2013 Program Progress

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

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

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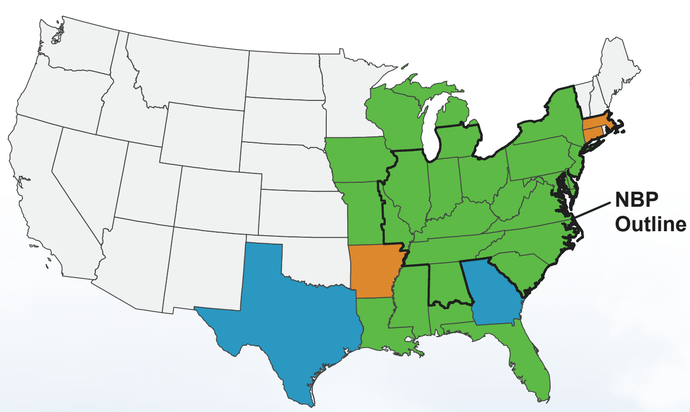
Executive Summary

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

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



2013 ARP and CAIR at a Glance

- **CAIR and ARP Annual SO_2 Emissions:** 3.2 million tons (69 percent below 2005)
- **CAIR and ARP Annual NO_x Emissions:** 1.7 million tons (53 percent below 2005)
- **CAIR Ozone Season NO_x Emissions:** 470,000 tons (41 percent below 2005)
- **Ambient particulate sulfate concentrations** have decreased since the ARP was implemented, with average concentrations decreasing by 60 to 65 percent in observed regions from 1989–1991 to 2011–2013
- **The Northeast and Mid-Atlantic** have showed the greatest improvement with an overall 64 percent reduction in wet sulfate deposition from 1989–1991 to 2011–2013
- **Levels of Acid Neutralizing Capacity (ANC)** have increased significantly from 1990 in lake and stream long-term monitoring sites in the Adirondack Mountains and the Northern Appalachian Plateau. These increasing ANC levels indicate trends toward recovery from acidification

Chapter 1: Program Basics

The Acid Rain Program (ARP) and the Clean Air Interstate Rule (CAIR) are cap and trade programs designed to reduce emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO_x) from covered power plants. Both programs were in effect in 2013. The ARP covers power plants across the contiguous United States while CAIR covers power plants in 27 eastern states. The NO_x Budget Trading Program (NBP) operated from 2003 to 2008 in the eastern United States during the summer months and was replaced by CAIR in 2009. In 2015, EPA's Cross-State Air Pollution Rule (CSAPR) replaced CAIR.

Analysis and Background Information

Acid Rain Program

Title IV of the 1990 Clean Air Act (CAA) Amendments established the ARP to achieve reductions in SO_2 and NO_x emissions from coal-fired power plants. In contrast to traditional command and control regulatory methods that establish specific emissions limitations, the ARP introduced a novel allowance trading system that harnessed the incentives of the free market to reduce pollution. This was done in two phases. Phase I began in 1995 and affected the largest coal-burning units in 21 eastern and midwestern states. Phase II began in 2000 and expanded the program to include smaller units fired by coal, oil and gas. Under Phase II, EPA also tightened the annual SO_2 emissions limits, 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 program integrity through measurement and reporting. However, it does not "cap" NO_x emissions as the SO_2 program does, nor does it utilize an allowance trading system. Instead, the ARP NO_x program provisions apply boiler-specific NO_x emission limits – or rates – in pounds per million British thermal units (lb/mmBtu) on certain coal-fired boilers.

NO_x Budget Trading Program

The NO_x Budget Trading Program (NBP) was a market-based cap and trade program created to reduce NO_x emissions from power plants and other large combustion sources to address regional pollution transport that contributes to ozone nonattainment in the eastern United States. The program was a central component of the NO_x SIP Call, promulgated in 1998. All 20 states covered by the NO_x SIP Call participated in the NBP, which operated from 2003 to 2008. In 2009, CAIR's NO_x ozone season program began, effectively replacing the NBP to continue achieving summertime NO_x emission reductions from the power sector.

Clean Air Interstate Rule

The Clean Air Interstate Rule (CAIR) required 24 eastern states to limit annual power sector emissions of NO_x and SO_2 to address regional transport that contributes to the formation of soot (fine particulate matter). It also required 25 states to limit ozone season power sector NO_x emissions to address regional transport that contributes to the formation of smog during the summer ozone season. Similar to the ARP, CAIR used three separate market-based cap and trade programs to achieve emission reductions.

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

Cross-State Air Pollution Rule

EPA issued the Cross-State Air Pollution Rule (CSAPR) in July 2011. As amended, CSAPR requires 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 ozone and fine particle pollution in other states. CSAPR was scheduled to replace CAIR starting on January 1, 2012. However, the timing of CSAPR's implementation was affected by D.C. Circuit actions that stayed and then vacated CSAPR before implementation. On April 29, 2014, the U.S. Supreme Court reversed the D.C. Circuit's vacatur, and on October 23, 2014, the D.C. Circuit granted EPA's motion to lift the stay and shift the CSAPR compliance deadlines by three years. Accordingly, CSAPR Phase I implementation began January 1, 2015, with Phase II to begin in 2017.

Next Steps to Address Interstate Air Pollution Transport

EPA is working with state partners on the next steps to address transported air pollution for more recently finalized health-based air quality standards, specifically the 2008 ozone NAAQS. In addition, EPA will continue supporting efforts across the United States that reduce SO_2 and NO_x emissions by implementing existing programs, finalizing pending rules, and working with regional, state, and local air quality planners to evaluate the need for complementary clean air actions.

Key Points

The Acid Rain Program (ARP)

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

The NO_x Budget Trading Program (NBP)

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

The Clean Air Interstate Rule (CAIR)

- CAIR required 27 eastern states and the District of Columbia to reduce power sector SO_2 and/or NO_x emissions to address regional interstate transport for the 1997 $PM_{2.5}$ and ozone National Ambient Air Quality Standards (NAAQS). CAIR required reductions in annual emissions of SO_2 and NO_x from power plants in 24 states and D.C. and emission reductions of NO_x during the ozone season from 25 states and D.C.

- CAIR included three separate cap and trade programs to achieve the required reductions: the CAIR SO_2 annual trading program, the CAIR NO_x annual trading program, and the CAIR NO_x ozone season trading program.
- A December 2008 court decision kept the requirements of CAIR in place temporarily but directed EPA to issue a new rule to address interstate transport. CAIR was replaced by CSAPR starting on January 1, 2015.

The Cross-State Air Pollution Rule (CSAPR)

- CSAPR was developed in response to the December 2008 court decision on CAIR and replaced CAIR starting on January 1, 2015.
- CSAPR addresses regional interstate transport of fine particle and ozone pollution for the 1997 ozone and $PM_{2.5}$ NAAQS and the 2006 $PM_{2.5}$ NAAQS. CSAPR requires a total of 28 eastern states to reduce annual SO_2 emissions, annual NO_x emissions and/or ozone season NO_x emissions.
- CSAPR includes three separate cap and trade programs to achieve these reductions: the CSAPR SO_2 annual trading program, the CSAPR NO_x annual trading program, and the CSAPR NO_x ozone season trading program.

More Information

Acid Rain Program (ARP) http://www.epa.gov/airmarkets/programs/arp/index.html
Clean Air Interstate Rule (CAIR) http://www.epa.gov/airmarkets/programs/cair/index.html
NO_x Budget Trading Program (NBP) / NO_x SIP Call http://www.epa.gov/airmarkets/programs/nox/
Cross State Air Pollution Rule (CSAPR) http://www.epa.gov/airtransport/CSAPR/index.html
Cap and Trade Basics http://www.epa.gov/airmarkets/programs/capandtrade.html

Figures

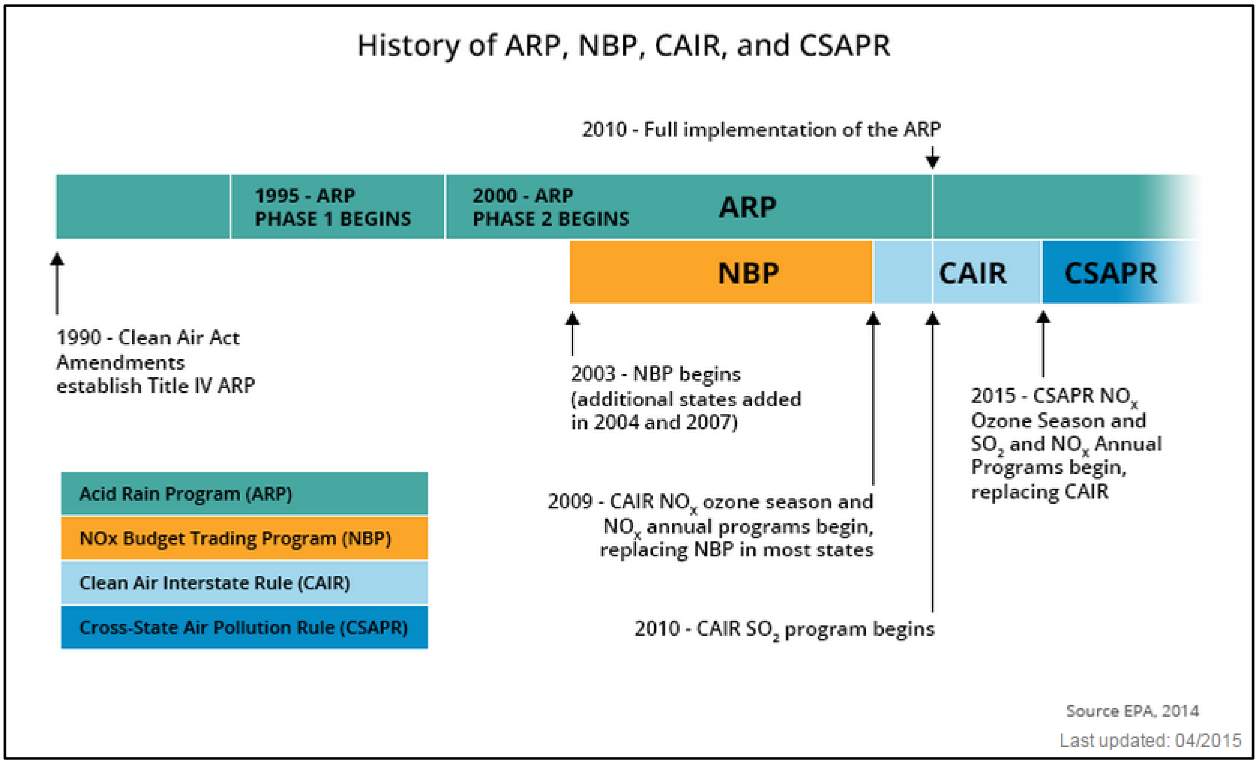


Figure 1. History of ARP, NBP, CAIR, and CSAPR

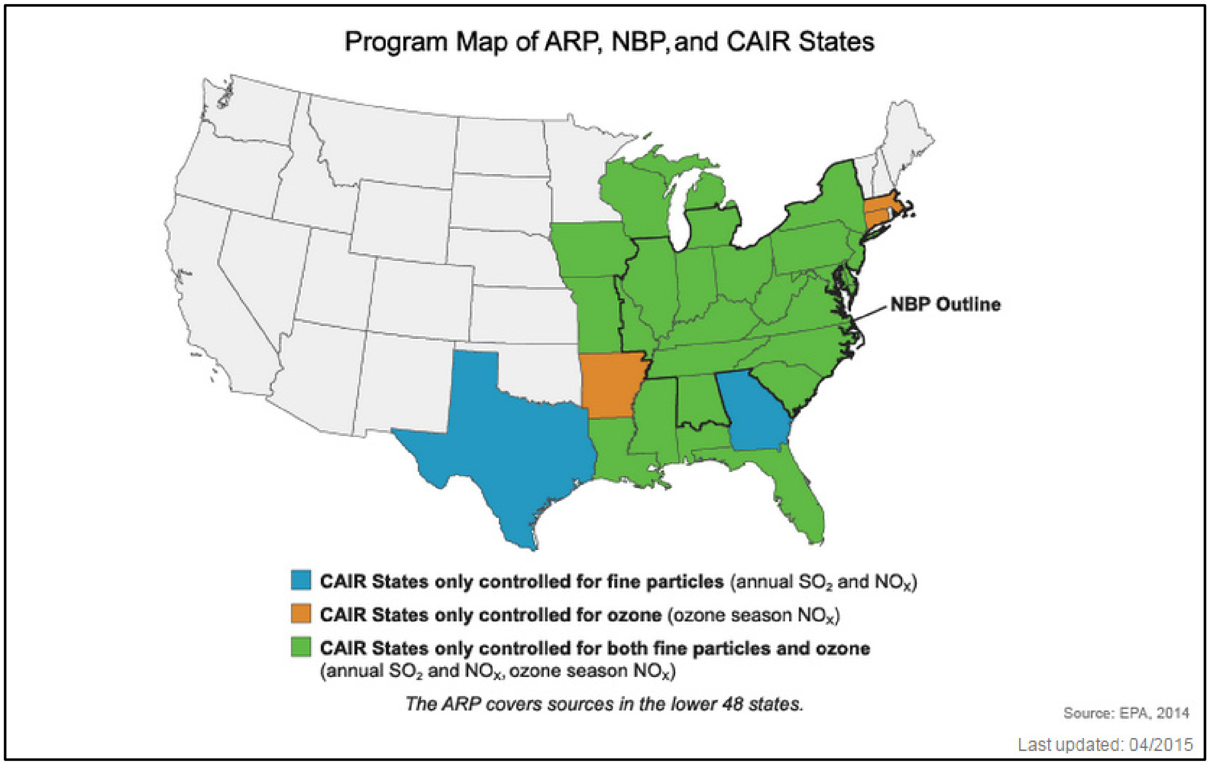


Figure 2. Program Map of ARP, NBP, and CAIR States

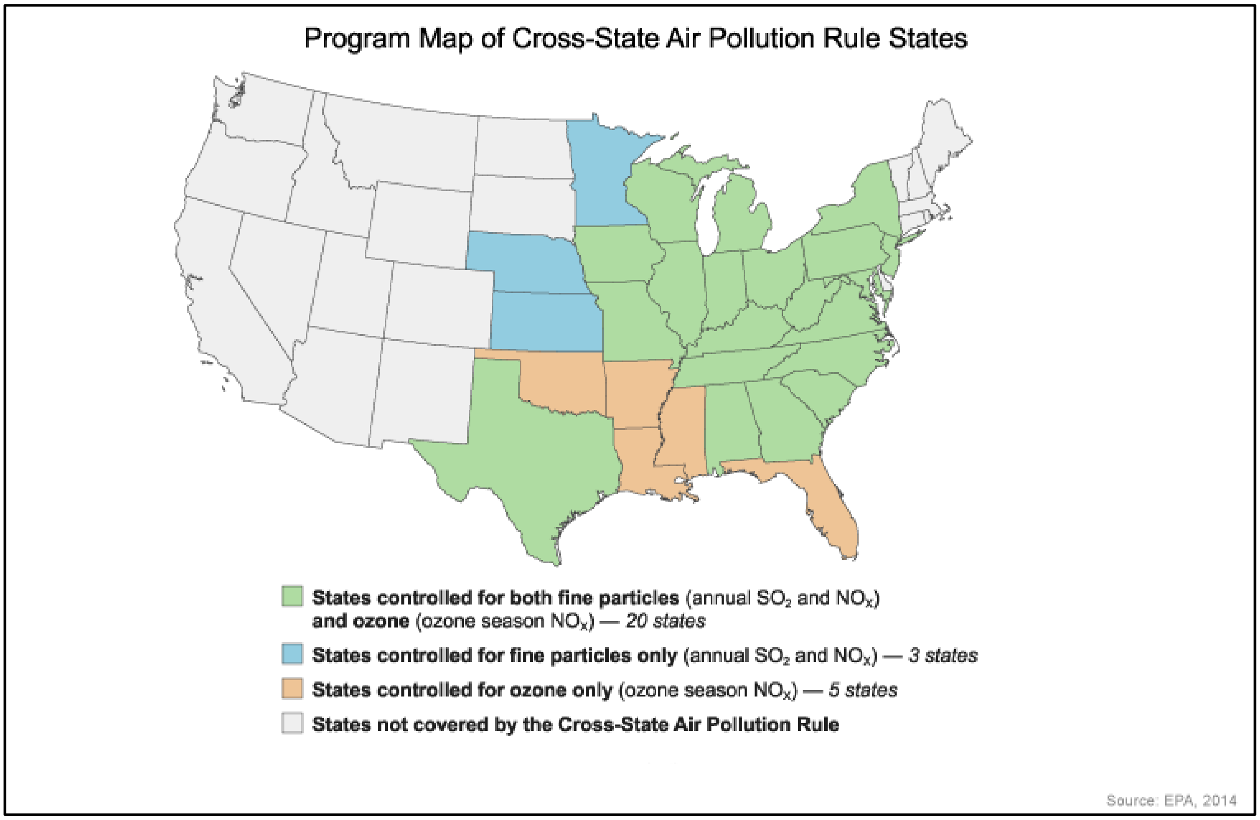


Figure 3. Large Map of Cross-State Air Pollution Rule

Chapter 2: Affected Units

Under the Acid Rain Program (ARP) and Clean Air Interstate Rule (CAIR) SO_2 and NO_x annual programs, emission reductions generally apply to large electricity generating units (EGUs) — boilers, turbines, and combined cycle units that primarily burn fossil fuels to generate electricity for sale. The CAIR NO_x ozone season program includes EGUs and, in some states, large industrial units which produce power for primarily internal use and have been carried over from the NO_x Budget Trading Program (NBP). This section covers units affected in 2013, and does not include programs not being implemented in 2013 (NBP, CSAPR).

