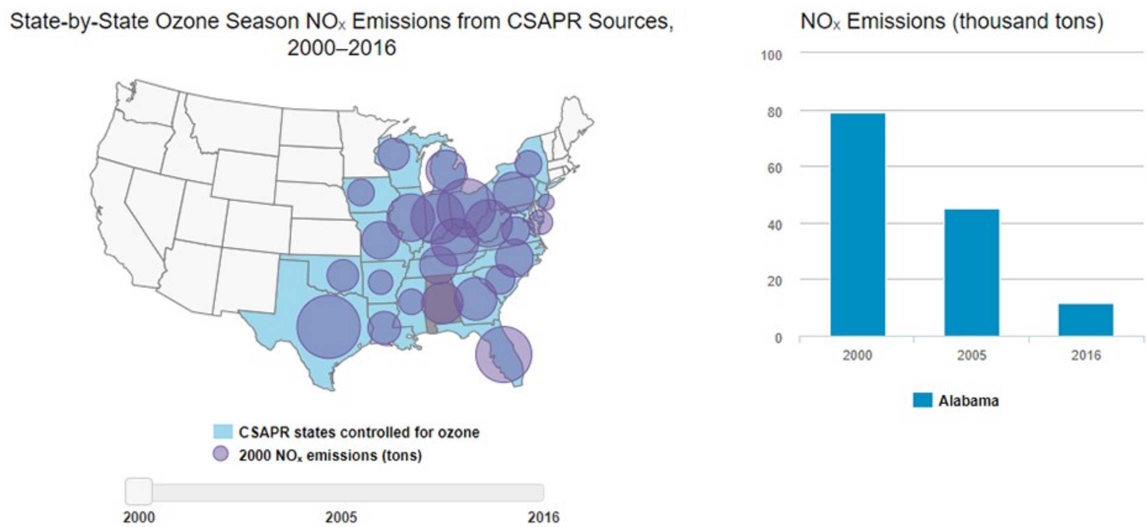


Figure 1. Ozone Season NO_X Emissions from CSAPR Sources, 2005–2016



Notes:
• The 2000 and 2005 ozone season values reflect data that were reported under other programs. For facilities that were not covered by another program and did not report 2000 or 2005 emissions, their reported emissions for 2015 were substituted.

Source: EPA, 2018

Figure 2. State-by-State Ozone Season NO_X Emissions from CSAPR Sources, 2000–2016

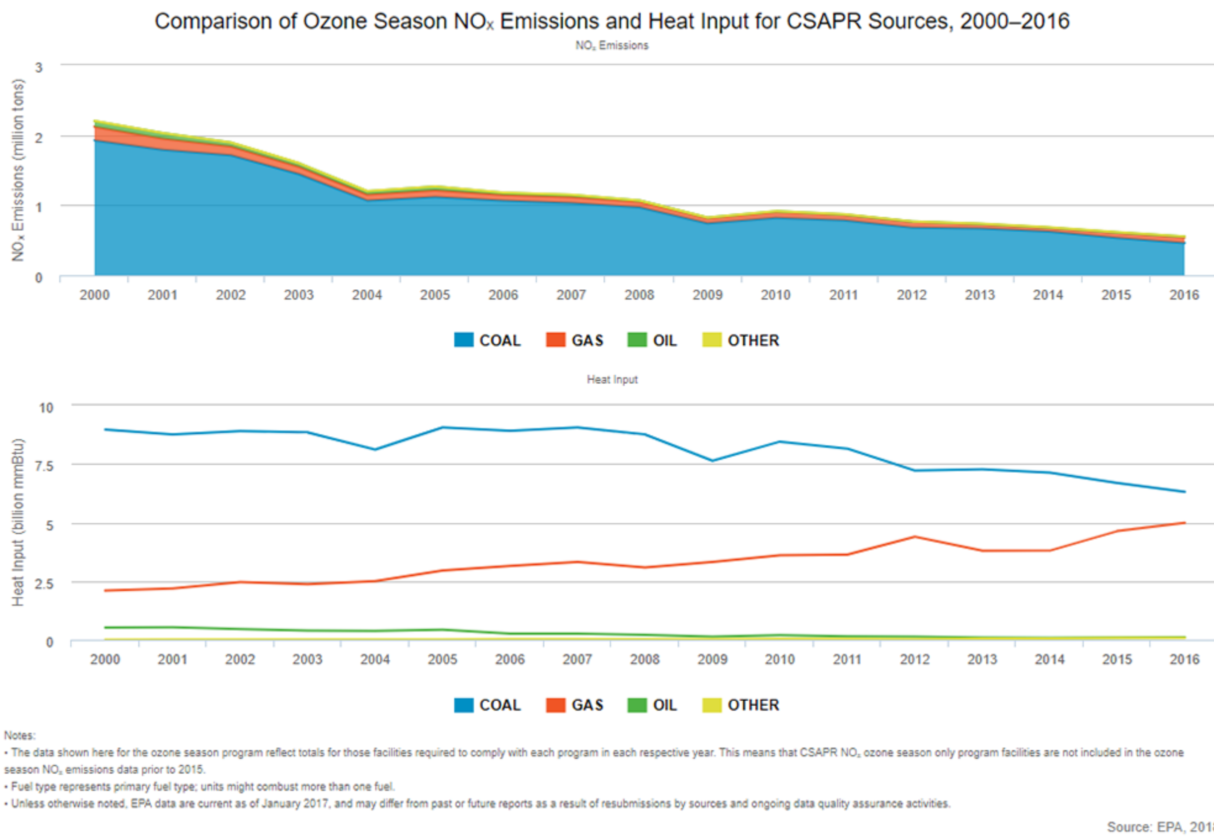


Figure 3. Comparison of Ozone Season NO_X Emissions and Heat Input for CSAPR Sources, 2000–2016

CSAPR Ozone Season NO_X Emissions Trends, 2016

	Ozone Emissions (thousand tons)				Ozone Rate (lb/mmBtu)				Heat Input (billion mmBtu)			
Primary Fuel	**2000**	**2005**	**2010**	**2016**	**2000**	**2005**	**2010**	**2016**	**2000**	**2005**	**2010**	**2016**
Coal	1,926	1,117	821	460	0.43	0.25	0.19	0.15	8.96	9.06	8.45	6.31
Gas	195	95	78	83	0.19	0.06	0.04	0.03	2.10	2.96	3.60	4.99
Oil	79	53	13	5	0.31	0.25	0.13	0.11	0.51	0.43	0.20	0.10
Other	1	2	2	4	0.21	0.39	0.11	0.10	0.01	0.01	0.04	0.08
Total	**2,201**	**1,267**	**915**	**552**	**0.38**	**0.20**	**0.15**	**0.10**	**11.58**	**12.45**	**12.29**	**11.47**

Notes:
- The data shown here 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 2018, and may differ from past or future reports as a result of resubmissions by sources and ongoing data quality assurance activities.

Source: EPA, 2018

Figure 4. CSAPR Ozone Season NO_X Emissions Trends, 2016

Chapter 4: Emission Controls and Monitoring

Allowance trading provisions in cap and trade programs allow sources to choose the most cost-effective strategy to reduce emissions. Many sources opted to install control technologie to meet the Acid Rain Program (ARP) and Cross-State Air Pollution Rule (CSAPR) emission reduction targets. A wide range of controls is available to help reduce emissions. However sources choose to comply, they are held to very high standards of accountability for emissions. Accurate and consistent emissions monitoring data is critical to ensure program results. Most sources are required to use continuous emission monitoring systems (CEMS).

Highlights

ARP and CSAPR SO_2 Program Controls and Monitoring

- Units with advanced flue gas desulfurization (FGD) controls (also known as scrubbers) accounted for 68 percent of coal-fired units and 84 percent of coal-fired generation, measured in megawatt hours, or MWh, in 2016.
- In 2016, 30 percent of CSAPR units (including 100 percent of coal-fired units) monitored SO_2 emissions using CEMS. Ninety-nine percent of SO_2 emissions were measured by CEMS.

CSAPR NO_x Annual Program Controls and Monitoring

- Seventy-two percent of fossil fuel-fired generation (as measured in megawatt hours, or MWh) was produced by units with advanced pollution controls (either selective catalytic reduction [SCR] or selective non-catalytic reduction [SNCR]).
- In 2016, the 325 coal-fired units with advanced add-on controls (either SCRs or SNCRs) generated 72 percent of coal-fired generation. At oil- and natural gas-fired units, SCR- and SNCR- controlled units produced 72 percent of generation.
- In 2016, 72 percent of CSAPR units (including 100 percent of coal-fired units) monitored NO_X emissions using CEMS. Ninety-nine percent of NO_X emissions were measured by CEMS.

CSAPR NO_x Ozone Season Program Controls and Monitoring

- Seventy percent of all the fossil fuel-fired generation (as measured in megawatt hours, or MWh) was produced by units with advanced pollution controls (either SCRs or SNCRs).
- In 2016, units with advanced add-on controls (either SCR or SNCR) accounted for 68 percent of coal-fired generation. At oil- and natural gas-fired units, SCR- and SNCR- controlled units produced 69 percent of generation.
- In 2016, 73 percent of CSAPR units (including 100 percent of coal-fired units) monitored ozone season NO_X emissions using CEMS. Ninety-eight 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 are allowed to use other approved monitoring methods, the vast majority of SO_2 and NO_X emissions are 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, employing various types of FGDs, or utilizing fluidized bed limestone units. 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 post-combustion controls such as SCR or SNCR, and combustion controls, such as low NO_X burners.