Analysis and Background Information

When Phase II of the ARP began in 2000, the ARP encompassed over 2,000 units. The ARP affects EGUs with an output capacity greater than 25 megawatts that burn coal, oil, or gas as well as all new EGUs. The ARP NO_x program affects boilers at mostly coal-fired power plants.

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

In addition to large EGUs that generate electricity for sale, the CAIR NO_x ozone season program included some facilities that were carried over from the NBP and which produce electricity mostly for internal use. Such facilities may include large industrial units, such as boilers and turbines at heavy manufacturing facilities, including paper mills, petroleum refineries, and iron and steel production facilities. These units also include some steam plants at institutions such as large universities or hospitals.

Key Points

Acid Rain Program (ARP)

- In 2013, the ARP SO_2 requirements applied to the 3,609 fossil fuel-fired combustion units at 1,237 facilities across the country; 847 units at 350 facilities were subject to the ARP NO_x program.

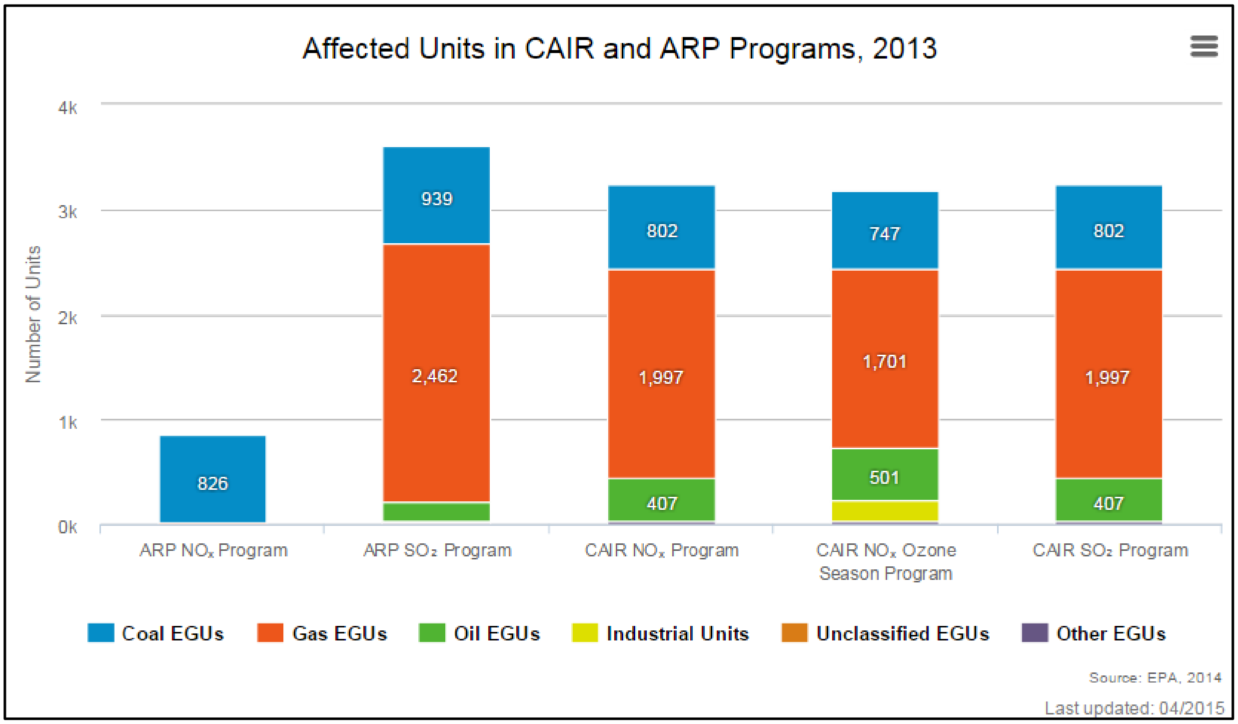
Clean Air Interstate Rule (CAIR)

- In 2013, there were 3,239 affected EGUs at 935 facilities in the CAIR SO_2 annual program. Of those, 2,554 (79 percent) were also covered by the ARP.
- In 2013, there were 3,239 affected EGUs at 935 facilities in the CAIR NO_x annual program and 3,177 EGUs and industrial units at 928 facilities in the CAIR NO_x ozone season program.

More Information

Acid Rain Program (ARP) http://www.epa.gov/airmarkets/programs/arp/index.html
Clean Air Interstate Rule (CAIR) http://www.epa.gov/airmarkets/programs/cair/index.html

Figures



Notes:

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

Figure 1. Affected Units in CAIR and ARP Programs, 2013

Affected Units in the CAIR and ARP Programs, 2013

Fuel	ARP NO_x Program	ARP SO_2 Program	CAIR NO_x Program	CAIR NO_x Ozone Season Program	CAIR SO_2 Program
Coal EGUs	826	939	802	747	802
Gas EGUs	17	2462	1997	1701	1997
Oil EGUs	0	173	407	501	407
Industrial Units	0	4	0	196	0
Unclassified EGUs	0	12	4	1	4
Other EGUs	4	19	29	31	29
Total Units	**847**	**3609**	**3239**	**3177**	**3239**

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, 2014

Last updated: 4/2015

Notes:

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

Figure 2. Affected Units in the CAIR and ARP Programs, 2013

Chapter 3: Emissions Reductions

Sulfur Dioxide (SO_2)

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

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

Analysis and Background Information

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

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

Key Points

SO_2 Emission Trends

- Units in the ARP emitted 3.2 million tons of SO_2 in 2013, well below the ARP's statutory annual cap of 8.95 million tons. ARP sources reduced emissions by 12.5 million tons (80 percent) from 1990 levels and 14.1 million tons (81 percent) from 1980 levels.
- In 2013, the fourth year of operation of the CAIR SO_2 trading program, sources in both the CAIR SO_2 annual program and the ARP together reduced SO_2 emissions by 12.5 million tons (79 percent) from 1990 levels (before implementation of the ARP), 8.0 million tons (71 percent) from 2000 levels (ARP Phase II), and 7.1 million tons (69 percent) from 2005 levels (before implementation of CAIR).
- All ARP and CAIR sources together emitted a total of 3.2 million tons of SO_2 in 2013.
- Annual SO_2 emissions from sources in the CAIR SO_2 program alone fell from 9.1 million tons in 2005 to 2.7 million tons in 2013, a 70 percent reduction. Between 2012 and 2013, SO_2 emissions fell 65,000 tons (3 percent) and were about 920,000 tons below the regional CAIR emission budget.

SO_2 State-by-State Emission Maps

- From 1990 to 2013, annual SO_2 emissions in the ARP and the CAIR SO_2 program dropped in 42 states and D.C. by a total of approximately 12 million tons. In contrast, annual SO_2 emissions increased by a total of 29,000 tons in six states (Arkansas, Idaho, Nebraska, Oregon, Rhode Island, and Vermont) from 1990 to 2013.
- Seventeen states and D.C. had emissions below their CAIR allowance budgets, collectively by about 1.1 million tons. Another seven states exceeded their 2013 budgets by a total of about 150,000 tons, indicating that, on an aggregate basis, sources within those states covered a portion of their emissions with allowances banked from earlier years, transferred from an out-of-state account, or purchased from the market.

SO_2 Emission Rates

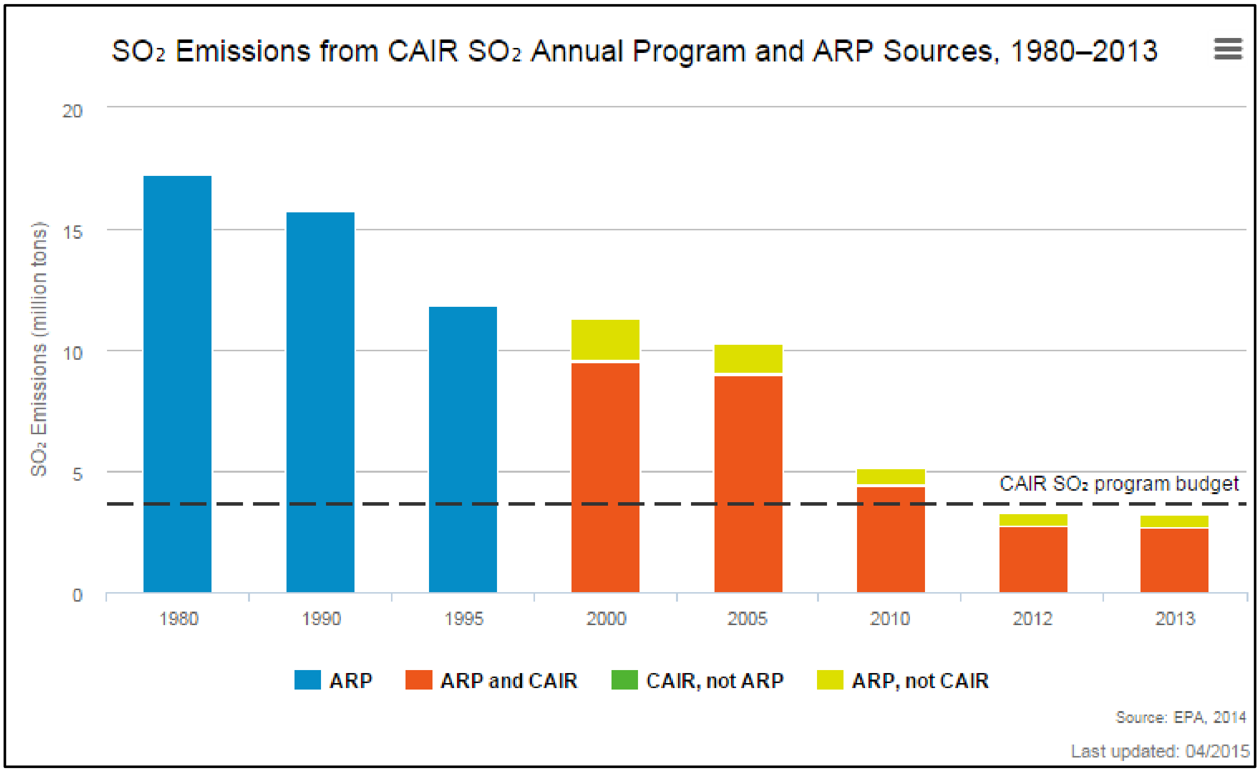
- In 2013 the SO_2 emission rate fell to 0.26 lb/mmBtu. This indicates a 70 percent reduction from 2000 rates, with the majority of reductions from coal-fired units.
- Despite dramatic decreases in emissions since 2000, heat input has remained steady over the past thirteen years, indicating an improvement in emission rate at the sources. This is due in large part to greater use of control technology on coal-fired units and increased heat input at natural gas-fired units.

More Information

Acid Rain Program (ARP) http://www.epa.gov/airmarkets/programs/arp/index.html
Clean Air Interstate Rule (CAIR) http://www.epa.gov/airmarkets/programs/cair/index.html

Figures

Subtopic: Sulfur Dioxide (SO_2)



Notes:

- For CAIR units not in the ARP, the 2009 annual SO_2 emissions were applied retroactively for each pre-CAIR year following the year in which the unit began operating.

Figure 1. SO_2 Emissions from CAIR SO_2 Annual Program and ARP Sources, 1980-2013