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

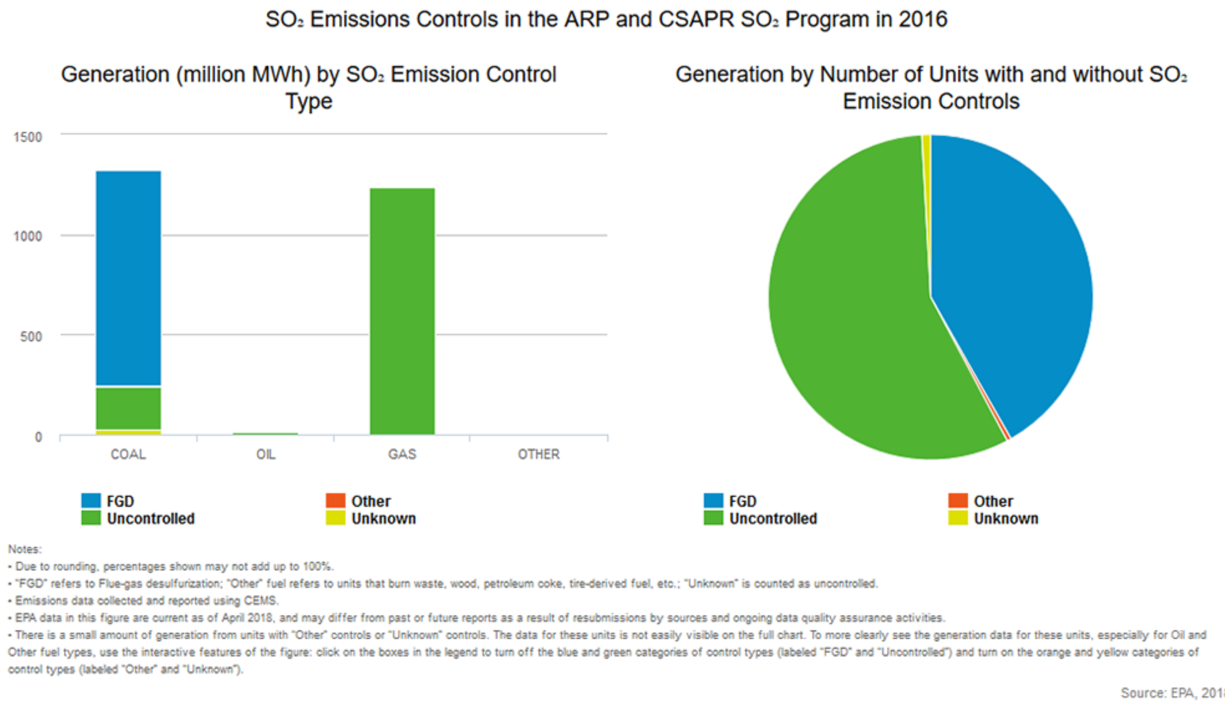


Figure 1. SO_2 Emission Controls in the ARP and CSAPR SO_2 Program in 2016

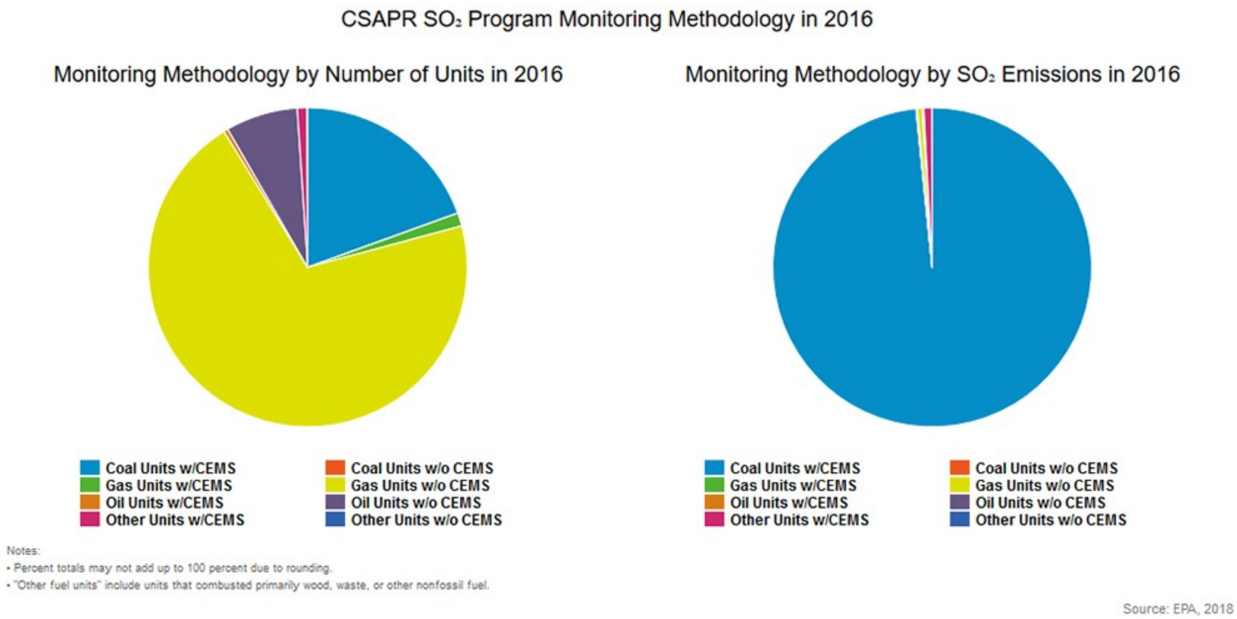
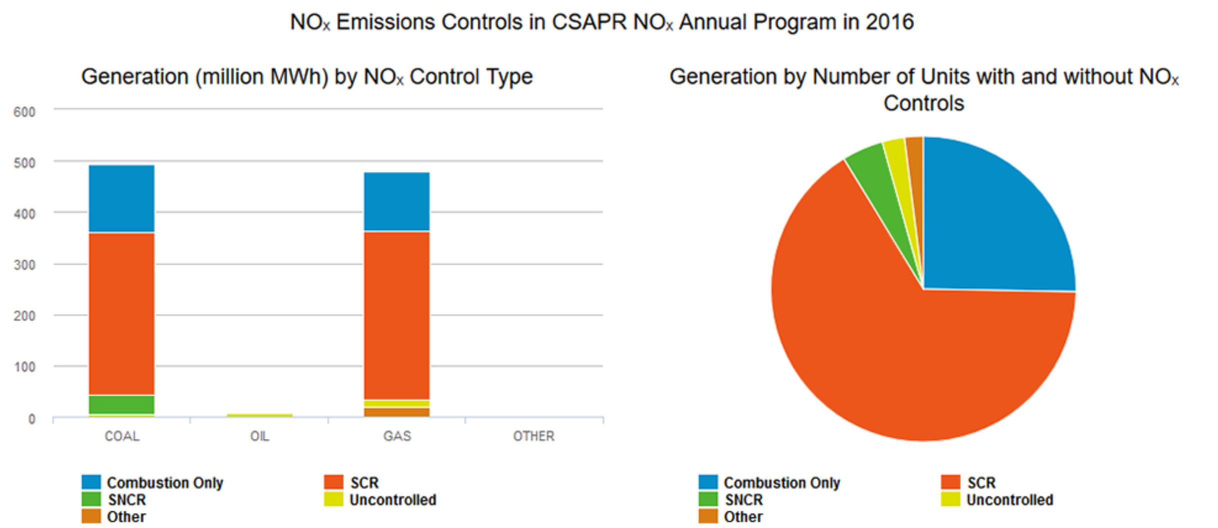


Figure 2. CSAPR SO_2 Program Monitoring Methodology in 2016



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 April 2018, 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, 2018

Figure 3. NO_X Emissions Controls in CSAPR NO_X Annual Program in 2016

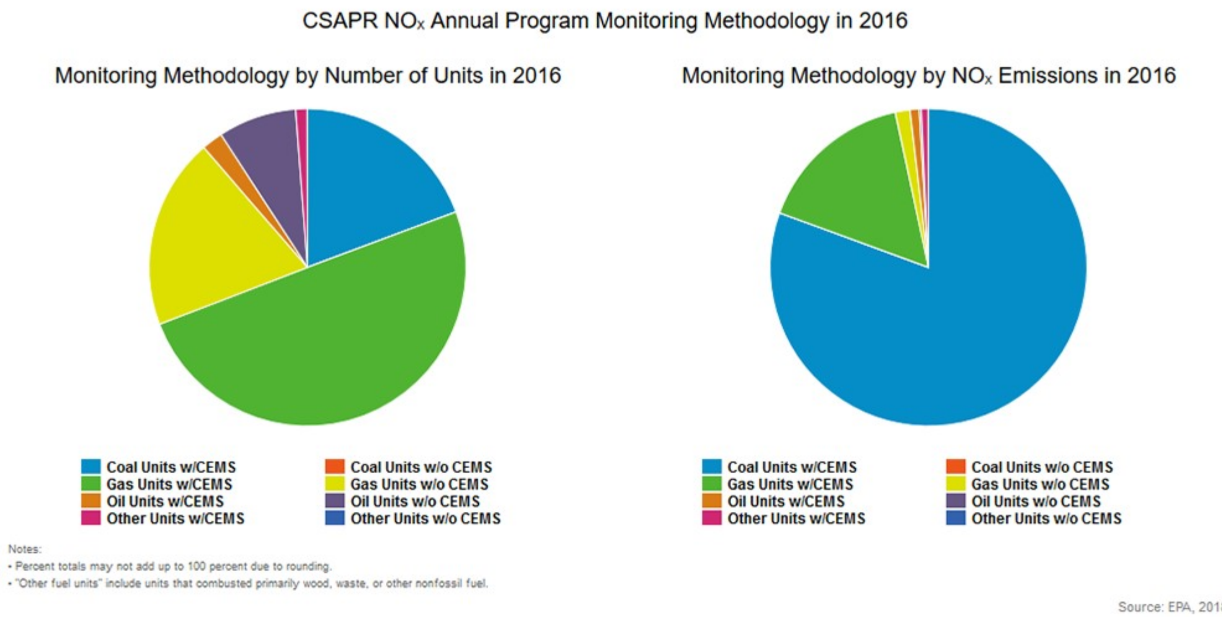
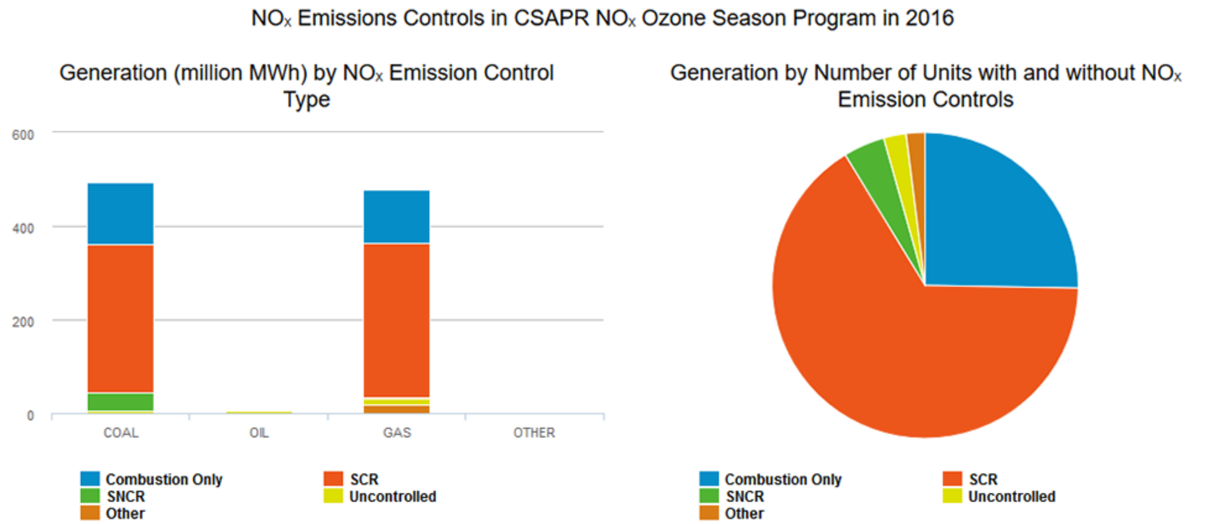


Figure 4. CSAPR NO_X Annual Program Monitoring Methodology in 2016



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 April 2018, 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, 2018

Figure 5. NO_X Emissions Controls in CSAPR NO_X Ozone Season Program in 2016

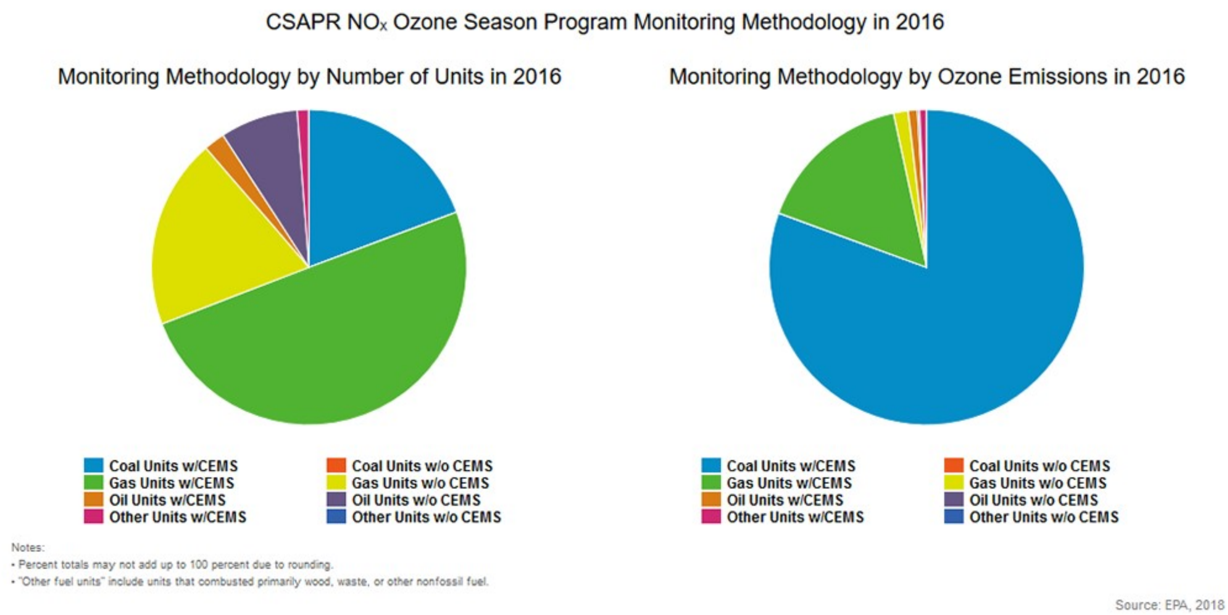


Figure 6. CSAPR NO_X Ozone Season Program Monitoring Methodology in 2016

Chapter 5: Program Compliance

This analysis shows how the Acid Rain Program (ARP) and Cross-State Air Pollution Rule (CSAPR) allowances are used for compliance under the trading programs in 2016.

Highlights

ARP SO_2 Programs

- The reported 2016 SO_2 emissions by ARP sources totaled 1,469,779 tons.
- Almost 42 million SO_2 allowances were available for compliance (9 million vintage 2016 and nearly 33 million banked from prior years).
- EPA deducted just under 1.5 million allowances for ARP compliance. After reconciliation, over 40.2 million ARP SO_2 allowances were banked and carried forward to the 2017 ARP compliance year.
- All ARP SO_2 facilities were in compliance in 2016 (holding sufficient allowances to cover their SO_2 emissions).

CSAPR SO_2 Group 1 Program

- The reported 2016 SO_2 emissions by CSAPR Group 1 sources totaled 785,248 tons.
- Over 3.7 million SO_2 Group 1 allowances were available for compliance.
- EPA deducted just over 785,000 million allowances for CSAPR SO_2 Group 1 compliance. After reconciliation, over 2.9 million CSAPR SO_2 Group 1 allowances were banked and carried forward to the 2017 compliance year.
- All CSAPR SO_2 Group 1 facilities were in compliance in 2016 (holding sufficient allowances to cover their SO_2 emissions).

CSAPR SO_2 Group 2 Program

- The reported 2016 SO_2 emissions by CSAPR Group 2 sources totaled 371,723 tons.
- Over 1.3 million SO_2 Group 2 allowances were available for compliance.
- EPA deducted just over 371,000 allowances for CSAPR SO_2 Group 2 compliance. After reconciliation, over 961,000 CSAPR SO_2 Group 2 allowances were banked and carried forward to the 2017 compliance year.
- All CSAPR SO_2 Group 2 facilities were in compliance in 2016 (holding sufficient allowances to cover their SO_2 emissions).

CSAPR NO_X Annual Program

- The reported 2016 annual NO_X emissions by CSAPR sources totaled 801,872 tons.
- Just over 1.6 million NO_X Annual allowances were available for compliance.

- EPA deducted just over 801,000 allowances for CSAPR NO_X Annual compliance. After reconciliation, over 802,000 CSAPR NO_X Annual allowances were banked and carried forward to the 2017 compliance year.
- All CSAPR NO_X Annual facilities were in compliance with the CSAPR NO_X Annual program (holding sufficient allowances to cover their NO_X emissions).

CSAPR NO_X Ozone Season Program

- The reported 2016 ozone season NO_X emissions by CSAPR sources totaled 422,361 tons.
- Just over 777,000 NO_X ozone season allowances were available for compliance.
- EPA deducted just over 422,000 allowances for CSAPR NO_X Ozone Season compliance. After reconciliation, almost 354,000 CSAPR NO_X Ozone Season allowances were banked. These banked allowances were converted to CSAPR NO_X ozone season group 1 and group 2 allowances under the CSAPR Update Rule. Banked allowances held in Georgia facility accounts were converted at 1 for 1 to CSAPR NO_X ozone season group 1 allowances. All other banked allowances were converted at a ratio of 3.278 to 1 to vintage 2017 CSAPR NO_X ozone season group 2 allowances. The conversion resulted in 100,134 year 2017 CSAPR NO_X ozone season group 2 allowances, and 18,513 CSAPR NO_X ozone season group 1 allowances.
- Two facilities were out of compliance with the CSAPR NO_X Ozone Season program and had 17 total tons of excess emissions.

Analysis and Background Information

The year 2016 was the second 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 "Highlights" may differ slightly from 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 slightly 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, 2016

Total Allowances Held (1995 - 2016 Vintage)	**41,723,807**	Held by Affected Facility Accounts	**26,526,882**
		Held by Other Accounts (General and Non-Affected Facility Accounts)	**15,196,925**
Allowances Deducted for Acid Rain Compliance*	1,477,512		
Penalty Allowance Deductions	0		
Banked Allowances	**40,246,295**	Held by Affected Facility Accounts	**25,049,370**
		Held by Other Accounts (General and Non-Affected Facility Accounts)	**15,196,925**

* Allowances deducted for ARP Compliance Includes 649 allowances deducted from opt-ins for reduced utilization.

ARP SO_2 Program Compliance Results

Reported Emissions (tons)	**1,469,779**
Compliance issues, rounding, and report resubmission adjustments (tons)	**7,084**
Emissions not covered by allowances (tons)	**0**
Total allowances deducted for emissions	**1,476,863**

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 July 2017 and subsequent allowance deduction adjustments and penalties are not reflected.

Source: EPA, 2018

Figure 1. ARP SO_2 Program Allowance Reconciliation Summary, 2016

Cross-State Air Pollution Rule SO_2 Group 1 Program Allowance Reconciliation Summary, 2016

Total Allowances Held (2015 - 2016 Vintage)	**3,709,960**	Held by Affected Facility Accounts	**3,286,939**
		Held by Other Accounts (General, State Holding and Non-Affected Facility Accounts)	**423,021**
Allowances Deducted for Cross-State Air Pollution Rule SO_2 Group 1 Program	785,247		
Penalty Allowance Deductions	0		
Banked Allowances	**2,924,713**	Held by Affected Facility Accounts	**2,501,692**
		Held by Other Accounts (General, State Holding and Non-Affected Facility Accounts)	**423,021**

CSAPR SO_2 Group 1 Program Compliance Results

Reported Emissions (tons)	**785,248**
Compliance issues, rounding, and report resubmission adjustments (tons)	**-1**
Emissions not covered by allowances (tons)	**0**
Total allowances deducted for emissions	**785,247**

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 July 2017 and subsequent allowance deduction adjustments and penalties are not reflected.