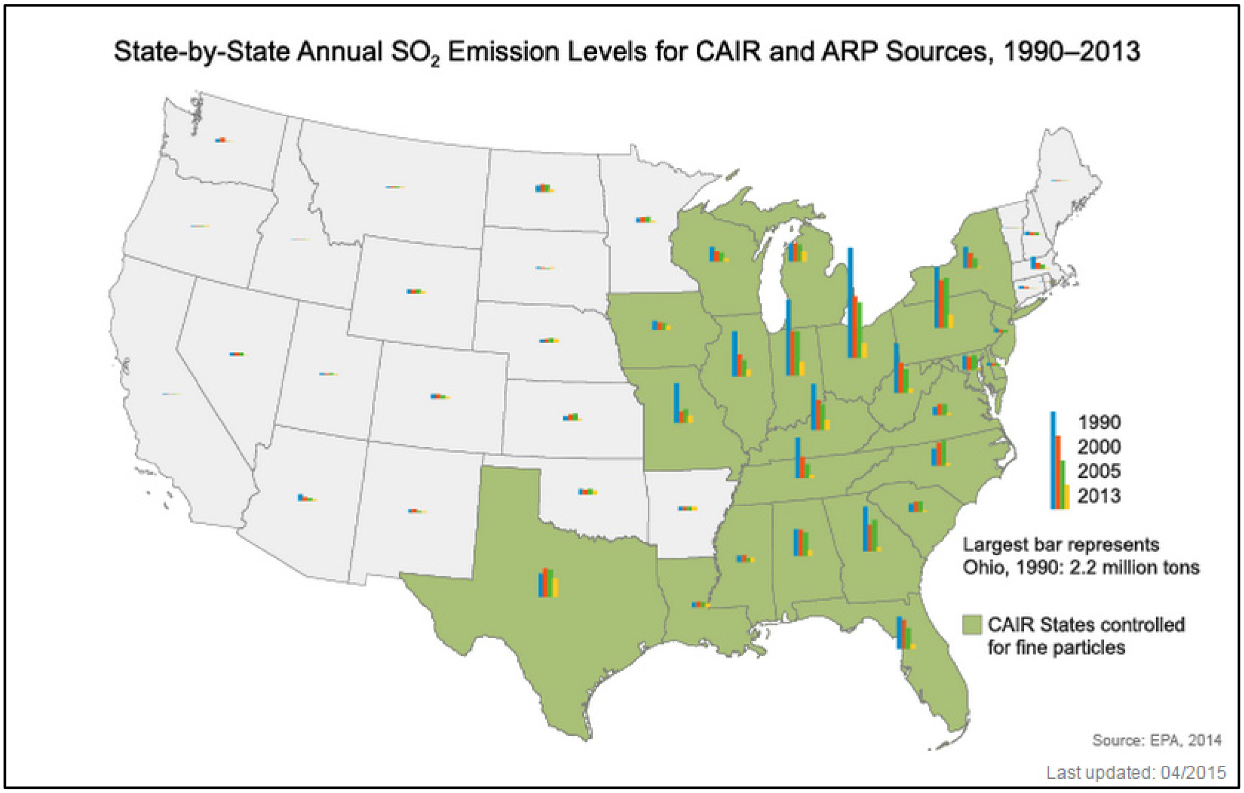
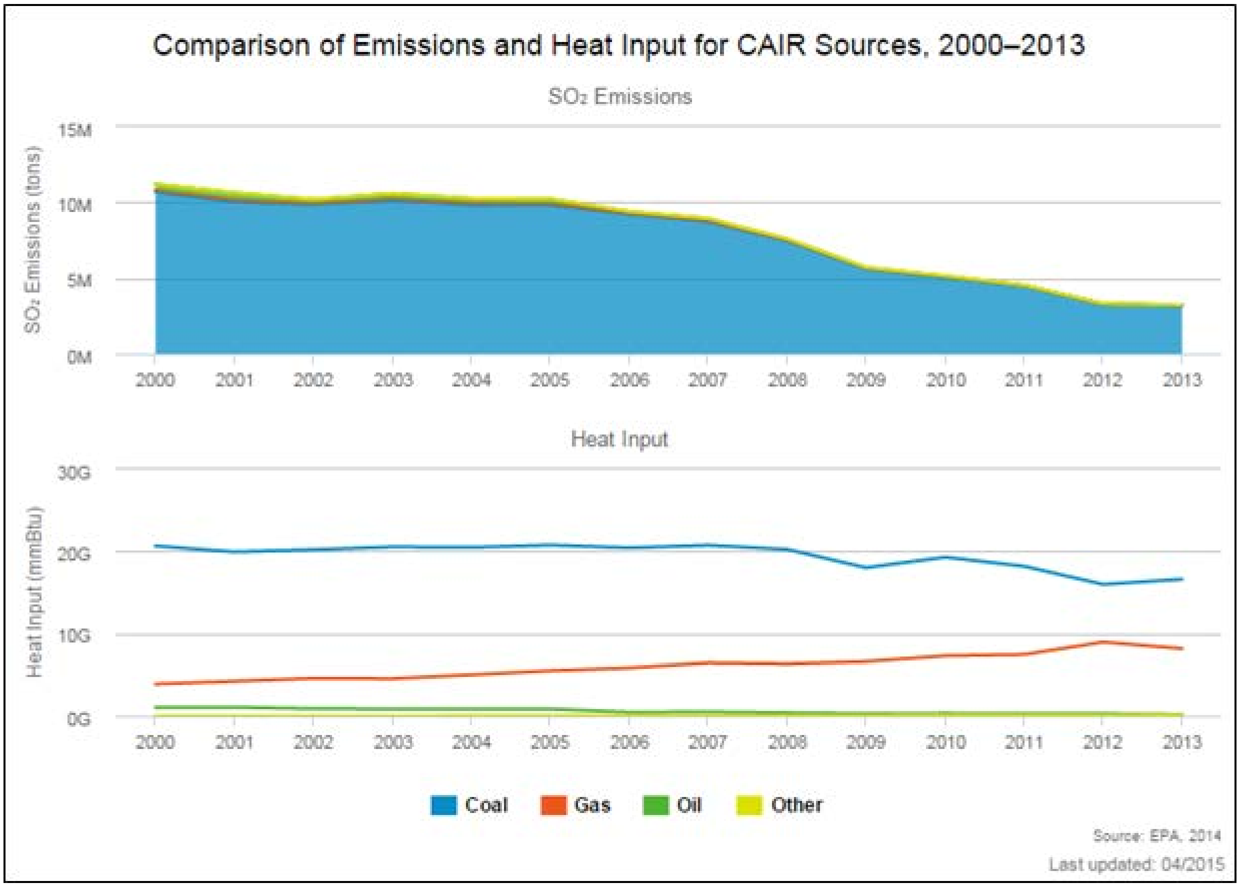


Figure 2. State-by-State Annual SO_2 Emission Levels for CAIR and ARP Sources, 1990-2013



Notes:

- The data shown here for the annual programs reflect totals for those facilities required to comply with each program in each respective year. This means that CAIR SO_2 annual program facilities are not included in the annual SO_2 data prior to 2009.
- Fuel type represents primary fuel type; units might combust more than one fuel.
- Unless otherwise noted, EPA data are current as of June 2014, and may differ from past of future reports as a result of resubmissions by sources and ongoing data quality assurance activities.

Figure 3. Comparison of Emissions and Heat Input for CAIR Sources, 2000-2013

CAIR and ARP Annual SO_2 Trends

	SO_2 Emissions (thousand tons)					SO_2 Rate (lb/mmBtu)					Heat Input (billion mmBtu)				
Primary Fuel	2000	2005	2009	2010	2013	2000	2005	2009	2010	2013	2000	2005	2009	2010	2013
Coal	10,708	9,835	5,653	5,090	3,210	1.04	0.95	0.63	0.53	0.39	20.67	20.77	18.02	19.30	16.61
Gas	108	91	22	20	6	0.06	0.03	0.01	0.01	0.00	3.88	5.49	6.59	7.28	8.16
Oil	385	292	38	31	7	0.73	0.70	0.27	0.19	0.07	1.06	0.84	0.29	0.33	0.21
Other	1	4	8	26	19	0.22	0.27	0.27	0.53	0.28	0.01	0.03	0.06	0.10	0.14
Total	**11,201**	**10,223**	**5,722**	**5,168**	**3,242**	**0.88**	**0.75**	**0.46**	**0.38**	**0.26**	**25.61**	**27.13**	**24.96**	**27.00**	**25.10**

Source EPA, 2014

Last updated: 04/2015

Notes:

The data shown here for the annual programs reflect totals for those facilities required to comply with each program in each respective year. This means that CAIR SO_2 annual program facilities are not included in the annual SO_2 data prior to 2009.

- Fuel type represents primary fuel type; units might combust more than one fuel.
- Totals may not reflect the sum of individual rows due to rounding.
- Each year's total emission rate does not equal the arithmetic mean of the four fuel-specific rates, as each facility influences the annual emission rate in proportion to its heat input, and heat input is unevenly distributed across the fuel categories.
- Unless otherwise noted, EPA data are current as of June 2014, and may differ from past of future reports as a result of resubmissions by sources and ongoing data quality assurance activities.

Figure 4. CAIR and ARP Annual SO_2 Trends

Nitrogen Oxides (NO_x)

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

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

Analysis and Background Information

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

Overall, NO_x emissions have declined dramatically under the ARP, former NBP and CAIR programs, with the majority of reductions from coal-fired units. Other programs—such as regional and state NO_x emission control programs—also contributed significantly to the annual NO_x reductions achieved by sources in 2013.

Key Points

Annual NO_x Trends

- Units in the ARP NO_x program emitted 1.7 million tons of NO_x in 2013, indicating that ARP sources reduced emissions by 6.4 million tons from the projected level in 2000 without the ARP, and over three times the Title IV NO_x emission reduction objective.
- In 2013, the fifth year of operation of the CAIR NO_x annual trading program, sources in both the CAIR NO_x annual program and the ARP together emitted 1.7 million tons, a reduction of 4.7 million tons (73 percent reduction) from 1990 levels, 3.4 million tons (66 percent reduction) from 2000, and 1.9 million tons (53 percent reduction) from 2005 levels.
- Emissions from CAIR NO_x annual program sources alone were about 1.2 million tons in 2013. This is about 320,000 tons (21 percent) below the 2013 CAIR NO_x annual program's regional budget of 1,490,264 tons and 2.5 million tons (68 percent) lower than in 2005.

Annual NO_x State-by-State Emission Maps

- All states participating in the ARP and CAIR NO_x annual program decreased their NO_x emissions from 1990 to 2013 as well as from 2005 to 2013.
- Seventeen states and D.C. had emissions below their CAIR 2013 allowance budgets, collectively by about 370,000 tons. Another seven states exceeded their 2013 budgets by a total of about 58,000

tons. This indicates that, on an aggregate basis, sources within those states covered a portion of their emissions with allowances banked from earlier years, transferred from an out-of-state account, or purchased from the market.

- Overall, in 2013 the total NO_x emissions from participating sources were about 320,000 tons below the regional emission budget of 1,490,264 tons.

Annual NO_x Emission Rates

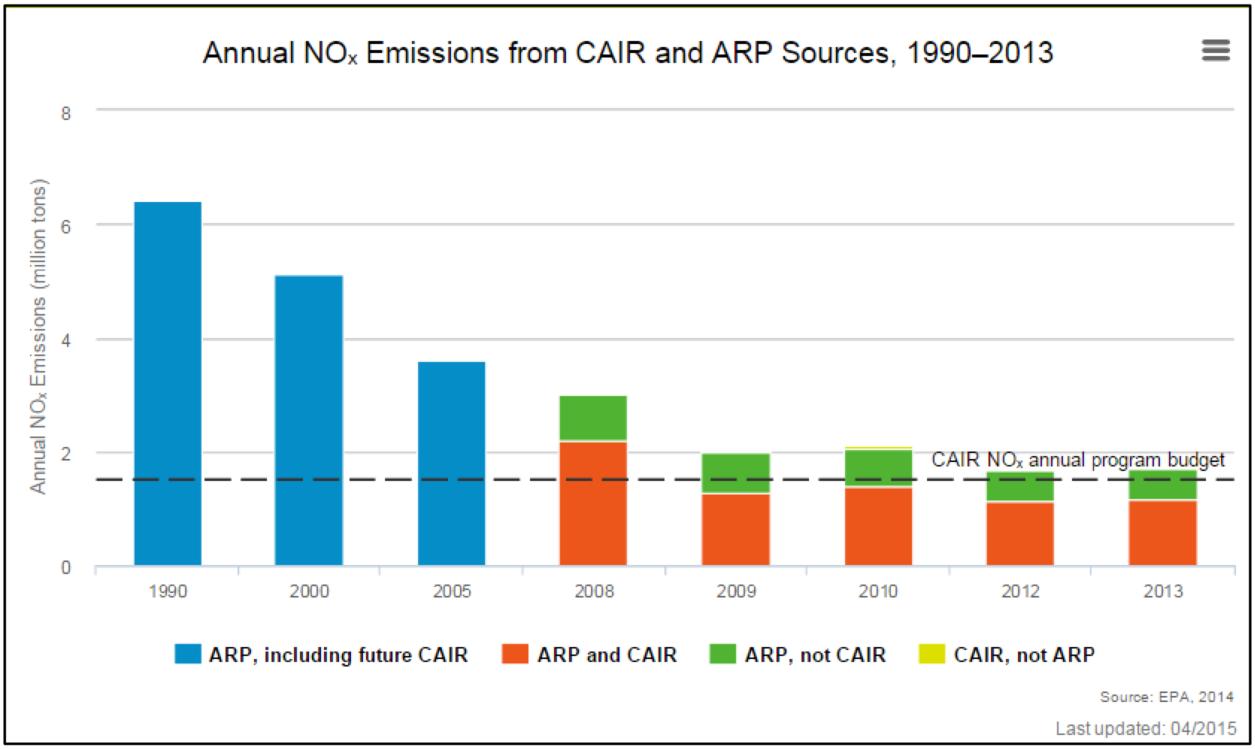
- In 2013 the CAIR and ARP annual NO_x emission rate was 0.14 lbs/mmBtu, a 49 percent reduction from 2005.
- Despite the dramatic decrease in tons of NO_x emission, heat input has remained relatively steady, indicating an improvement in emission rate (see table). This is due in large part to greater use of control technology on coal-fired units and increased heat input at natural gas-fired units.

More Information

Visit EPA's Power Plant Emission Trends site for the most up-to-date emissions and control data for sources in CAIR and the ARP http://www.epa.gov/airmarkets/progress/datatrends/index.html
Learn more about nitrogen oxides (NO_x) http://www.epa.gov/air/nitrogenoxides/
Learn more about Particulate Matter (PM) http://www.epa.gov/pm/
Learn more about Ozone http://www.epa.gov/air/ozonepollution/

Figures

Subtopic: Nitrogen Oxides (NO_x)



Notes:

- For CAIR units not in the ARP in 1990, 2000, and 2005, the 2008 annual NO_x emissions were applied retroactively for each pre-CAIR year following the year in which the unit began operating.

Figure 1. Annual NO_x Emissions from CAIR and ARP Sources, 1990-2013

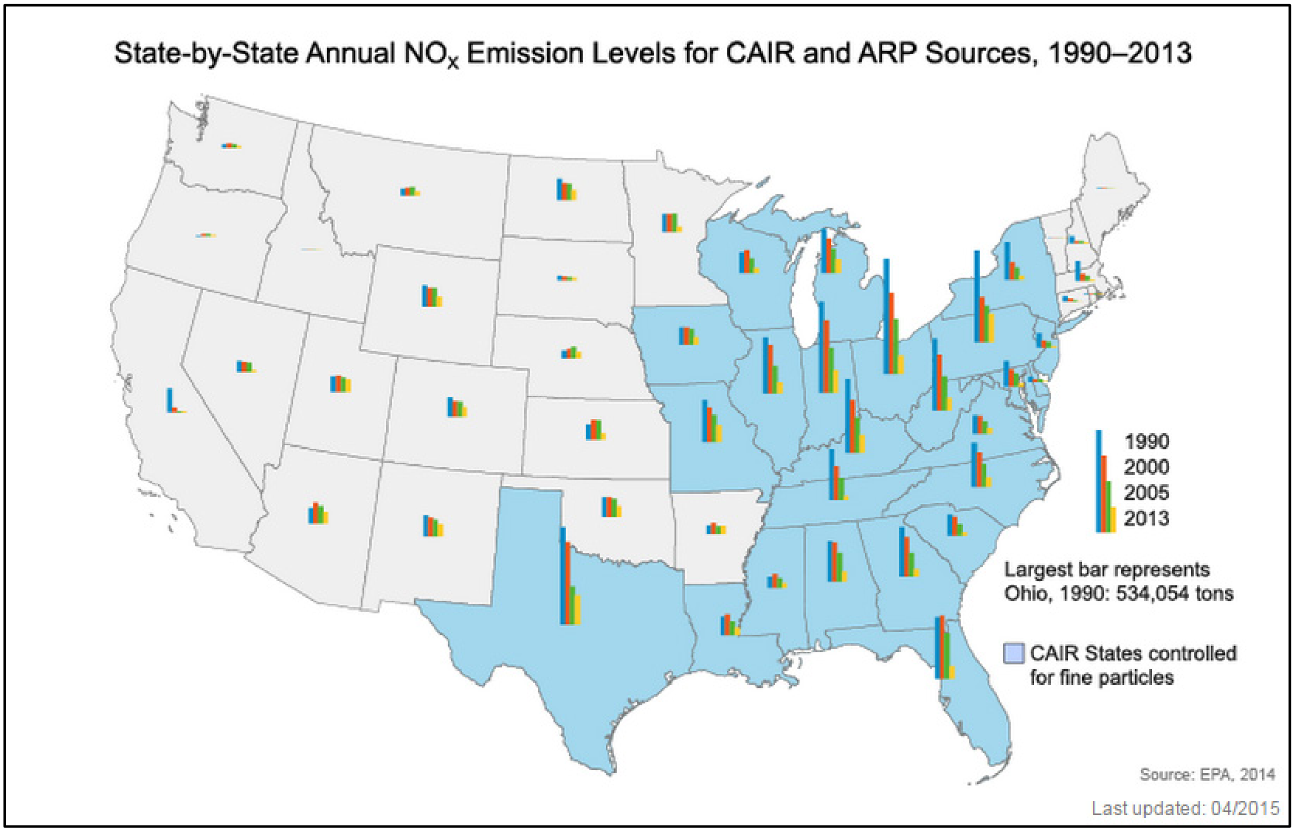
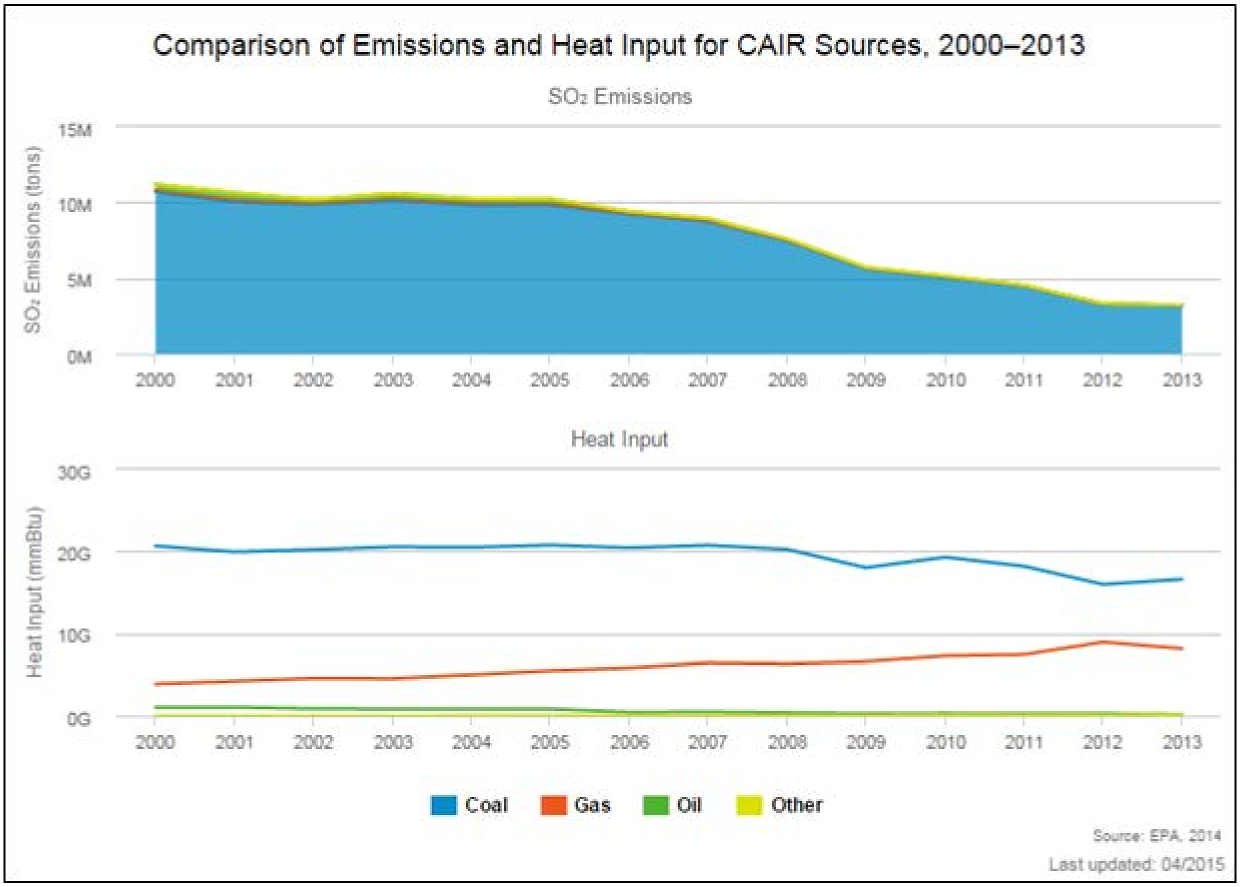


Figure 2. State-by-State Annual NO_x Emission Levels for CAIR and ARP Sources, 1990-2013



Notes:

- The data shown here for the annual programs reflect totals for those facilities required to comply with each program in each respective year. This means that CAIR NO_x annual program facilities are not included in the annual NO_x data for 2000 and 2005.
- Fuel type represents primary fuel type; units might combust more than one fuel.
- Unless otherwise noted, EPA data are current as of June 2014, and may differ from past of future reports as a result of resubmissions by sources and ongoing data quality assurance activities.

Figure 3. Comparison of Emissions and Heat Input for CAIR Sources, 2000-2013

CAIR and ARP Annual NO_x Trends

	NO_x Emissions (thousand tons)					NO_x Rate (lb/mmBtu)					Heat Input (billion mmBtu)				
Primary Fuel	2000	2005	2009	2010	2013	2000	2005	2009	2010	2013	2000	2005	2009	2010	2013
Coal	4,587	3,356	1,848	1,923	1,573	0.44	0.32	0.20	0.20	0.19	20.67	20.77	18.28	19.30	16.61
Gas	354	167	143	150	128	0.18	0.06	0.04	0.04	0.03	3.88	5.49	6.80	7.28	8.16
Oil	162	104	25	24	11	0.31	0.25	0.17	0.15	0.11	1.06	0.84	0.29	0.33	0.21
Other	2	6	5	7	7	0.25	0.42	0.12	0.13	0.11	0.01	0.03	0.09	0.10	0.14
Total	**5,104**	**3,633**	**2,020**	**2,103**	**1,720**	**0.40**	**0.27**	**0.16**	**0.16**	**0.14**	**25.61**	**27.13**	**25.46**	**27.00**	**25.10**

Source EPA, 2014

Last updated: 04/2015

Notes:

- The data shown here includes emissions and heat input data for 2000 and 2005 that were reported under other programs. For facilities that were not covered by another program and did not report 2005 emissions, their reported emissions for the 2008 training year were substituted.
- Fuel type represents primary fuel type; units might combust more than one fuel.
- Totals may not reflect the sum of individual rows due to rounding.
- Each year's total emission rate does not equal the arithmetic mean of the four fuel-specific rates, as each facility influences the annual emission rate in proportion to its heat input, and heat input is unevenly distributed across the fuel categories.
- Unless otherwise noted, EPA data are current as of June 2014, and may differ from past of future reports as a result of resubmissions by sources and ongoing data quality assurance activities.

Figure 4. CAIR and ARP Annual NO_x Trends

Ozone Season Nitrogen Oxides (NO_x)

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

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

Analysis and Background Information

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

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

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

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

Key Points

Ozone Season NO_x Trends

- Units in the CAIR NO_x ozone season program emitted 470,000 tons in 2013, a 1.6 million ton reduction from 1990 (77 percent reduction), 980,000 tons lower (67 percent reduction) than in 2000 (before implementation of the NBP), 330,000 tons lower than in 2005 (41 percent reduction), and about 40,000 tons lower than in 2012 (8 percent reduction).
- In 2013 CAIR NO_x ozone season emissions were 16 percent below the regional emission budget of 567,744 tons.
- In 2013, sources from both CAIR and the former NBP, together with a small number of sources that were previously in the NBP but did not enter CAIR, reduced their overall NO_x emissions from

820,000 tons in 2005 (before implementation of CAIR) to 480,000 tons in 2013 (41 percent reduction).

Ozone Season NO_x State-by-State Emission Maps

- Between 2005 and 2013, ozone season NO_x emissions from CAIR and former NBP sources fell in every state participating in the CAIR NO_x ozone season program except Arkansas and Pennsylvania, where emissions increased by a total of 11,000 tons.
- Nineteen states and D.C. had emissions below their CAIR allowance budgets, collectively by about 120,000 tons. Another six states exceeded their 2013 budgets by a total of about 30,000 tons, indicating that, on an aggregate basis, sources within those states covered a portion of their emissions with allowances banked from earlier years, transferred from an out-of-state account, or purchased from the market.

Ozone Season NO_x Emission Rates

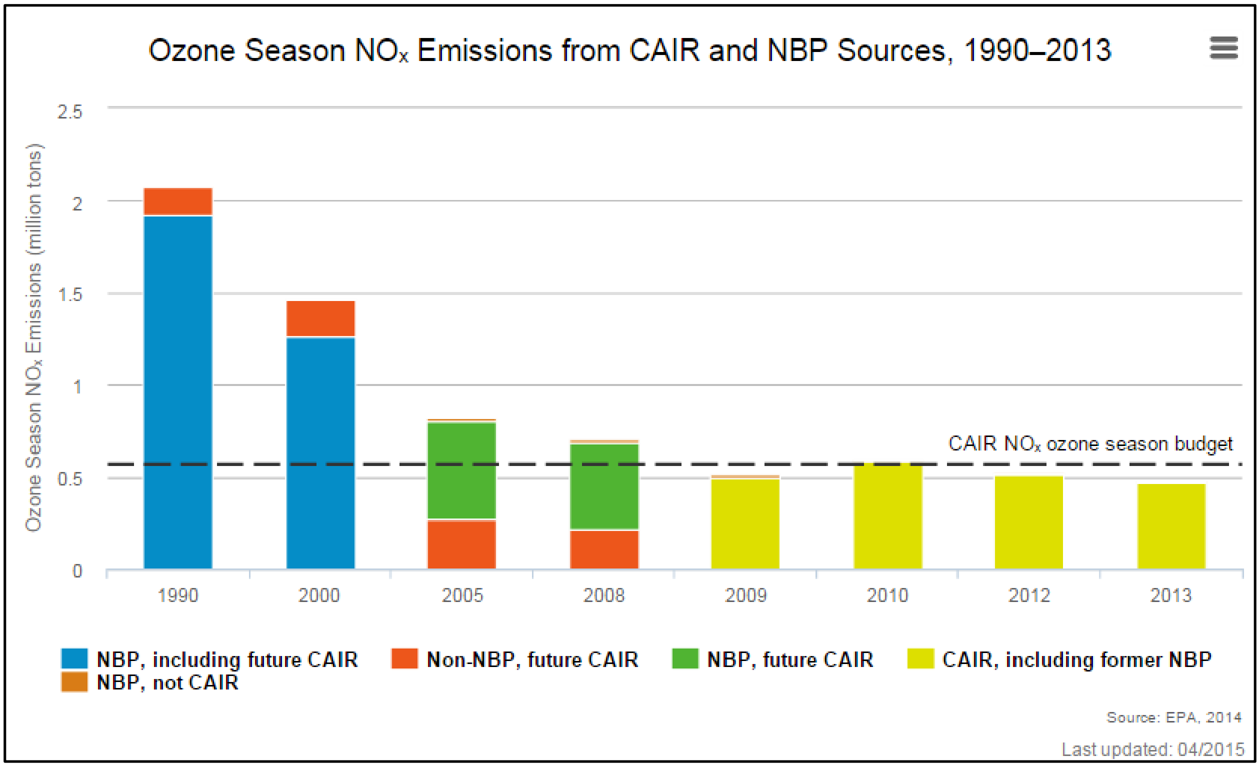
- In 2013 the NO_x ozone season emission rate fell to 0.13 lb/mmBtu. This indicates a 68 percent reduction from 2000 emission rates, with the majority of reductions from coal-fired units.
- Despite the dramatic decrease in tons of ozone season NO_x emissions, heat input has remained relatively constant, indicating an improvement in 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.

More Information

Visit EPA's Power Plant Emission Trends site for the most up-to-date emissions and control data for sources in CAIR and the ARP http://www.epa.gov/airmarkets/progress/datatrends/index.html
Learn more about nitrogen oxides (NO_x) http://www.epa.gov/air/nitrogenoxides/
Learn more about Particulate Matter (PM) http://www.epa.gov/pm/
Learn more about Ozone http://www.epa.gov/air/ozonepollution/

Figures

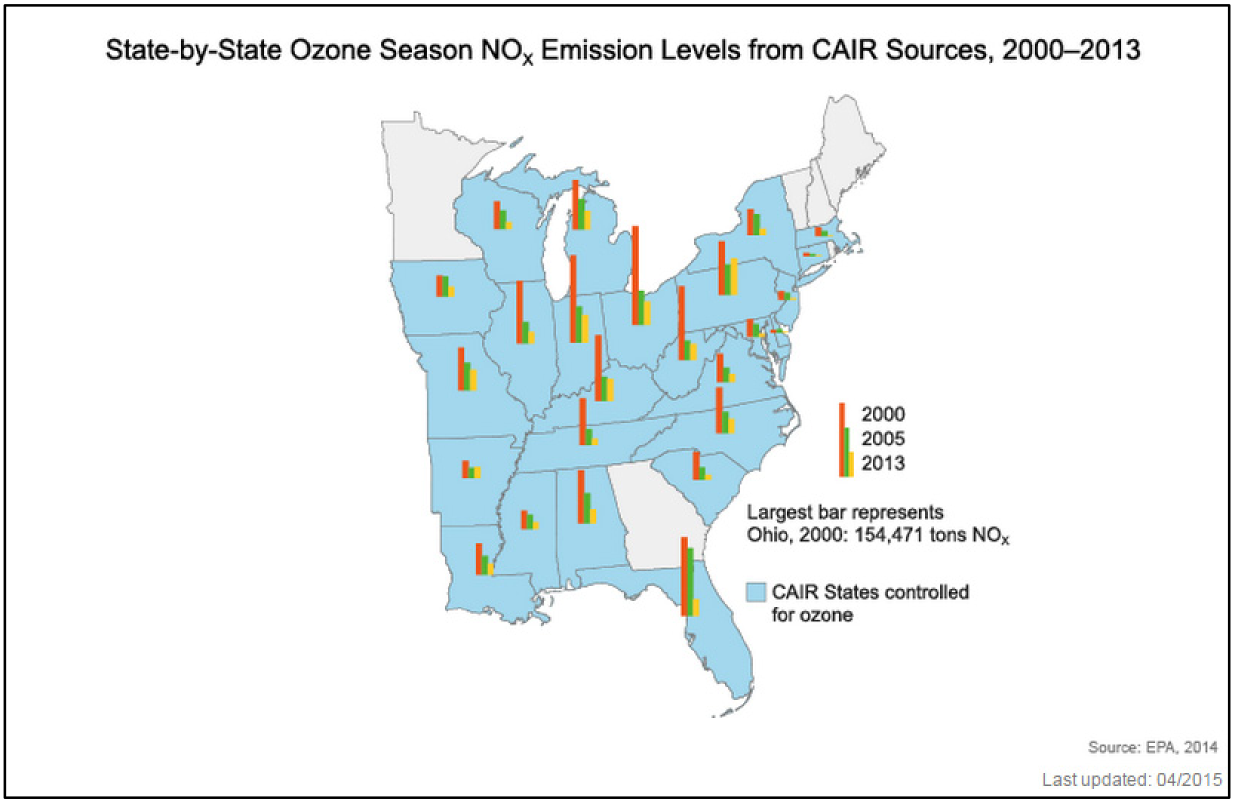
Subtopic: Ozone Season Nitrogen Oxides (NO_x)



Notes:

- For CAIR units not in the NBP, the 2008 emissions were applied retroactively to 1990 and 2000 if the unit operated in the previous year's ozone season.