Source: EPA, 2018

Figure 2. CSAPR SO_2 Group 1 Program Allowance Reconciliation Summary, 2016

Cross-State Air Pollution Rule SO_2 Group 2 Program Allowance Reconciliation Summary, 2016

Total Allowances Held (2015 - 2016 Vintage)	**1,332,789**	Held by Affected Facility Accounts	**1,174,231**
		Held by Other Accounts (General, State Holding and Non-Affected Facility Accounts)	**158,558**
Allowances Deducted for Cross-State Air Pollution Rule SO_2 Group 2 Program	371,565		
Penalty Allowance Deductions	0		
Banked Allowances	**961,224**	Held by Affected Facility Accounts	**802,666**
		Held by Other Accounts (General, State Holding and Non-Affected Facility Accounts)	**158,558**

CSAPR SO_2 Group 2 Program Compliance Results

Reported Emissions (tons)	**371,723**
Compliance issues, rounding, and report resubmission adjustments (tons)	**-158**
Emissions not covered by allowances (tons)	**0**
Total allowances deducted for emissions	**371,565**

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 July 2017 and subsequent allowance deduction adjustments and penalties are not reflected.

Source: EPA, 2018

Figure 3. CSAPR SO_2 Group 2 Program Allowance Reconciliation Summary, 2016

Cross-State Air Pollution Rule NO_X Annual Program Allowance Reconciliation Summary, 2016

Total Allowances Held (2015 - 2016 Vintage)	**1,603,562**	Held by Affected Facility Accounts	**1,404,344**
		Held by Other Accounts (General, State Holding and Non-Affected Facility Accounts)	**199,218**
Allowances Deducted for Cross-State Air Pollution Rule NO_X Annual Program	800,945		
Penalty Allowance Deductions	0		
Banked Allowances	**802,617**	Held by Affected Facility Accounts	**603,399**
		Held by Other Accounts (General, State Holding and Non-Affected Facility Accounts)	**199,218**

CSAPR NO_X Annual Program Compliance Results

Reported Emissions (tons)	**801,872**
Compliance issues, rounding, and report resubmission adjustments (tons)	**-927**
Emissions not covered by allowances (tons)	**0**
Total allowances deducted for emissions	**800,945**

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 July 2017 and subsequent allowance deduction adjustments and penalties are not reflected.

Source: EPA, 2018

Figure 4. CSAPR NO_X Annual Program Allowance Reconciliation Summary, 2016

Cross-State Air Pollution Rule NO_X Ozone Season Program Allowance Reconciliation Summary, 2016

Total Allowances Held (2015 - 2016 Vintage)	**776,979**	Held by Affected Facility Accounts	**713,087**
		Held by Other Accounts (General, State Holding and Non-Affected Facility Accounts)	**63,892**
Allowances Deducted for Cross-State Air Pollution Rule NO_x Ozone Season Program	422,573		
Penalty Allowance Deductions	34		
Banked Allowances	**354,372**	Held by Affected Facility Accounts	**290,480**
		Held by Other Accounts (General, State Holding and Non-Affected Facility Accounts)	**63,892**

CSAPR NO_x Ozone Season Program Compliance Results

Reported Emissions (tons)	**422,361**
Compliance issues, rounding, and report resubmission adjustments (tons)	**195**
Emissions not covered by allowances (tons)	**17**
Total allowances deducted for emissions	**422,573**

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 July 2017 and subsequent allowance deduction adjustments and penalties are not reflected.

Source: EPA, 2018

Figure 5. CSAPR NO_X Ozone Season Program Allowance Reconciliation Summary, 2016

Chapter 6: Market Activity

Cap and trade programs allow participants to independently determine their best compliance strategy. 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.

Highlights

Transaction Types and Volumes

- In 2016, more than 1,000,000 allowances were traded across all four of the CSAPR trading programs. Just under one-third of the transactions within the CSAPR programs were between distinct organizations.
- In 2016, over 2 million ARP allowances were traded, the majority (82 percent) between related organizations.

2016 Allowance Prices[2]

- ARP SO_2 allowance prices averaged less than $1 per ton in 2016.
- CSAPR SO_2 Group 1 allowance prices started 2016 at $2.75 per ton and ended 2016 at $5.25 per ton.
- CSAPR SO_2 Group 2 allowance prices started 2016 at $5 per ton and ended 2016 at $5.25 per ton.
- CSAPR NO_X annual program allowances started 2016 at $80 per ton and ended 2016 at $6 per ton.
- CSAPR NO_X ozone season program allowances started 2016 at $182.5 per ton and ended 2016 at $142.5 per ton.[2]

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[2] Allowance prices as reported by SNL Finance, 2017.

[2] These prices reflect CSAPR ozone season NO_X allowances. In October 2016, EPA published an update to the CSAPR ozone season allowance trading programs. On October 23rd, 2017, CSAPR most ozone season NO_X allowances were converted to CSAPR Update ozone season NO_X allowances.

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).

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.

Allowance Markets

The 2016 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

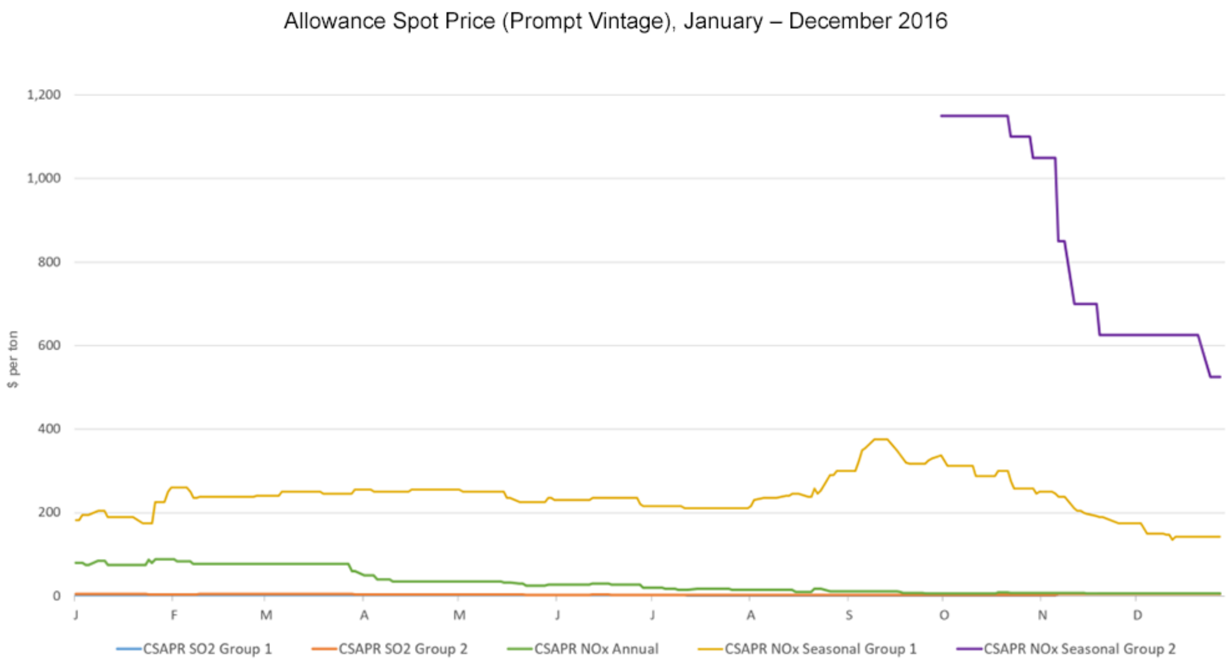
2016 Allowance Transfers under CSAPR and ARP

	Transactions Conducted	Allowances Transferred	Share of Program's Allowances Transferred	
			Related (%)	Distinct (%)
ARP SO_2	880	2,797,308	82%	18%
CSAPR SO_2 Group 1	433	387,886	66%	34%
CSAPR SO_2 Group 2	208	189,845	83%	17%
CSAPR NO_X Annual	893	321,699	74%	26%
CSAPR NO_X Ozone Season	1,093	177,488	65%	35%

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, 2018

Figure 1. 2016 Allowance Transfers under CSAPR and ARP



Notes:

- Prompt vintage is the vintage for the "current" compliance year.
- CSAPR NO_x Seasonal Group 2 allowance prices reflect the CSAPR Update Rule, which was published in October 2016 and created two geographically distinct trading groups, the other being CSAPR NO_x Seasonal Group 1.

Source: SNL Financial, 2018

Figure 2. Allowance Spot Price (Prompt Vintage), January–December 2016

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

Highlights

National SO_2 Air Quality

- Based on EPA's air trends data, the national average of SO_2 annual mean ambient concentrations decreased from 12.0 parts per billion (ppb) to 1.1 ppb (91 percent) between 1980 and 2016.
- 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 87 percent from the 1989–1991 to the 2014–2016 observation periods.
- Ambient particulate sulfate concentrations have decreased since the ARP was implemented, with average concentrations decreasing by 71 to 75 percent in observed regions from 1989–1991 to 2014–2016.
- Average annual ambient total nitrate concentrations declined 51 percent from 1989–1991 to 2014–2016 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 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

Nitrogen oxides are 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 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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1. Katsouyanni, K., Schwartz, J., Spix, C., Touloumi, G., Zmirou, D., Zanobetti, A., Wojtyniak, B., Vonk, J.M., Tobias, A., Pönkä, A., Medina, S., Bachárová, L., & Anderson, H.R. (1996). Short term effects of air pollution on health: a European approach using epidemiologic time series data: the APHEA protocol. *J. of Epidemiol Community Health,* 50: S12–S18.