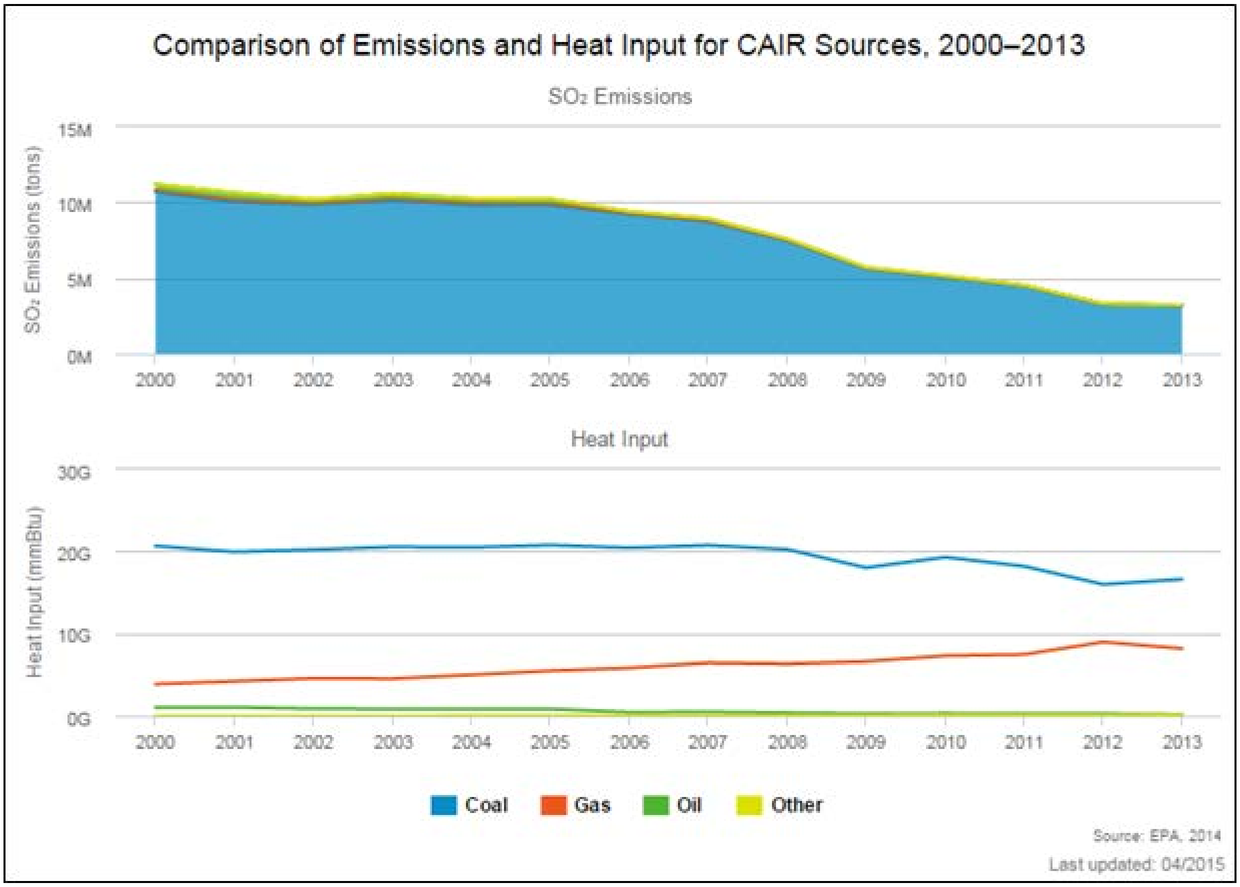
Figure 1. Ozone Season NO_x Emissions from CAIR and NBP Sources, 1990-2013



Notes:

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

Figure 2. State-by-State Ozone Season NO_x Emission Levels from CAIR Sources, 2000-2013



Notes:

- The data shown here include emissions and heat input data for 2000 and 2005 that were reported under other programs. For facilities that were not covered by another program and did not report 2005 emissions, their reported emissions for the 2008 training year were substituted.
- Fuel type represents primary fuel type; units might combust more than one fuel.
- Unless otherwise noted, EPA data are current as of June 2014, and may differ from past of future reports as a result of resubmissions by sources and ongoing data quality assurance activities.

Figure 3. Comparison of Emissions and Heat Input for CAIR Sources, 2000-2013

CAIR Ozone Season NO_x Trends

	NO_x Emissions (thousand tons)					NO_x Rate (lb/mmBtu)					Heat Input (billion mmBtu)				
Primary Fuel	2000	2005	2009	2010	2013	2000	2005	2009	2010	2013	2000	2005	2009	2010	2013
Coal	1,395	692	442	527	428	0.45	0.22	0.17	0.18	0.18	6.17	6.30	5.21	5.85	4.81
Gas	78	58	39	49	37	0.17	0.08	0.05	0.05	0.04	0.92	1.54	1.58	2.02	2.08
Oil	66	57	13	16	7	0.27	0.25	0.17	0.15	0.11	0.48	0.45	0.15	0.22	0.12
Other	1	2	2	2	3	0.15	0.17	0.14	0.12	0.10	0.02	0.02	0.02	0.04	0.05
Total	**1,541**	**809**	**495**	**594**	**474**	**0.41**	**0.20**	**0.14**	**0.15**	**0.13**	**7.59**	**8.31**	**6.98**	**8.13**	**7.07**

Source EPA, 2014

Last updated: 04/2015

Notes:

- The data shown here include emissions and heat input data for 2000 and 2005 that were reported under other programs. For facilities that were not covered by another program and did not report 2005 emissions, their reported emissions for the 2008 training year were substituted.
- Fuel type represents primary fuel type; units might combust more than one fuel.
- Totals may not reflect the sum of individual rows due to rounding.
- Each year's total emission rate does not equal the arithmetic mean of the four fuel-specific rates, as each facility influences the annual emission rate in proportion to its heat input, and heat input is unevenly distributed across the fuel categories.
- Unless otherwise noted, EPA data are current as of June 2014, and may differ from past of future reports as a result of resubmissions by sources and ongoing data quality assurance activities.

Figure 4. CAIR NO_x Ozone Season Trends

Chapter 4: Emission Controls and Monitoring

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

Analysis and Background Information

Continuous Emission Monitoring Systems (CEMS)

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

SO_2 Controls

Sources in the ARP and CAIR SO_2 annual program have a number of SO_2 control options available. These include switching to low sulfur coal, employing various types of flue gas desulfurization technologies (FGDs), or utilizing fluidized bed limestone units. FGDs on coal-fired generators are the principal means of controlling SO_2 and tend to be present on the highest generating coal-fired generating units.

NO_x Controls

Sources have a variety of options by which to reduce NO_x emissions, including advanced controls like selective catalytic reduction (SCR) or selective non-catalytic reduction (SNCR), combustion controls, and others. While some CAIR units with low levels of emissions do not have to use CEMS, the vast majority of NO_x emissions—over 99 percent—were measured by CEMS.

Key Points

ARP and CAIR SO_2 Annual Program Controls

- Of all coal-fired generation (measured in megawatt hours, MWh) from sources participating in the ARP and CAIR SO_2 annual program, 70 percent was produced by units with pollution controls.
- Flue-gas desulfurization (FGD) controlled units accounted for 49 percent of coal-fired units and 69 percent of coal-fired generation.
- Sixty six percent of units, accounting for 37 percent of energy generation, primarily use natural gas, oil, or other fuel sources, and make up one percent of SO_2 emissions.

- In 2013, CEMS monitored over 99 percent of SO_2 emissions from CAIR sources, including 100 percent from coal-fired units and 24 percent from oil-fired units.

CAIR NO_x Annual Program Controls

- The 376 coal-fired units with add-on controls (either SCRs or SNCRs) generated 64 percent of annual coal-fired generation. At oil- and natural gas-fired units, SCR- and SNCR- controlled units produced 70 percent of generation.
- Although 61 coal-fired units remain uncontrolled, they represent one percent of coal-fired generation under the CAIR NO_x annual program.

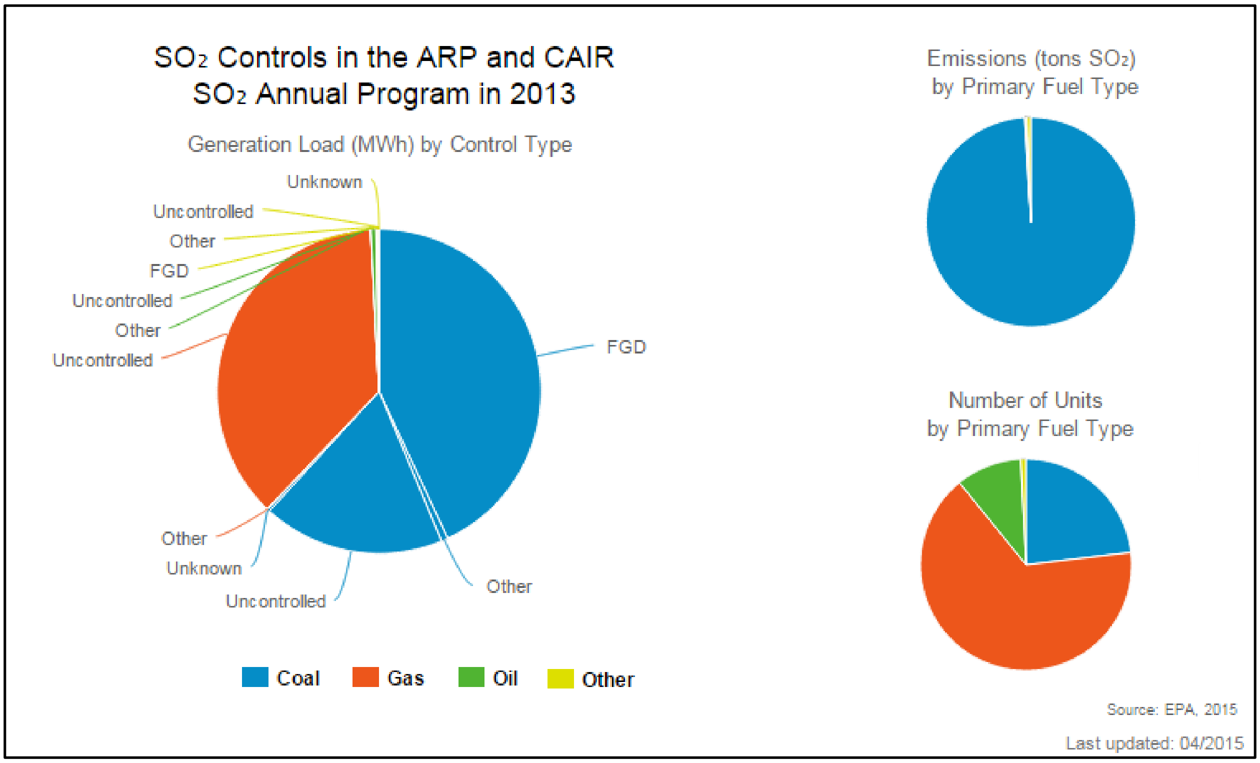
CAIR NO_x Ozone Season Program Controls

- Selective catalytic reduction (SCR) or selective non-catalytic reduction (SNCR) accounted for 65 percent of coal-fired generation. At oil- and natural gas-fired units, SCR- and SNCR- controlled units produced 72 percent of generation.
- Although 77 coal-fired units remain uncontrolled, they represent one percent of coal-fired generation under the CAIR NO_x ozone season program.

More Information

Visit EPA's Quarterly Emissions Tracking site for the most up-to-date emissions and control data for sources in CAIR and the ARP http://www.epa.gov/airmarkets/quarterlytracking.html
Air Markets Program Data http://ampd.epa.gov/ampd/
Emissions Monitoring http://epa.gov/airmarket/participants/monitoring/index.html
Learn more about CEMS http://www.epa.gov/ttnemc01/cem.html
Plain English guide to 40 CRF Part 75
http://epa.gov/airmarket/documents/monitoring/plain_english_guide_part75_rule.pdf

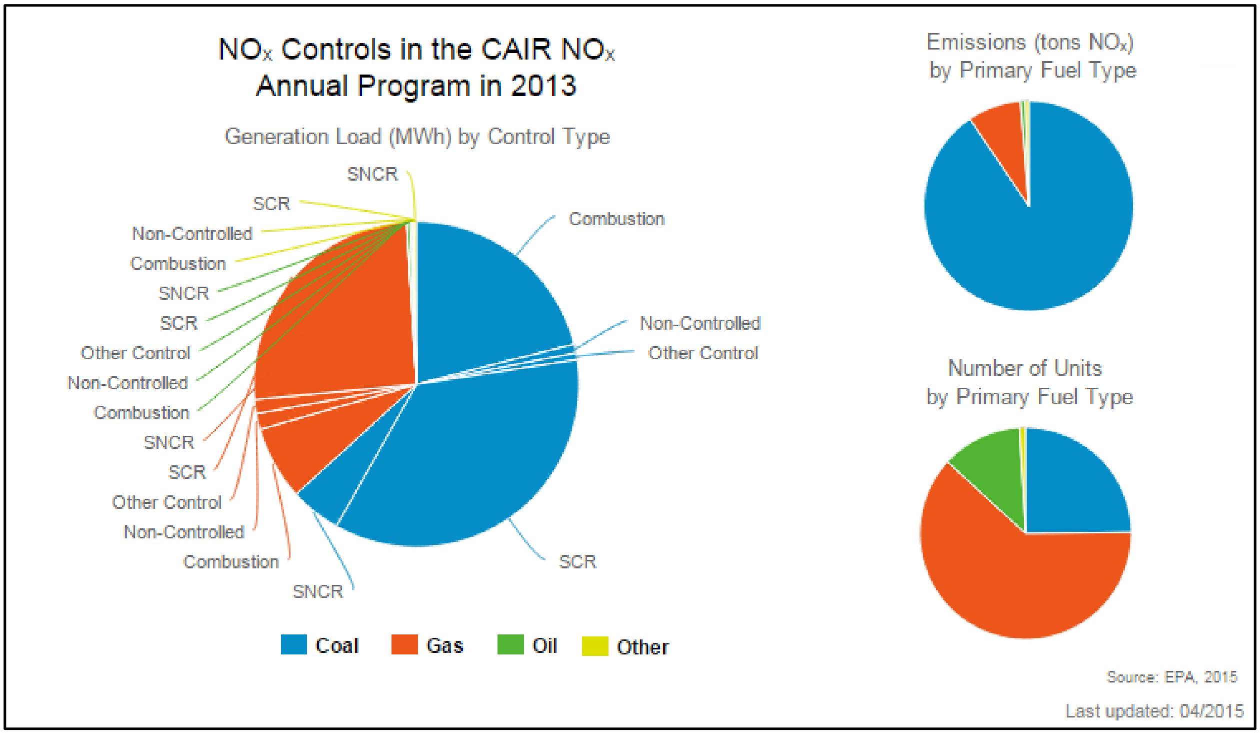
Figures



Notes:

- Due to rounding, percentages shown may not add up to 100%.
- "FGD" refers to Flue-gas desulfurization; "Other" fuel refers to units that burn waste, wood, petroleum coke, tire-derived fuel, etc.; "Unknown" is counted as uncontrolled.
- Emissions data collected and reported using CEMS.
- EPA data in this figure are current as of March 2015, and may differ from past or future reports as a result of resubmissions by sources and ongoing data quality assurance activities.

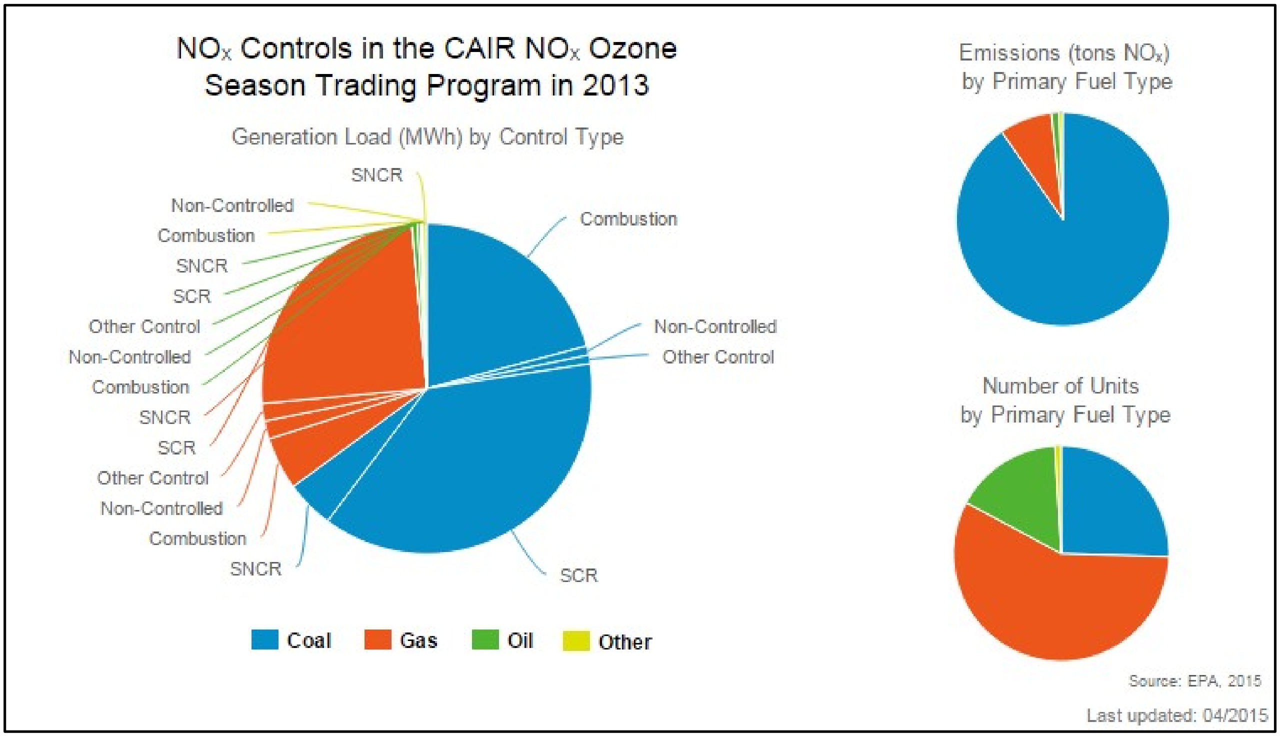
Figure 1. SO_2 Controls in the ARP and CAIR SO_2 Annual Program in 2013



Notes:

- Due to rounding, percentages shown may not add up to 100%.
- "SCR" refers to selective catalytic reduction; "SNCR" fuel refers to selective non-catalytic reduction; "Other" fuel refers to units that burn waste, wood, petroleum coke, tire-derived fuel, etc.
- Emissions data collected and reported using CEMS.
- EPA data in this figure are current as of March 2015, and may differ from past or future reports as a result of resubmissions by sources and ongoing data quality assurance activities.

Figure 2. NO_x Controls in the CAIR NO_x Annual Program in 2013



Notes:

- Due to rounding, percentages shown may not add up to 100%.
- "SCR" refers to selective catalytic reduction; "SNCR" fuel refers to selective non-catalytic reduction; "Other" fuel refers to units that burn waste, wood, petroleum coke, tire-derived fuel, etc.
- Emissions data collected and reported using CEMS.
- EPA data in this figure are current as of March 2015, and may differ from past or future reports as a result of resubmissions by sources and ongoing data quality assurance activities.

Figure 3. NO_x Controls in the CAIR NO_x Ozone Season Program in 2013

Chapter 5: Program Compliance

This analysis shows how ARP and CAIR allowances are used for compliance under the trading programs in 2013. Because SO_2 allowances from the ARP are used by sources to comply with the CAIR SO_2 annual program, compliance results for both programs are displayed together.

Analysis and Background Information

2013 was the fourth year for compliance with the CAIR SO_2 program. Under this program, allowances are used to cover emissions based on the vintage year of the allowances, with pre–2010 vintage allowances used at 1 allowance for 1 ton of SO_2 emissions, and 2010 - 2013 vintage allowances used at 2 allowances for 1 ton of SO_2 emissions. For facilities covered by both CAIR and the ARP, reconciliation is a two-step process. First, ARP deductions are made. Then, any additional deductions to comply with the CAIR SO_2 program are made. The additional deductions under CAIR could be used to cover the 2 for 1 use of 2010 - 2013 allowances or to cover emissions for units that are subject to CAIR, but not the ARP.

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

Key Points

ARP and CAIR SO_2 Programs

- The reported 2013 SO_2 emissions by CAIR and ARP sources totaled 3,241,593 tons (see Analysis section).
- Over 30.1 million SO_2 allowances were available for compliance under both programs (9 million vintage 2013 and over 21.1 million banked from prior years).
- Just over 3.2 million allowances were deducted for ARP compliance and an additional 2.4 million allowances were deducted to complete reconciliation for CAIR. After reconciliation for both programs, over 24.5 million ARP SO_2 allowances were banked and carried forward to the 2014 compliance year.
- One ARP and CAIR SO_2 facility was out of compliance with both programs in 2013 and had excess emissions of 4 tons.

CAIR NO_x Annual Program

- The reported 2013 annual NO_x emissions by CAIR sources totaled 1,174,853 tons (see Analysis section).
- All covered facilities were in compliance with the CAIR NO_x annual program and held enough allowances to cover their NO_x emissions.

CAIR NO_x Ozone Season Program

- The reported 2013 NO_x ozone season emissions by CAIR sources totaled 474,232 tons (see Analysis section).
- One facility was out of compliance with the CAIR NO_x ozone season program and had one ton of excess emissions.

More Information

Allowance Markets http://www.epa.gov/airmarkets/participants/allowance/index.html
Air Markets Business Center http://www.epa.gov/airmarkets/participants/business/index.html
Air Markets Program Data http://ampd.epa.gov/ampd/

Figures

CAIR and ARP SO_2 Allowance Reconciliation Summary, 2013

Total Allowances Held (1995–2013 Vintage)	**30,142,693**	Held by Affected Facility Accounts	**20,819,014**
		Held by Other Accounts (General and Non-Affected Facilities)	**9,323,679**
Allowances Deducted for Acid Rain Compliance*	-3,217,365		
Penalty Allowance Deductions	4		
Banked Allowances (after ARP Compliance)	**26,925,324**	Held by Affected Facility Accounts	**17,601,645**
		Held by Other Accounts (General and Non-Affected Facilities)	**9,323,679**
Acid Rain Program Allowances Deducted for CAIR	-2,418,304		
Banked Allowances (after ARP and CAIR SO_2)	**24,507,020**	Held by Affected Facility Accounts	**15,183,341**
		Held by Other Accounts (General and Non-Affected Facilities)	**9,323,679**

ARP and CAIR SO_2 Programs Compliance Results

Reported emissions (tons)	**3,241,593**
Compliance issues, rounding, and report resubmission adjustments (tons)	**-34,035**
Emissions not covered by allowances (tons)	**-4**
Additional vintage 2010 - 2013 allowances deducted for CAIR	**+2,418,304**
Total allowances deducted for emissions (includes some 2 for 1 CAIR deductions)	**5,625,858**

Source EPA, 2014

Last updated: 04/2015

Notes:

- *Allowance Deducted for ARP Compliance includes 9,811 allowances deducted from opt-ins for reduced utilization.
- Compliance emissions data may vary from other report sections as a result of variation in rounding conventions, changes due to resubmissions by sources, or allowance compliance issues at certain units.
- Reconciliation and Compliance data as of June 2014, and subsequent adjustments of penalties are not reflected.

Figure 1. CAIR and ARP SO_2 Allowance Reconciliation Summary, 2013

CAIR NO_x Annual Allowance Reconciliation Summary, 2013

Total Allowances Held (2009–2013 Vintage)	2,314,310	Held by Affected Facility Accounts	2,047,627
		Held by Other Accounts (General, State Holding, and Non-Affected Facilities)	266,683
Allowances Deducted for CAIR NO_x Annual Trading Program	1,175,069		
Penalty Allowance Deductions	0		
Banked Allowances	1,139,241	Held by Affected Facility Accounts	872,558
		Held by Other Accounts (General, State Holding, and Non-Affected Facilities)	266,683

CAIR NO_x Annual Program

Reported emissions (tons)	1,174,853
Compliance issues, rounding, and report resubmission adjustments (tons)	+216
Emissions not covered by allowances (tons)	0
Total allowances deducted for emissions	1,175,069

Source EPA, 2014

Last updated: 04/2015

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 as of June 2014, and subsequent adjustments of penalties are not reflected.

Figure 2. Affected Units in the CAIR and ARP Programs, 2013

CAIR NO_x Ozone Season Allowance Reconciliation Summary

Total Allowances Held (2003–2013 Vintage)	**1,147,408**	Held by Affected Facility Accounts	**942,100**
		Held by Other Accounts (General, State Holding, and Non-Affected Facilities)	**205,308**
Allowances Deducted for CAIR NO_x Ozone Season Trading Program	-474,566		
Penalty Allowance Deductions	-3		
Banked Allowances	**672,839**	Held by Affected Facility Accounts	**467,531**
		Held by Other Accounts (General, State Holding, and Non-Affected Facilities)	**205,308**

CAIR NO_x Ozone Season

Reported emissions (tons)	**474,232**
Compliance issues, rounding, and report resubmission adjustments (tons)	**+335**
Emissions not covered by allowances (tons)	**-1**
Total allowances deducted for emissions	**474,566**

Source EPA, 2014

Last updated: 04/2015

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 as of June 2014, and subsequent adjustments of penalties are not reflected.

Figure 3. CAIR NO_x Ozone Season Allowance Reconciliation Summary

Chapter 6: Market Activity

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

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

Analysis and Background Information

Transaction Types and Volumes

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

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

- Transfers between separate and distinct economic entities, 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 unit compliance account and any account held by a company with an ownership interest in the unit).

Allowance Markets

The 2013 emissions were below emission budgets for the ARP and for all three CAIR programs. As a result, CAIR allowance prices were well below the marginal cost for reductions projected at the time of the final rule, and are in part subject to downward pressure from the available banks of allowances.

Overall, allowance prices remained relatively stable throughout 2013, with only the NO_x ozone season allowances increasing in cost during the ozone season.

Key Points

Transaction Types and Volumes

- In 2013, about one quarter of CAIR NO_x ozone season program allowance transactions and about a third of ARP and CAIR SO_2 annual and CAIR NO_x annual allowance transactions were between unrelated parties, often with a broker facilitating the trade.

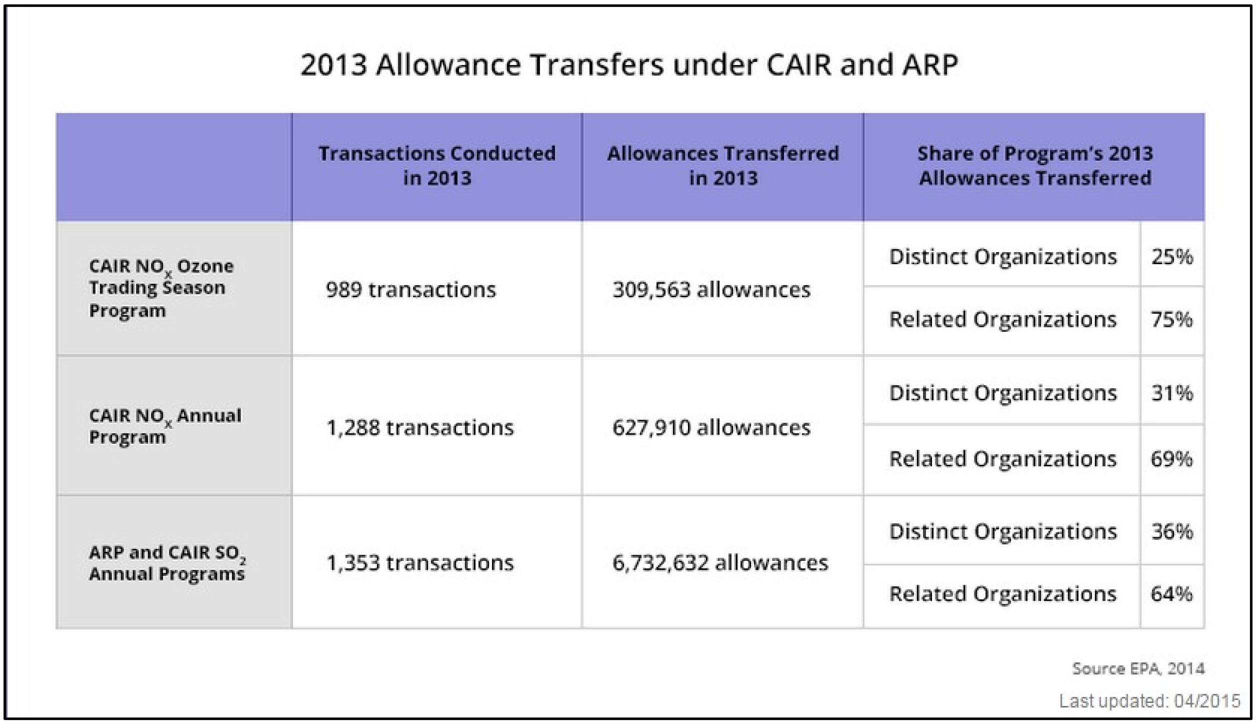
2013 Allowance Market Prices

- CAIR SO_2 allowance prices averaged less than $1 per ton.
- CAIR NO_x annual program allowances averaged $40 per ton.
- CAIR NO_x ozone season program allowances averaged $17 per ton.

More Information

Allowance Markets http://www.epa.gov/airmarkets/participants/allowance/index.html
Air Markets Business Center http://www.epa.gov/airmarkets/participants/business/index.html
Air Markets Program Data http://ampd.epa.gov/ampd/

Figures



2013 Allowance Transfers under CAIR and ARP

	Transactions Conducted in 2013	Allowances Transferred in 2013	Share of Program's 2013 Allowances Transferred	
CAIR NO_x Ozone Trading Season Program	989 transactions	309,563 allowances	Distinct Organizations	25%
			Related Organizations	75%
CAIR NO_x Annual Program	1,288 transactions	627,910 allowances	Distinct Organizations	31%
			Related Organizations	69%
ARP and CAIR SO_2 Annual Programs	1,353 transactions	6,732,632 allowances	Distinct Organizations	36%
			Related Organizations	64%

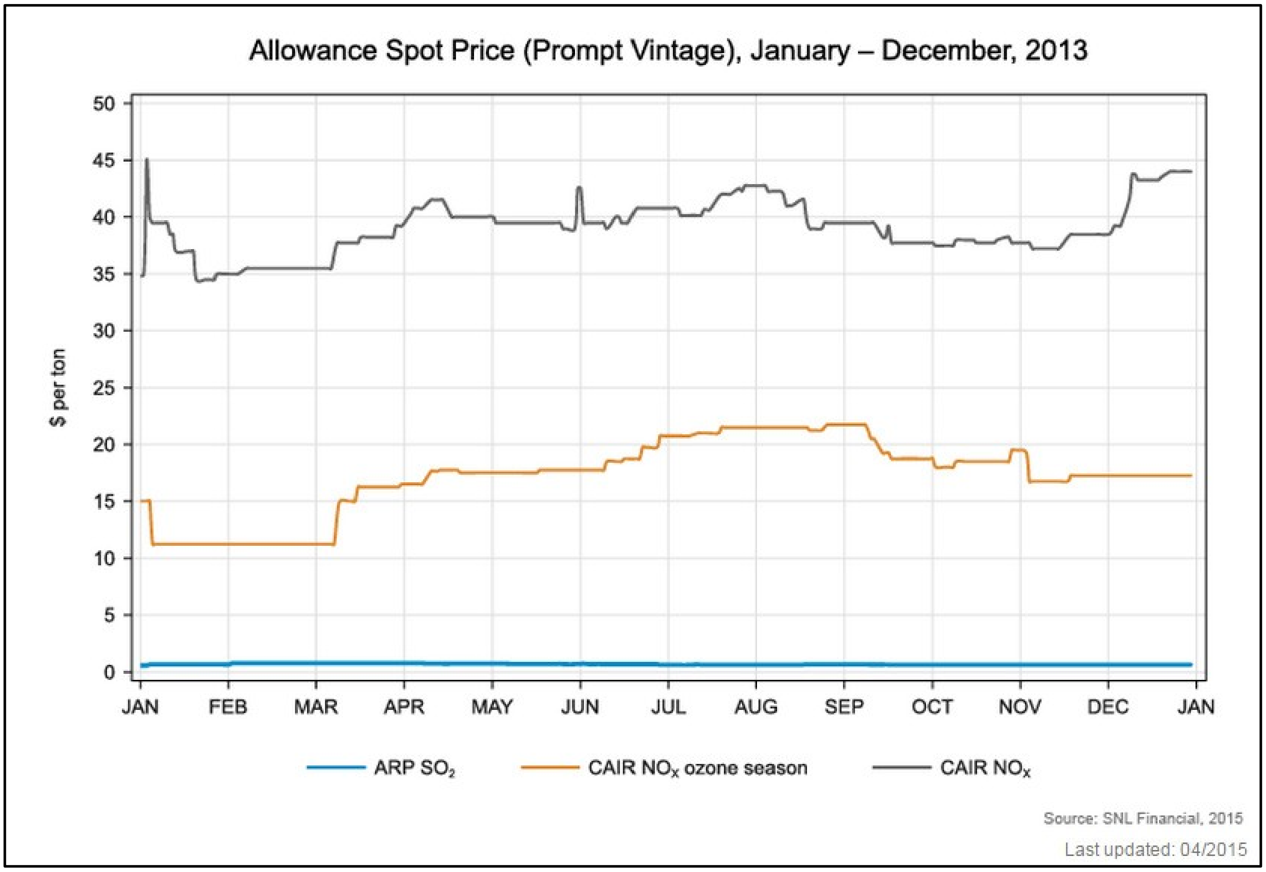
Source EPA, 2014

Last updated: 04/2015

Notes:

- Most, but not all, of the transactions were characterized. The actual percentage shares may vary by less than 1% of the total allowances transferred for each program.
- Percentages may not add up to 100% due to rounding.