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

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

Figures

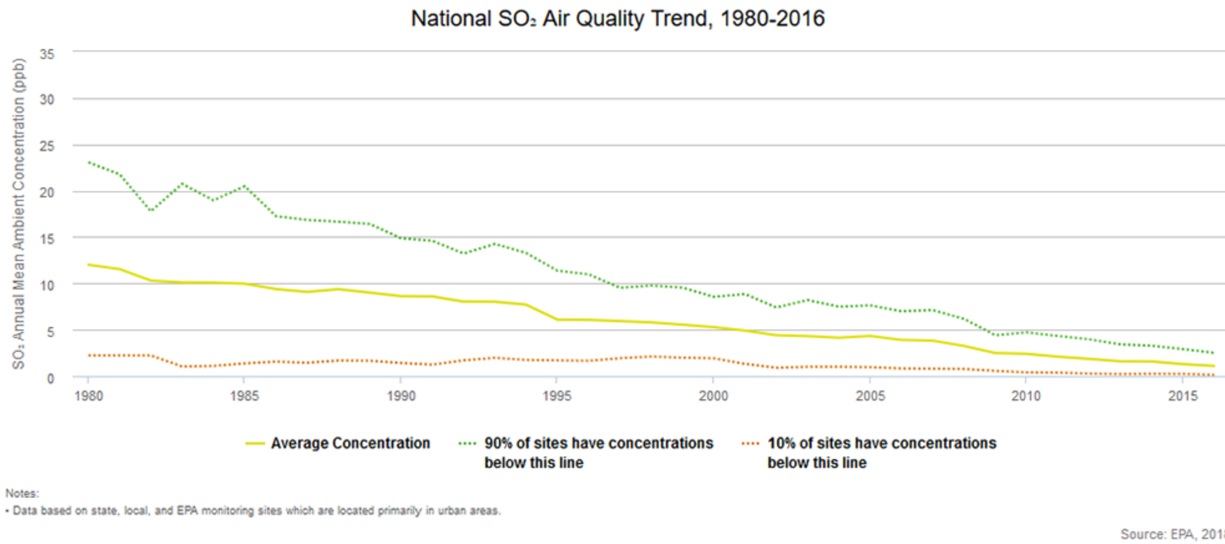

Figure 1. National SO_2 Air Quality Trend, 1980–2016

Regional Changes in Air Quality

Measurement	Region	Annual Average, 1989-1991	Annual Average, 2014-2016	Percent Change	Number of Sites	Statistical Significance
Ambient particulate sulfate concentration (µg/m³)	Mid-Atlantic	6.3	1.6	-75	12	***
	Midwest	5.8	1.7	-71	9	***
	Northeast	3.4	0.9	-74	4	
	Southeast	5.5	1.5	-73	8	***
Ambient sulfur dioxide concentration (µg/m³)	Mid-Atlantic	13.0	2.0	-85	12	***
	Midwest	11.0	1.5	-86	9	***
	Northeast	5.2	0.7	-87	4	
	Southeast	5.1	0.6	-88	8	***
Ambient total nitrate concentration (µg/m³)	Mid-Atlantic	3.3	1.5	-55	12	***
	Midwest	4.6	2.4	-48	9	***
	Northeast	1.7	0.7	-59	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, 2018

Figure 2. Regional Changes in Air Quality

Ozone

Highlights

Changes in 1-Hour Ozone during Ozone Season

- There was an overall regional reduction in ozone levels between 2000–2002 and 2014–2016, with a 25 percent reduction in the highest (99^{th} 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 2014 to 2016, rural ozone concentrations averaged 66 ppb in CSAPR states, a decrease of 24 ppb (26 percent) from the 1990 to 2002 period.
- The Autoregressive Integrated Moving Average (ARIMA) model shows how the reductions in rural ozone concentrations compare with 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).
- Four of the five lowest observed ozone concentrations were between 2013 and 2016. 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 2014–2016 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 2014–2016 was about 11 ppb (20 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 2014 to 2016, 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 2014-2016, 77 percent (17 areas) of the eastern ozone nonattainment areas now show concentrations below the level of the 2008 standard.

While five areas continue to show concentrations above the 2008 standard, three of those areas made progress toward meeting the standard in the 2014-2016 period. Given that power sector emissions are an important component of the NO_X emission inventory and that the majority of programs that reduce power sector ozone season NO_X emissions 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 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 2015. EPA revoked the 1-hour ozone standard in 2005 and also recently revoked the 1997 8-hour ozone standard in 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.

The Autoregressive Integrated Moving Average (ARIMA) model is an advanced statistical analysis tool used to visualize the trend in regional ozone concentrations following implementation of various programs geared toward reducing ozone season NO_X emissions. To show the shift in the highest daily ozone levels, EPA modeled the average of the 99th percentile of the daily maximum 8-hour ozone concentrations measured at CASTNET sites (as described above).

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. CASTNET retrieved daily maximum 8-hour ozone concentration data from EPA and daily meteorology data from the National Weather Service for 79 urban areas and 37 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 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 ozone season NO_X emission reductions are needed to attain that standard as well as the strengthened ozone standard that was finalized in 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 eastern US.

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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2. 40 CFR Part 81. Designation of Areas for Air Quality Planning Purposes.
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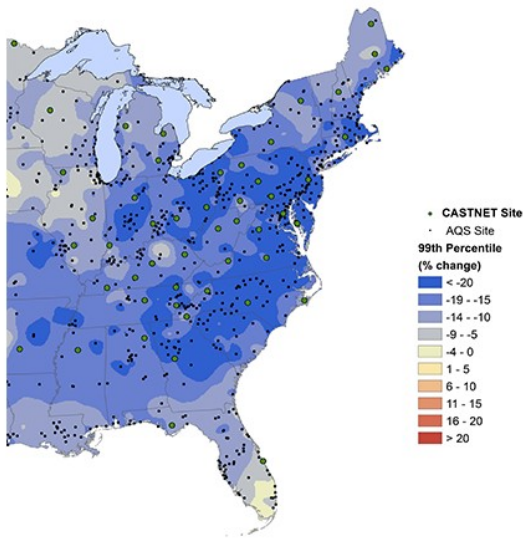
Figures

Percent Change in the Highest Values (99th percentile) of 1-hour Ozone Concentrations during the Ozone Season, 2000–2002 versus 2014-2016

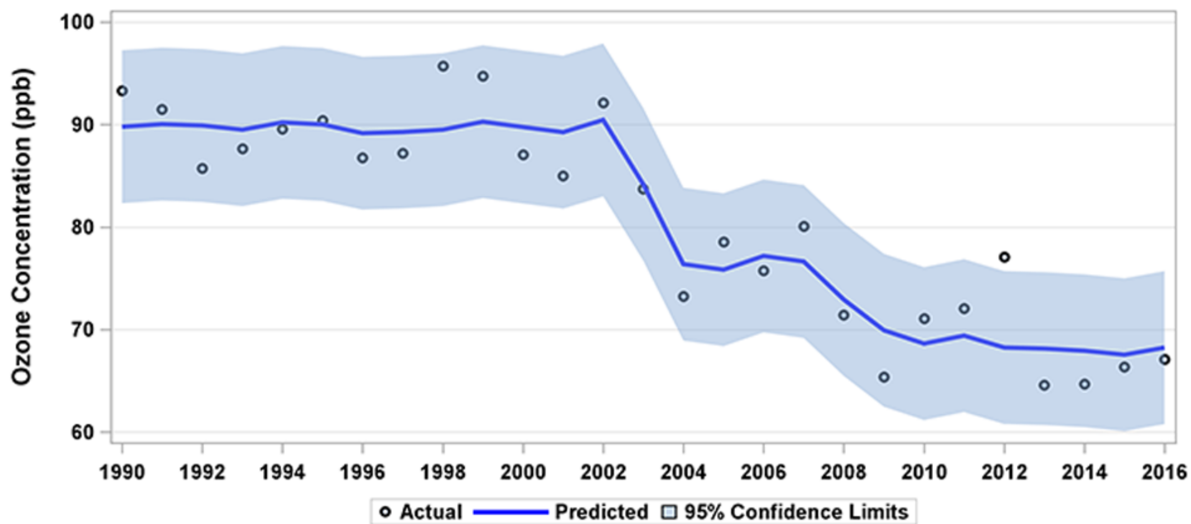


Notes:
• Data are from State and Local Air Monitoring Stations (SLAMS) AQS and CASTNET monitoring sites with two or more years of data within each three-year monitoring period.
• The 99th percentile represents the highest 1% of hourly ozone measurements at a given monitor.

Source: EPA, 2018

Figure 1. Percent Change in the Highest Values (99th percentile) of 1-hour Ozone Concentrations during the Ozone Season, 2000–2002 versus 2014-2016

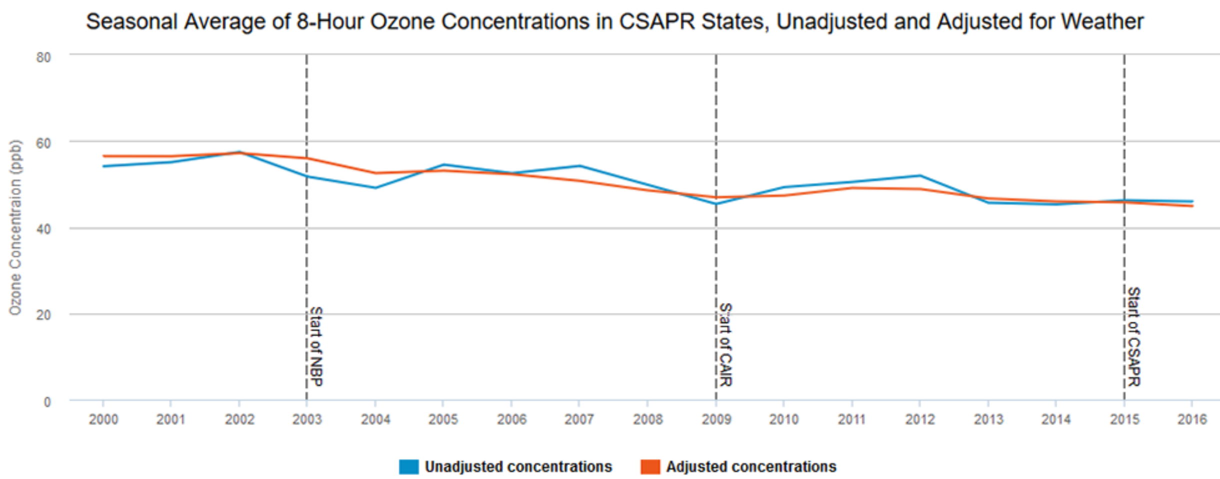
Shifts in 8-Hour Seasonal Rural Ozone Concentrations in the CSAPR NO_x Ozone Season Region, 1990–2016



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, 2018

Figure 2. Shifts in 8-hour Seasonal Rural Ozone Concentrations in CSAPR NO_X Ozone Season Region, 1990–2016