Figure 1. 2013 Allowance Transfers under CAIR and ARP



Notes:

- Prompt vintage is the vintage for the "current" compliance year.

Figure 2. Allowance Spot Price, January-December, 2013

Chapter 7: Ambient Air Quality

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

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

Sulfur Dioxide and Nitrogen Oxides Trends

Analysis and Background Information

Sulfur Dioxide

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

Nitrogen Oxides

NO_x is a group of highly reactive gases including nitric oxide (NO) and nitrogen dioxide (NO_2). In addition to contributing to the formation of ground-level ozone and $PM_{2.5}$, NO_x is linked with a number of adverse health effects on the respiratory system.[2, 3] NO_x also reacts in the atmosphere to form nitric acid (HNO_3) and particulate ammonium nitrate (NH_4NO_3). Nitric acid 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, NO_x State Implementation Plan (SIP) Call, and CAIR NO_x programs have contributed to significant NO_x reductions, primarily from electricity generating units, and improvements in air quality, emissions from other sources (such as motor vehicles and agriculture) contribute to ambient nitrate concentrations in many areas. Ambient nitrate levels can also be affected by emissions transported via air currents over wide regions.

Key Points

National SO_2 Air Quality

- Based on EPA's air trends data, the national average of SO_2 annual mean ambient concentrations decreased from 12.1 ppb to 1.5 ppb (87 percent) between 1980 and 2013.
- The two largest single-year reductions (over 20 percent) occurred in the first year of the ARP, between 1994 and 1995, and 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 all regions following implementation of the ARP and other emission reduction programs. The most dramatic decline was along the Ohio River Valley and in western Pennsylvania where regional average concentrations declined 86 percent from 1989-1991 to 2011-2013 observation periods.
- Ambient particulate sulfate concentrations have decreased since the ARP was implemented, with average concentrations decreasing by 60 to 65 percent in observed regions from 1989-1991 to 2011-2013.
- Average annual ambient total nitrate concentrations declined 47 percent from 1989 -1991 to 2011-2013, with the biggest reductions in the Mid-Atlantic and Northeast.

More Information

Clean Air Status and Trends Network (CASTNET) http://epa.gov/castnet/javaweb/index.html
Air Quality System (AQS) http://www.epa.gov/aqs
Learn more about National Ambient Air Quality Standards http://www3.epa.gov/ttn/naaqs/criteria.html
Learn more about SO_2 http://www.epa.gov/oaqps001/sulfurdioxide/
Learn more about NO_x http://www.epa.gov/airquality/nitrogenoxides/
Learn more about EPA's Clean Air Market Programs http://www.epa.gov/airmarkets/programs

References

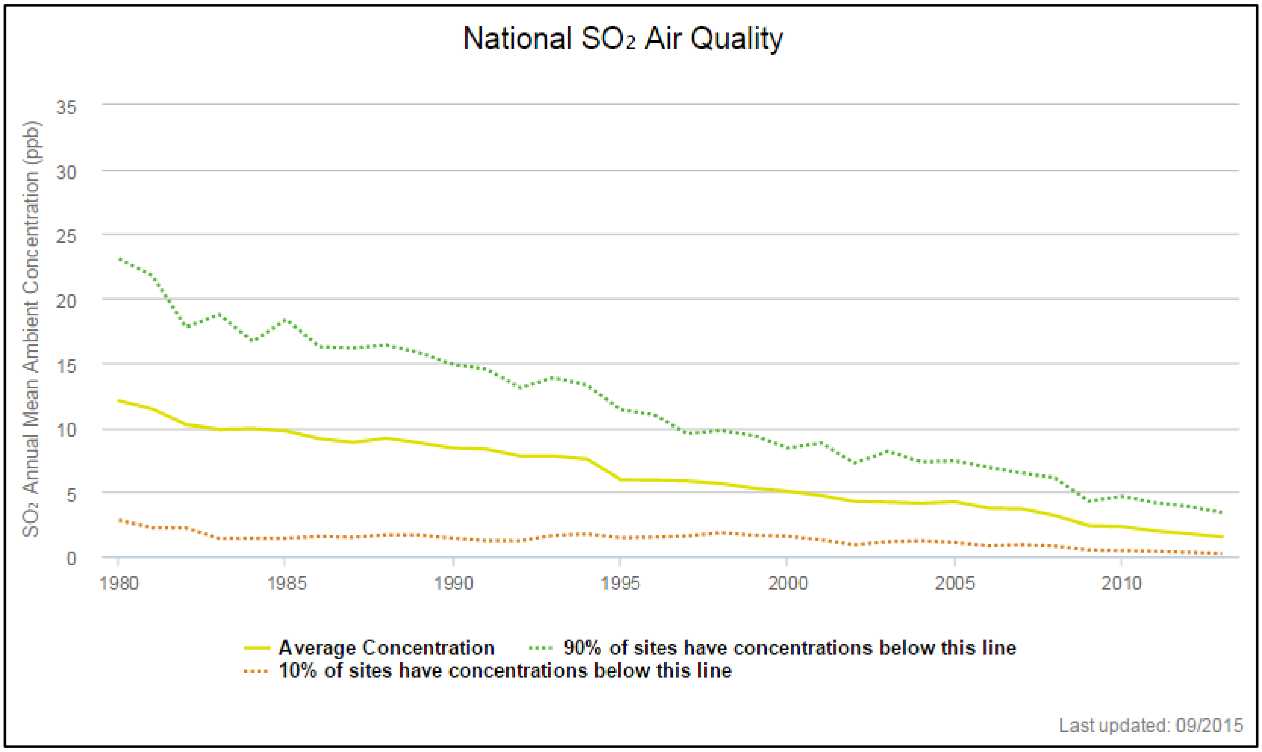
1. U.S. Environmental Protection Agency (U.S. EPA). 2009. Acid Rain and Related Programs: 2008 Emission, Compliance, and Market Analyses Progress Report. September.

2 U.S. Environmental Protection Agency (U.S. EPA). 2009. The NO_x Budget Trading Program: 2008 Environmental Results Progress Report. September.

3. U.S. Environmental Protection Agency (U.S. EPA). 2011. EPA's NO_x Reduction Program and Clean Air Interstate Rule 2009 Environmental and Health Results Progress Report. January.

Figures

Subtopic: Sulfur Dioxide and Nitrogen Oxides Trends



Notes:

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

Figure 1. National SO_2 Air Quality

Regional Changes in Air Quality

Measurement	Region	Annual Average, 1989-1991	Annual Average, 2011-2013	Percent Change	Number of Sites	Statistical Significance
Ambient particulate sulfate concentration (μg/m³)	Mid-Atlantic	6.3	2.4	-62	12	***
	Midwest	5.8	2.3	-60	9	***
	Northeast	3.4	1.2	-65	4	
	Southeast	5.5	2.1	-62	8	***
Ambient sulfur dioxide concentration (μg/m³)	Mid-Atlantic	13.0	2.0	-85	12	***
	Midwest	11.0	2.3	-79	9	***
	Northeast	5.2	0.7	-87	4	
	Southeast	5.1	0.9	-82	8	***
Ambient total nitrate concentration (μg/m³)	Mid-Atlantic	3.3	1.7	-48	12	***
	Midwest	4.6	2.7	-41	9	***
	Northeast	1.7	0.8	-53	4	
	Southeast	2.2	1.2	-45	8	***

Source EPA, 2014

Last updated: 09/2015

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 ($p < 0.05$). Changes that are not statistically significant may be unduly influenced by measurements at only a few locations or large variability in measurements.

Figure 2. Regional Changes in Air Quality

Ozone

Analysis and Background Information

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

Ozone Standards

In 1979, EPA established the NAAQS for 1-hour ozone at 12ppb, and in 1997, a more stringent daily maximum 8-hour ozone standard of 80 ppb was promulgated, revising the 1979 standard. CAIR was promulgated to help downwind states in the eastern U.S. achieve the 1997 ozone NAAQS set at 80 ppb, and therefore analyses in this report focus on that standard. In March 2008, EPA changed the daily maximum 8-hour ozone standard to 75 ppb and on October 1, 2015, the EPA strengthened the NAAQS for ground-level ozone to 70 ppb, based on extensive scientific evidence about ozone's effects on public health and welfare.

Regional Trends in Ozone

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

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

Meteorologically adjusted Daily Maximum 8-Hour Ozone Concentrations

Meteorologically-adjusted ozone trends provide additional insight on the influence of CAIR NO_x ozone season program emission reductions on regional air quality. Here, daily maximum 8-hour ozone concentration data from EPA and daily meteorology data from the National Weather Service were retrieved for 82 urban areas and 36 rural CASTNET monitoring sites located in the CAIR NO_x ozone season program region. EPA uses this data in a statistical model to account for the influence of weather on seasonal average ozone concentrations at each monitoring site.[6, 7]

Changes in Ozone Nonattainment Areas

The majority of ozone season NO_x emission reductions in the power sector that occur after 2003 are attributable to the NBP and CAIR. As power sector emissions are an important component of the NO_x emission inventory, it is reasonable to conclude that these NO_x ozone season reduction programs have been a significant contributor to these improvements in ozone air quality. However, because areas continue to be out of attainment for both the 1997 and 2008 ozone National Ambient Air Quality Standards (NAAQS), additional NO_x ozone season emission reductions are needed to attain EPA's health based air quality standards.

As part of an effort to help support states' obligations to address the problem of air pollution that is transported across state lines and help address the Agency's role in backstopping states' obligations under the Clean Air Act, the EPA issued the Cross-State Air Pollution Rule (CSAPR) in July 2011 to address interstate transport of ozone pollution with respect to the 1997 ozone NAAQS. Additionally, on November 16, 2015 the EPA proposed an update to the CSAPR ozone season program by issuing the CSAPR Update Rule to address interstate pollution for the newer 2008 ozone NAAQS.

Key Points

Changes in 1-Hour Ozone during Ozone Season

- An overall regional reduction in ozone levels was observed between 2000-2002 and 2011-2013, with an average reduction in ozone concentrations in CAIR states of 16 percent.
- Results demonstrate how NO_x emission reduction policies have affected ozone concentrations in the eastern United States, the region the policies were designed to target.

Trend in Rural Ozone

- The ARIMA model of rural ozone concentrations shows ozone reductions of 21 ppb (24 percent) from 1990 to 2013.
- A significant decrease of modeled ozone concentration occurred in 2003, following implementation of the NBP (11 ppb reduction from the previous year). That event was followed by an additional 10 percent (8 ppb) reduction just prior to the start of the CAIR NO_x ozone season program in 2009.

Changes in 8-Hour Ozone Concentrations

- The average reduction in ozone concentrations not adjusted for weather in the CAIR NO_x ozone season program region from 2000–2002 to 2011–2013 was about 6 ppb (11 percent).
- The average reduction in the meteorologically-adjusted ozone concentrations in the CAIR NO_x ozone season program region from 2000–2002 to 2010–2012 was about 9 ppb (15 percent).

Changes in Ozone Nonattainment Areas

- Ninety-four of the 113 designated nonattainment areas for the 1997 8-hour ozone NAAQS standard (0.08 ppm) are in the East and are home to about 122 million people.[4] The nonattainment areas were set in 2004 using 2001 to 2003 data.[5]

- Based on data from 2011 to 2013, 94 percent (88 areas) of the eastern ozone nonattainment areas show concentrations below the level of the 1997 standard while six areas show concentrations above the 1997 standard.
- Compared with the 2001-2003 period, these six eastern ozone nonattainment areas all showed improvement in the 2011-2013 period toward meeting the 1997 standard.

More Information

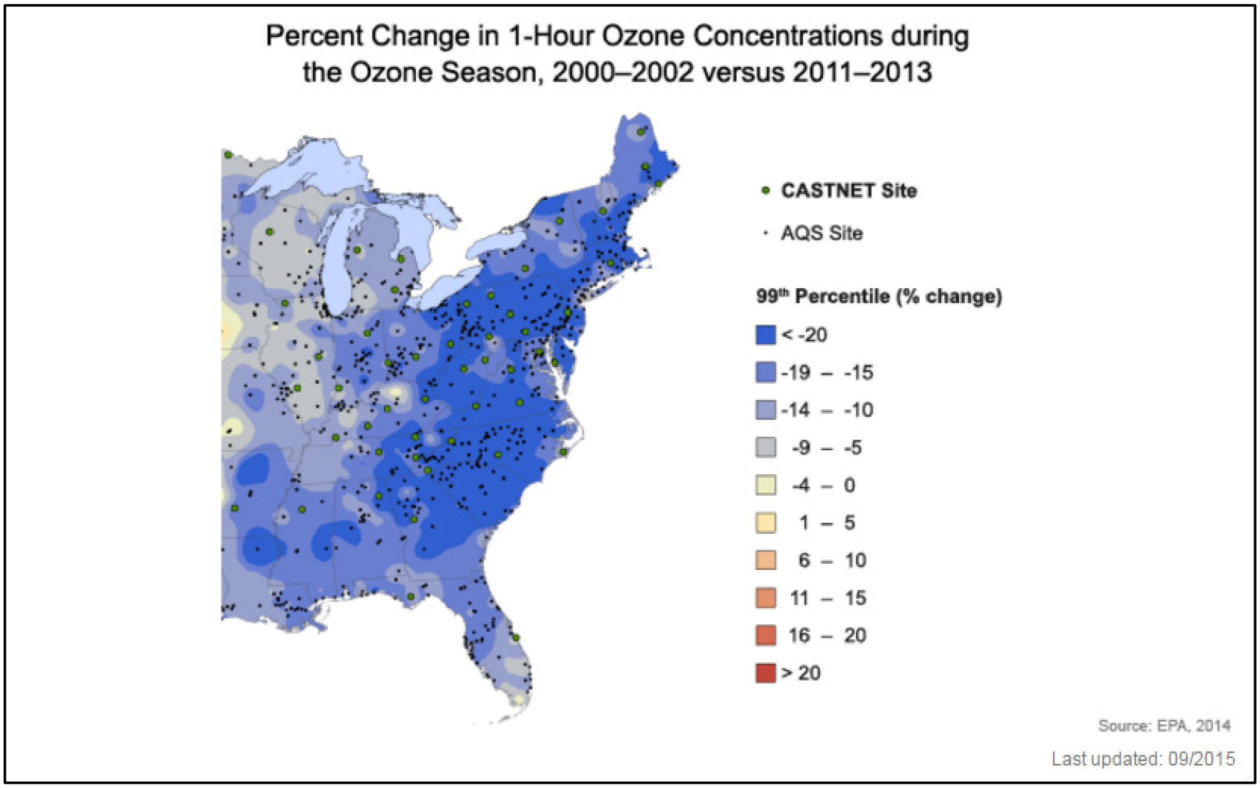
Clean Air Status and Trends Network (CASTNET) http://epa.gov/castnet/javaweb/index.html
Air Quality System (AQS) http://www.epa.gov/aqs
Learn more about oxides of nitrogen (NO_x) http://www.epa.gov/airquality/nitrogenoxides/
Learn more about ozone http://www.epa.gov/ozonepollution/
Learn more about National Ambient Air Quality Standards http://www3.epa.gov/ttn/naaqs/criteria.html
Learn more about Nonattainment Areas http://www.epa.gov/oaqps001/greenbk/
Learn more about EPA's Clean Air Market Programs http://www.epa.gov/airmarkets/programs

References

4. U.S. Census. 2010.
5. 40 CFR Part 81. Designation of Areas for Air Quality Planning Purposes.
6. Cox, W. M. & Chu, S.H. 1996. Assessment of interannual ozone variation in urban areas from a climatological perspective. *Atmospheric Environment.* 30:16, 2615–2625.
7. Camalier, L., Cox, W.M. & Dolwick, P. 2007. The effects of meteorology on ozone in urban areas and their use in assessing ozone trends. *Atmospheric Environment*. 41:33, 7127–7137.