Notes:

- 8-Hour daily maximum ozone concentration data from EPA's AQS and daily meteorology data from the National Weather Service were retrieved for 79 urban areas and 37 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, 2018

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

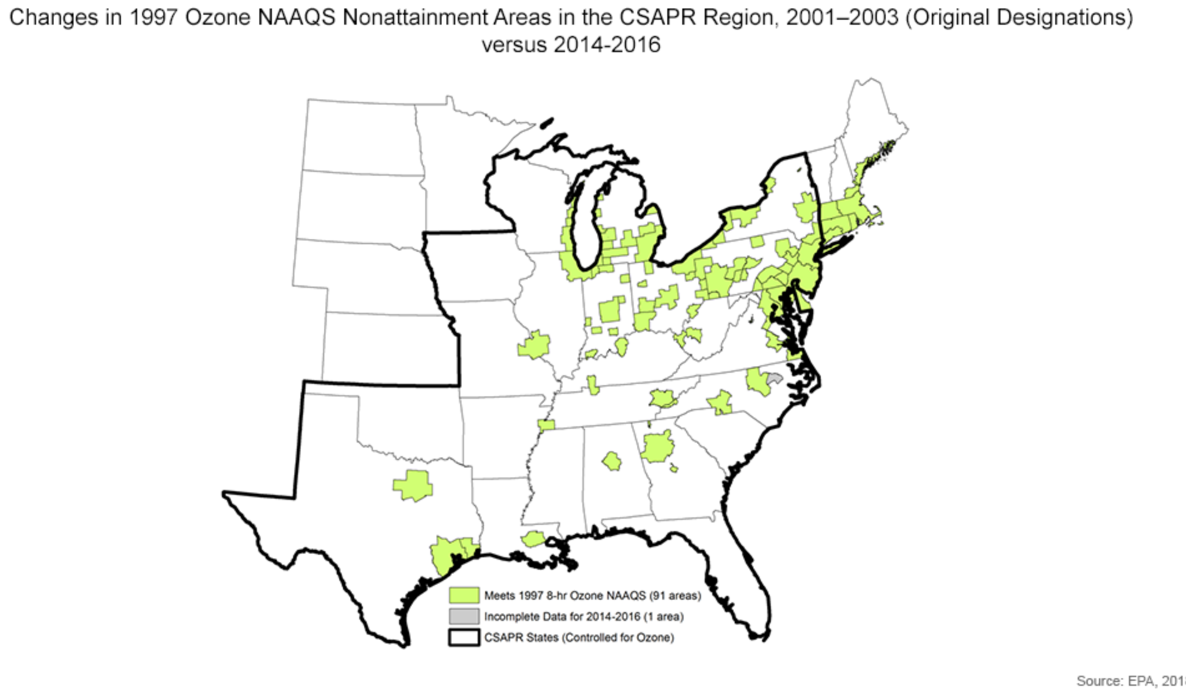


Figure 4. Changes in 1997 Ozone NAAQS Nonattainment Areas in CSAPR Region, 2001–2003 (Original Designations) versus 2014-2016

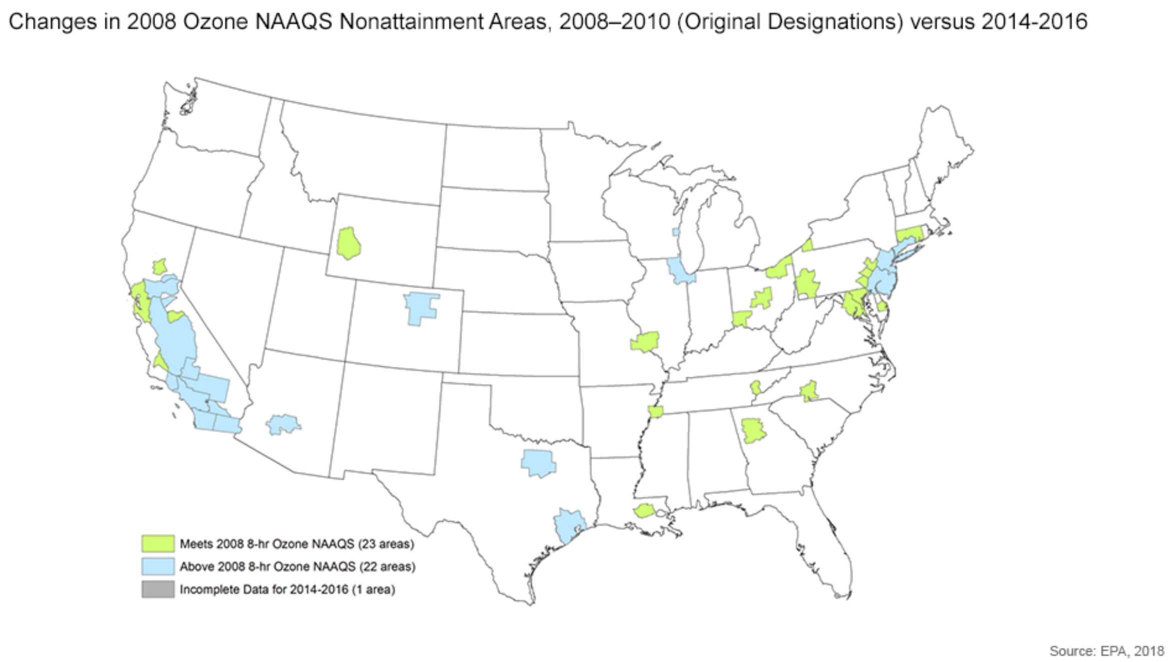


Figure 5. Changes in 2008 Ozone NAAQS Nonattainment Areas, 2008–2010 (Original Designations) versus 2014-2016

Particulate Matter

Highlights

PM Seasonal Trends

- The Air Quality System (AQS) includes average $PM_{2.5}$ concentration data for 249 sites located in the CSAPR SO_2 and annual NO_X 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 48 and 45 percent in the warm and cool season months, respectively, between 2000 and 2016.

Changes in $PM_{2.5}$ Nonattainment

- Thirty-six of the 39 designated nonattainment areas for the 1997 annual average $PM_{2.5}$ NAAQS are in the eastern United States and are home to about 75 million people.[1,2] The nonattainment areas were designated in January 2005 using 2001 to 2003 data.
    - Based on data gathered from 2014 to 2016, 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 power sector emissions are an important component of the SO_2 and annual NO_X emission inventory and 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
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- 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

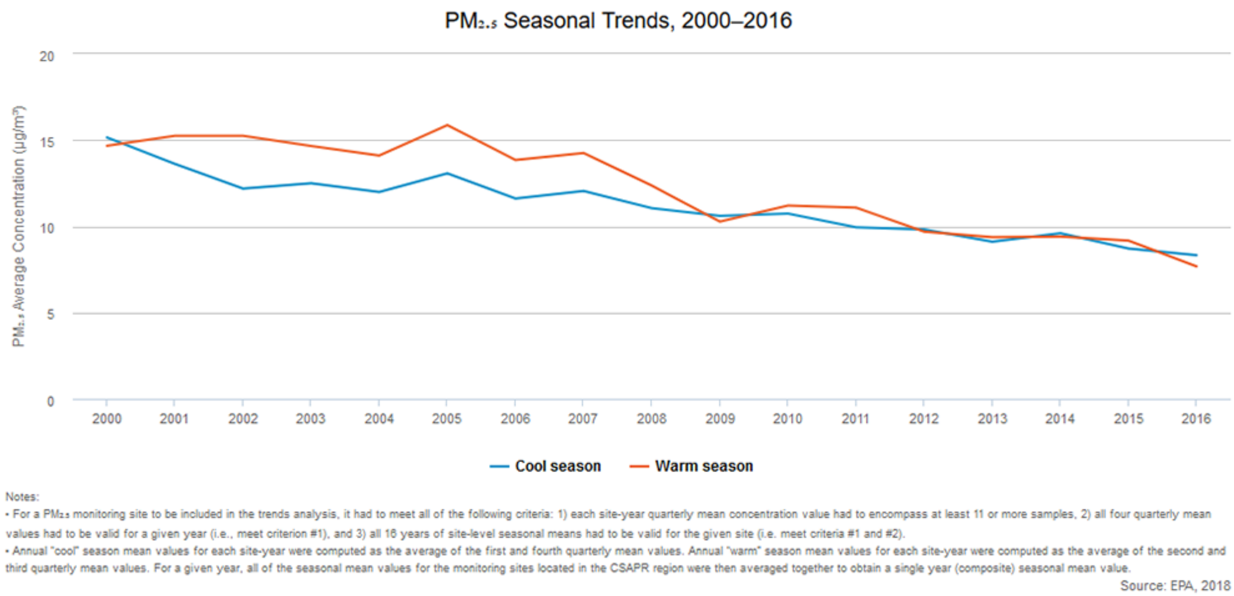

Figure 1. $PM_{2.5}$ Seasonal Trends, 2000–2016

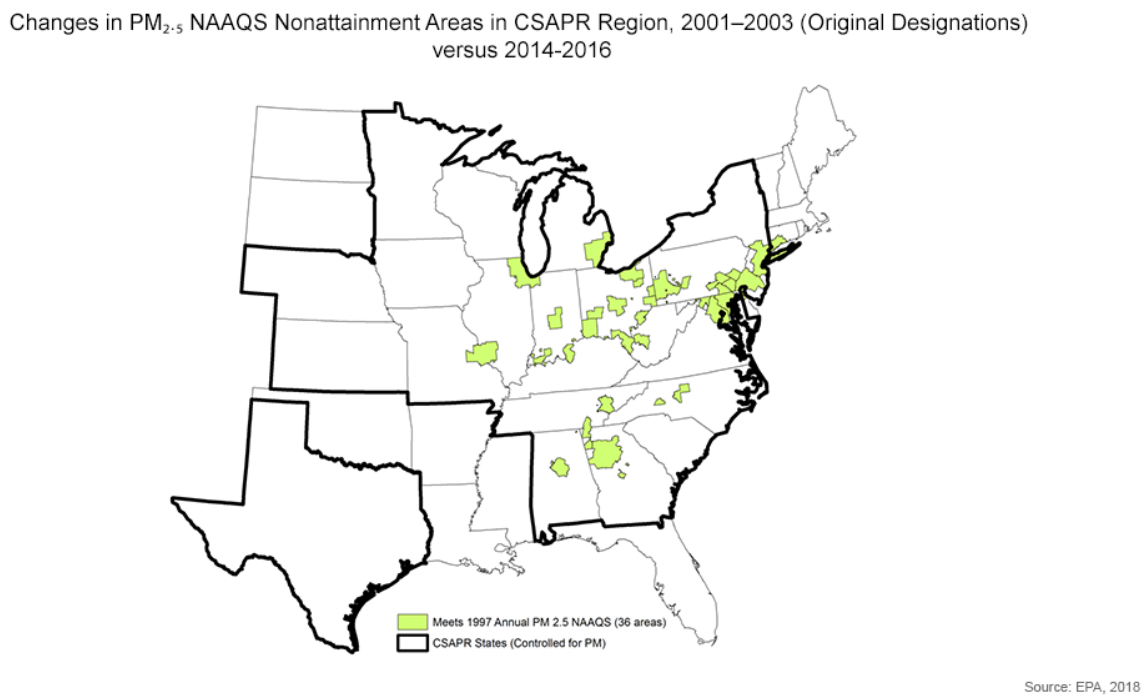

Figure 2. Changes in $PM_{2.5}$ NAAQS Nonattainment Areas in CSAPR Region, 2001–2003 (Original Designations) versus 2014–2016

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.

Highlights

Wet Sulfate Deposition

- All areas of the eastern United States have shown significant improvement, with an overall 66 percent reduction in wet sulfate deposition from 1989–1991 to 2014–2016.
- Between 1989–1991 and 2014–2016, the Northeast and Mid-Atlantic experienced the largest reductions in wet sulfate deposition, of 69 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 35 percent in the Mid-Atlantic and Northeast but decreased only 15 percent in the Midwest from 1989–1991 to 2014–2016. Smaller reductions in wet deposition of inorganic nitrogen deposition in the Midwest are attributed to a 15 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. Emissions from other source categories (e.g., mobile sources, agriculture, and manufacturing) contribute to 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 88 percent from 1989–1991 to 2014–2016.
- Decreases in dry and total inorganic nitrogen deposition have generally been greater than that of wet deposition, with average reductions of 62 percent and 71 percent, respectively. In contrast, wet deposition from inorganic nitrogen decreased by an average of 26 percent from 1989–1991 to 2014–2016.

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 earth's 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 in much of the Ohio River Valley and Northeastern United States due to SO_2 emission reductions achieved through implementation of the Acid Rain Program (ARP), the Clean Air Interstate Rule (CAIR) and the Cross-State Air Pollution Rule (CSAPR). 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, has 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 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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Figures

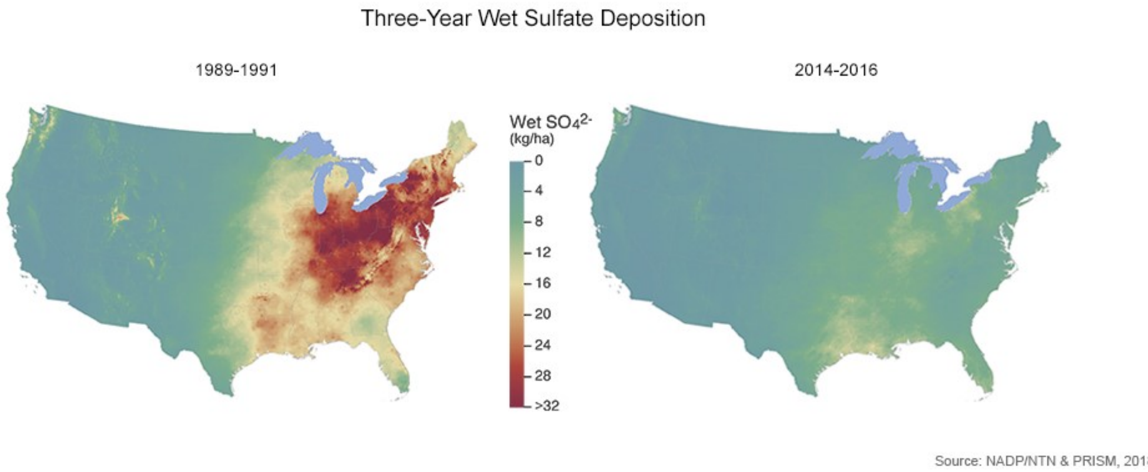

Figure 1. Three-Year Wet Sulfate Deposition

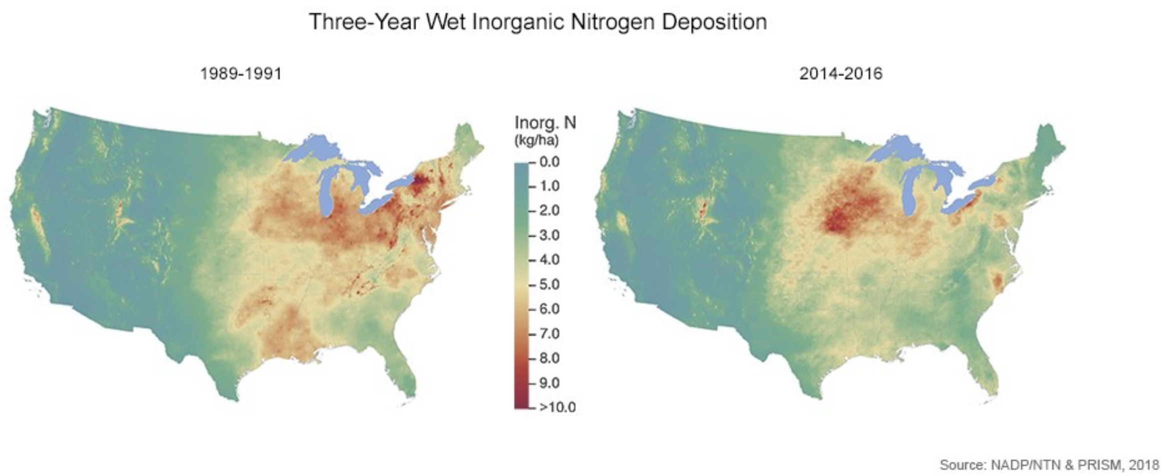

Figure 2. Three-Year Wet Inorganic Nitrogen Deposition

Regional Trends in Deposition

Measurement	Region	Annual Average, 1989-1991	Annual Average, 2014-2016	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	1.1	-54	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	0.9	-87	12	***
	Midwest	6.6	1.1	-83	9	***
	Northeast	2.6	0.4	-85	4	
	Southeast	3.1	0.5	-84	8	***
Total inorganic nitrogen deposition (kg-N/ha)	Mid-Atlantic	8.8	5.0	-43	12	***
	Midwest	8.6	6.1	-29	9	***
	Northeast	6.7	3.7	-45	4	
	Southeast	6.4	4.0	-38	8	***
Total sulfur deposition (kg-S/ha)	Mid-Atlantic	16.0	3.0	-81	12	***
	Midwest	15.0	4.0	-73	9	***
	Northeast	9.8	2.0	-80	4	
	Southeast	10.3	2.6	-75	8	***
Wet nitrogen deposition from inorganic nitrogen (kg-N/ha)	Mid-Atlantic	6.2	3.9	-37	11	***
	Midwest	6.0	5.1	-15	22	***
	Northeast	5.7	3.9	-32	16	***
	Southeast	4.3	3.4	-21	22	***
Wet sulfur deposition from sulfate (kg-S/ha)	Mid-Atlantic	9.2	2.7	-71	11	***
	Midwest	7.7	2.9	-62	22	***
	Northeast	7.5	2.3	-69	16	***
	Southeast	5.9	2.2	-63	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, 2018

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, forests, 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

Highlights

Regional Trends in Water Quality

- Between 1990 and 2016, 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 2016, streams in the central Appalachian region have experienced mixed results due in part to their soils and geology. Only 39 percent of monitored streams show lower sulfate concentrations (and statistically significant trends), while 12 percent show increased sulfate concentrations.
- Nitrate concentrations and trends are highly variable and many sites do not show improving trends between 1990 and 2016, despite reductions in NO_X emissions and inorganic nitrogen deposition.
- In 2016, 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 Forests

- Between 2000-2002 and 2014-2016, the area in the eastern United States with significant forest biomass loss (> 2 % biomass loss) decreased from 34 percent to 5.8 percent for seven tree species combined – black cherry, yellow poplar, sugar maple, eastern white pine, Virginia pine, red maple, and quaking aspen.
- For black cherry and yellow poplar individually (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 5.1 percent for black cherry, and from 3 percent to 0 percent for yellow poplar between 2000-2002 and 2014-2016.

- For the period 2014-2016, total land area in the eastern United States with significant biomass loss for the remaining five species combined (red maple, sugar maple, quaking aspen, Virginia pine, and eastern white pine) is now zero. This is in contrast to 3.4% 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 ozone season 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 can impact lakes and streams by mobilizing toxic forms of aluminum from soils (particularly in clay rich soils) and/or by lowering the pH of the water, harming fish and other aquatic wildlife. In a healthy well-buffered lake or stream, decreased acid deposition would be reflected by decreasing trends in surface water acidity. 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 (lower the pH) and leach base cations and toxic forms of aluminum from soils, leaving soils depleted of buffering base cations and releasing harmful aluminum into the surface waters.
- **Nitrate** also 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.
- **Base cations** neutralize both sulfate and nitrate anions, thereby preventing surface water acidification. Base cation availability is a function of local geology, soil type, and the vegetation community. Surface waters with fewer base cations are more susceptible to acidification.
- **ANC** is a key indicator of ecosystem impacts and recovery and is a measure of overall buffering capacity of surface waters against acidification. Higher ANC values indicate the ability to neutralize strong acids that enter aquatic systems from deposition and other sources. In acidified systems with poor base cation availability, ANC can be negative, indicating chronic acidification.

In the central Appalachian region, some watersheds have depleted, base cation-poor soils which have also accumulated and stored sulfate over the past decades of high sulfate deposition. As a result, the substantial decrease in acidic deposition has not yet resulted in comparably lower sulfate concentrations in many of the monitored Appalachian streams. A combination of low base cation availability and stored sulfate in the soils means that stream sulfate concentrations in some areas are not changing, or may be increasing, as the stored sulfate slowly bleeds out without adequate base cation concentrations to neutralize sulfate anions.[1]

Surface Water Monitoring Networks

In collaboration with other federal and state agencies and universities, EPA has administered two monitoring programs that provide information on the impacts of acidic deposition on otherwise pristine lakes and streams: the Long-term Monitoring (LTM) program and the Temporally Integrated Monitoring of Ecosystems (TIME) program. These programs are designed to track changes in surface water chemistry in 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). After 20 years of collection, the TIME program ended in 2015, having provided trend-based acidification probabilities for larger lake and stream populations. Like the LTM program, TIME trends suggest that surface waters in these regions are recovering from acidification, though the most sensitive surface waters remain impacted from air pollution. 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/clearn-air-martkets-monitoring-surface-water-chemistry
- Learn more about acid rain https://www.epa.gov/acidrain/

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Figures

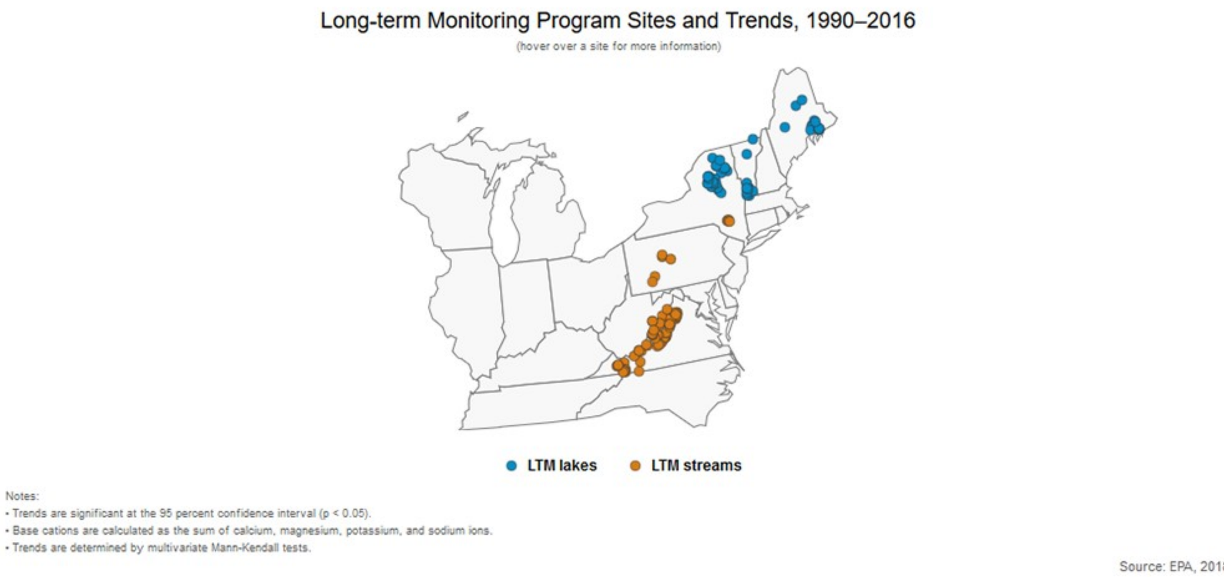

Figure 1. Long-term Monitoring Program Sites and Trends, 1990–2016

Regional Trends in Sulfate, Nitrate, ANC, and Base Cations at Long-term Monitoring Sites, 1990–2016

Region	Water Bodies Covered	% of Sites with Improving Sulfate Trend	% of Sites with Improving Nitrate Trend	% of Sites with Improving ANC Trend	% of Sites with Improving Base Cations Trend
Adirondack Mountains	38 lakes in NY*	100%	76%	92%	89%
New England	26 lakes in ME and VT	100%	26%	70%	64%
Catskills/ N. Appalachian Plateau	9 streams in NY and PA**	80%	40%	70%	90%
Central Appalachians	66 streams in VA	39%	80%	18%	26%

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)

* Data for Adirondack lakes from 1992
**Data for PA streams in N. Appalachian Plateau is only through 2015

Source: EPA, 2018

Figure 2. Regional Trends in Sulfate, Nitrate, ANC, and Base Cations at Long-term Monitoring Sites, 1990–2016

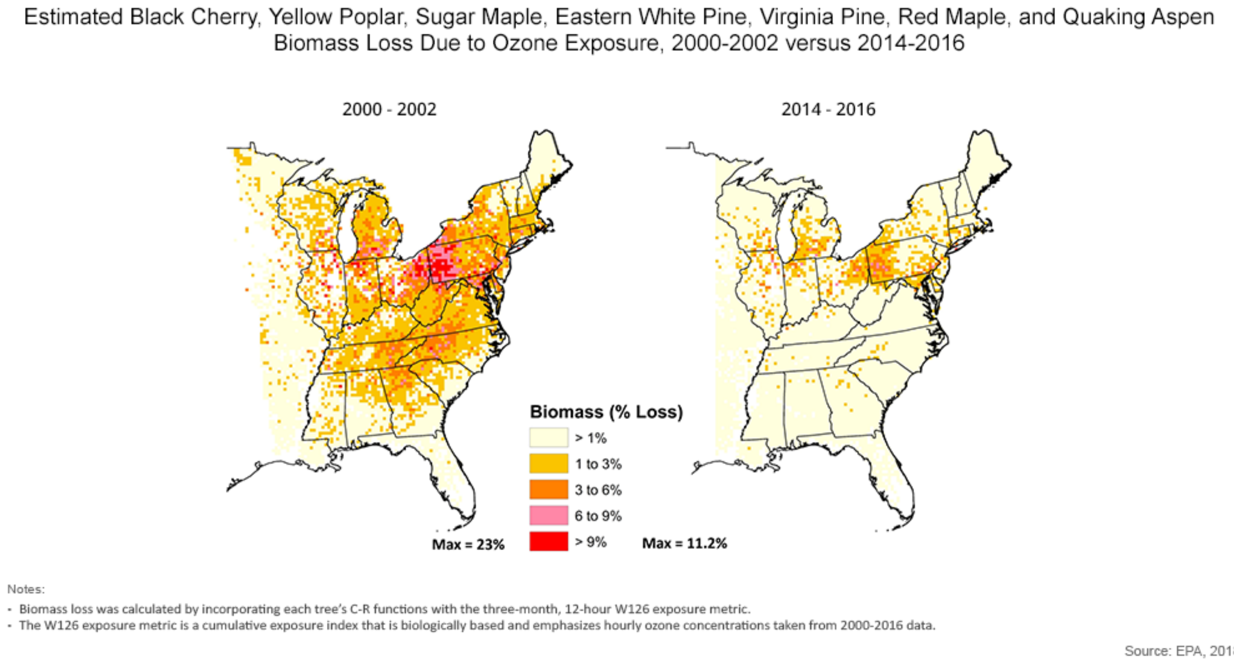

Figure 3. Estimated Black Cherry, Yellow Poplar, Sugar Maple, Eastern White Pine, Virginia Pine, Red Maple, and Quaking Aspen Biomass Loss Due to Ozone Exposure, 2000-2002 versus 2014-2016

Critical Loads Analysis

Highlights

Critical Loads and Exceedances

- For the period from 2014 to 2016, 9 percent of all studied lakes and streams still received levels of combined total sulfur and nitrogen deposition exceeding their calculated critical load. This is a 77 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 2016 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 2016 still exceed levels required for recovery of some lakes and streams, indicating that some additional emission reductions are 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 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 https://www.epa.gov/airmarkets/monitoring-surface-water-chemistry
- National Acid Precipitation Assessment Program (NAPAP) Report to Congress https://ny.water.usgs.gov/projects/NAPAP/

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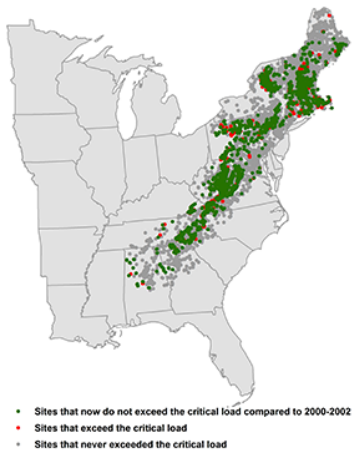
Figures

Lake and Stream Exceedances of Estimated Critical Loads for Total Nitrogen and Sulfur Deposition, 2000–2002 versus 2014–2016



Notes:

- Surface water samples from the represented lakes and streams complied from surface monitoring programs, such as National Surface Water Survey (NSWS), Environmental Monitoring and Assessment Program (EMAP), Wadeable Stream Assessment (WSA), National Lake Assessment (NLA), Temporally Integrated Monitoring of Ecosystems (TIME), Long Term Monitoring (LTM), and other water quality monitoring programs.
- Steady state exceedances calculated in units of meq/m²/yr.

Source: EPA, 2018

Figure 1. Lake and Stream Exceedances of Estimated Critical Loads for Total Nitrogen and Sulfur Deposition, 2000–2002 versus 2014–2016

Critical Load Exceedances by Region, 2000-2002 versus 2014-2016

Region	Number of Water Bodies Modeled	Water Bodies in Exceedance of Critical Load				Percent Reduction
		2000-2002		2014-2016		
		Number of Sites	Percent of Sites	Number of Sites	Percent of Sites	
New England (CT, MA, ME, NH, RI, VT)	2,195	580	26%	129	6%	78%
Adirondack (NY)	312	163	52%	41	13%	75%
Northern Mid-Atlantic (NY, NJ, PA)	1,146	301	26%	57	5%	81%
Southern Mid-Atlantic (KY, MD, VA, WV)	1,740	968	56%	239	14%	75%
Southern Appalachian Mountains (AL, GA, SC, TN)	882	298	34%	73	8%	76%
Total Units	**6,275**	**2,310**	**37%**	**539**	**9%**	**77%**

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

Source: EPA, 2018

Figure 2. Critical Load Exceedances by Region, 2000-2002 versus 2014-2016