Figures

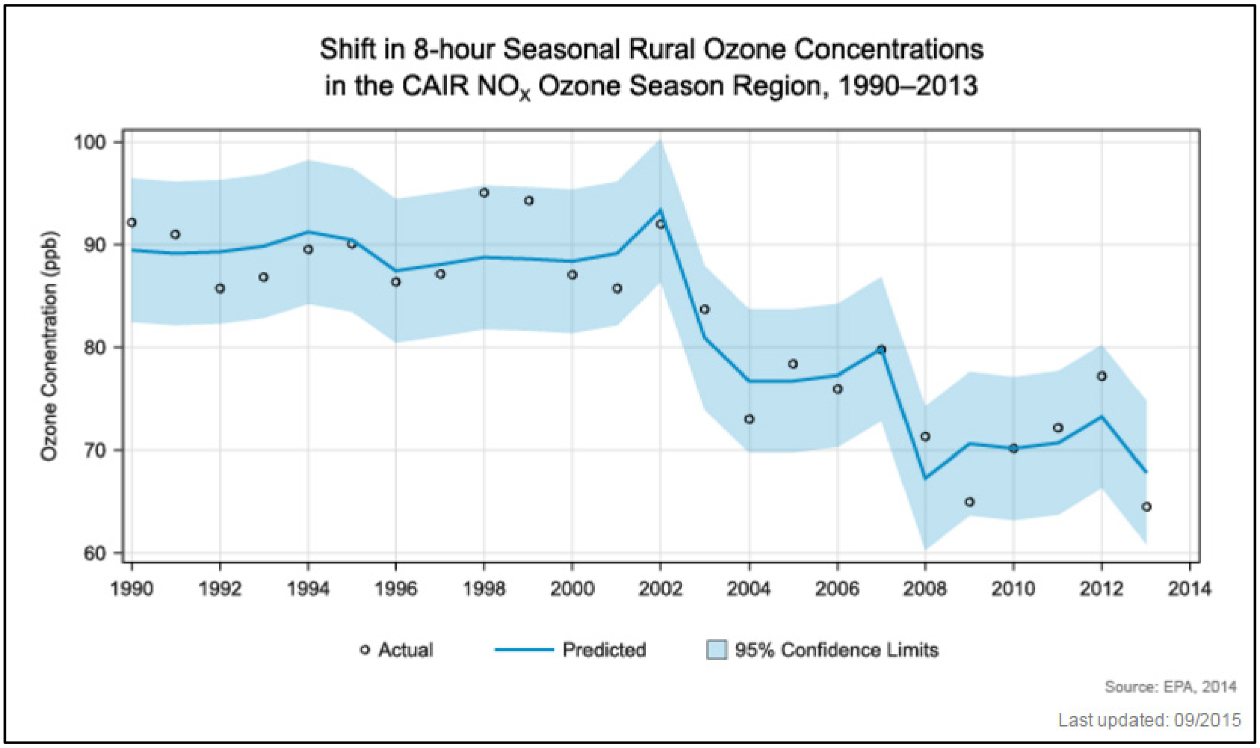
Subtopic: Ozone



Notes:

- Under CAIR, the ozone season is May 1st - September 30th.
- 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 ozone concentration for a given monitor, a value below which ninety nine percent of ozone data fall.

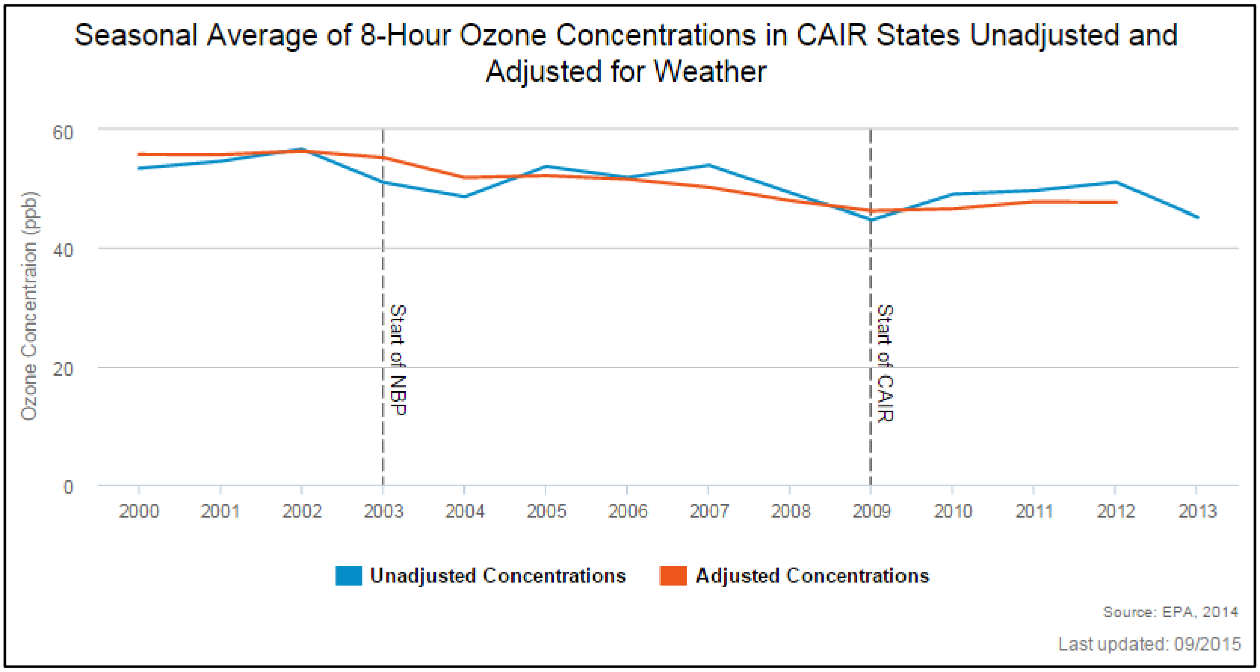
Figure 1. Percent Change in 1-Hour Ozone Concentrations during the Ozone Season, 2000–2002 versus 2011–2013



Notes:

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

Figure 2. Shift in 8-hour Seasonal Rural Ozone Concentrations in the CAIR NO_x Ozone Season Region, 1990–2013



Notes:

- 8-Hour daily maximum ozone concentration data from EPA's AQS and daily meteorology data from the National Weather Service were retrieved for 81 urban areas and 35 rural CASTNET monitoring sites located in the CAIR NO_x ozone season program region.
- For a monitor to be included in this trends analysis, it had to provide complete and valid data for 75 percent of the days in the May to September period, for each of the years from 2001 to 2013. In urban areas with more than one monitoring site, the highest observed ozone concentration in the area was used for each day.
- Meteorologically-adjusted concentration data for 2013 is currently unavailable.

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

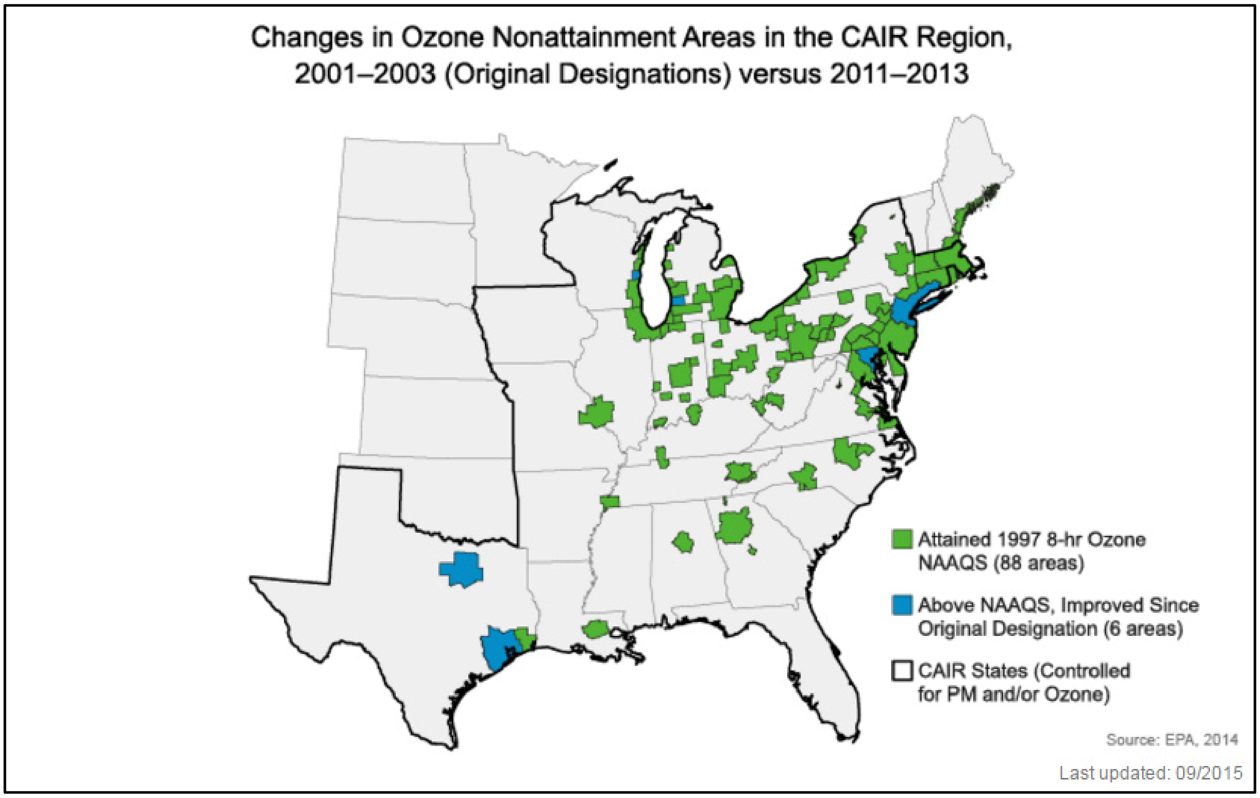


Figure 4. Changes in Ozone Nonattainment Areas in the CAIR Region, 2001–2003 (Original Designations) versus 2011–2013

Particulate Matter

Analysis and Background Information

Particulate matter—also known as 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 chemicals, metals, and soil or dust particles. Fine particles ($PM_{2.5}$) 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: increased respiratory symptoms, such as irritation of the airways, coughing, or difficulty breathing; decreased lung function; aggravated asthma; development of chronic bronchitis; irregular heartbeat; nonfatal heart attacks; and premature death in people with heart or lung disease.

Particulate Matter Standards

The CAA requires EPA to set NAAQS for particle pollution. The first PM standard for fine particles was set by EPA in 1997 at 65 micrograms per cubic meter ($\mu g/m^3$) measured as the three year average of the 98th percentile for 24-hour exposure, and at 15 $\mu g/m^3$ for annual exposure measured as the three-year annual mean. EPA revised the air quality standards for particle pollution in 2006, tightening the 24-hour fine particle standard to 35 $\mu g/m^3$ and retaining the annual fine particle standard at 15 $\mu g/m^3$. In December 2012, EPA strengthened the annual fine particle standard to 12 $\mu g/m^3$. CAIR was promulgated to help downwind states in the eastern U.S. achieve the 1997 annual average $PM_{2.5}$ NAAQS, and, therefore, analyses in this report focus on that standard.

Key Points

PM Seasonal Trends

- Average $PM_{2.5}$ concentration data were assessed from 431 urban AQS areas located in the CAIR NO_x and SO_2 annual program region. Trend lines in $PM_{2.5}$ concentrations show decreasing trends in both the warm months (April to September) and cool months (October to March) unadjusted for the influence of weather.
- The annual average $PM_{2.5}$ concentration has decreased by about 40 percent in the warm season and about 34 percent in the cool season between 2001 and 2013.

Changes in $PM_{2.5}$ Nonattainment

- Thirty-six of the 39 designated nonattainment areas for the 1997 annual average $PM_{2.5}$ standard are in the East and are home to about 75 million people.[8, 9] The nonattainment areas were set in January 2005 using 2001 to 2003 data.

- Based on data gathered from 2011 to 2013, 32 of these original eastern areas show concentrations below the level of the 1997 $PM_{2.5}$ standard (15.0 µg/m^3), indicating improvements in $PM_{2.5}$ air quality. Four areas have incomplete data.
- Given that the majority of power sector annual NO_x and SO_2 emission reductions occurring after 2003 are attributable to the ARP, NBP, and CAIR, it is reasonable to conclude that these emission reduction programs have been a significant contributor to these improvements in $PM_{2.5}$ air quality.

More Information

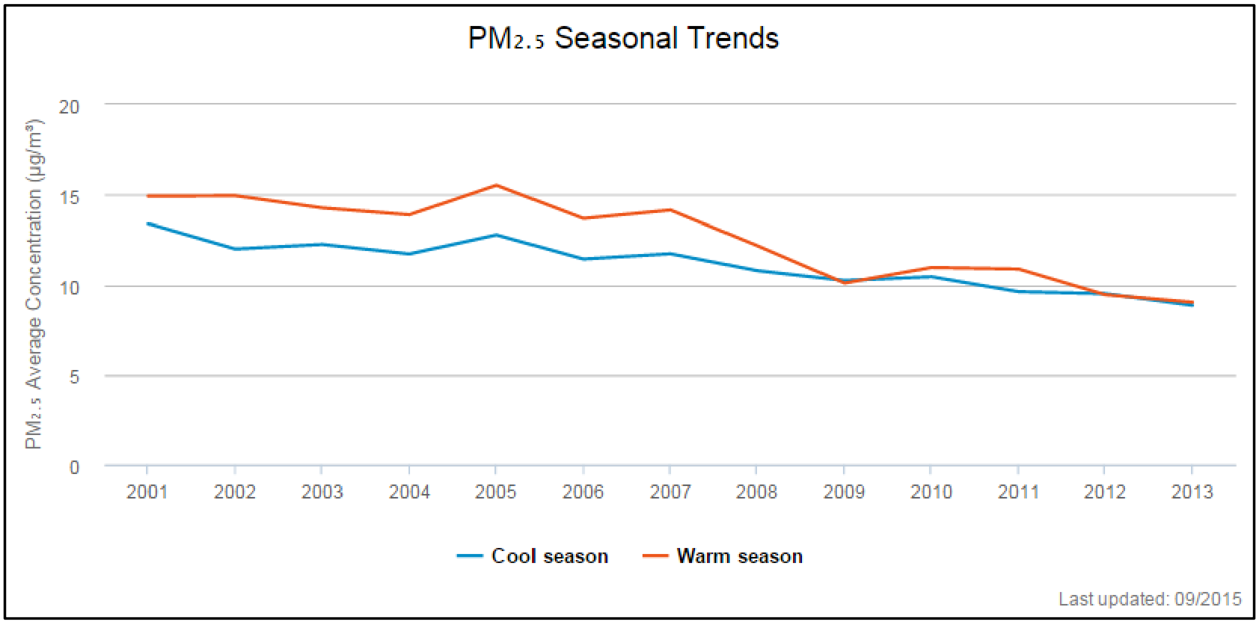
EPA's Power Plant Emission Trends page
http://www.epa.gov/airmarkets/progress/datatrends/index.html
Learn more about nitrogen oxides (NO_x) http://www.epa.gov/airquality/nitrogenoxides/
Learn more about Particulate Matter (PM) http://www.epa.gov/pm/
Learn more about National Ambient Air Quality Standards http://www3.epa.gov/ttn/naaqs/criteria.html
Learn more about EPA's Clean Air Market Programs http://www.epa.gov/airmarkets/programs

References

8. 40 CFR Part 81. Designation of Areas for Air Quality Planning Purposes.
9. U.S. Census. 2010.

Figures

Subtopic: Particulate Matter



Notes:

- For a $PM_{2.5}$ monitoring site to be included in the trends analysis, it had to meet all of the following criteria: 1) each site-year quarterly mean concentration value had to encompass at least 11 or more samples, 2) all four quarterly mean values had to be valid for a given year (i.e., meet criterion #1), and 3) all 12 years of site-level seasonal means had to be valid for the given site (i.e., meet criteria #1 and #2).
- Annual “cool” season mean values for each site-year were computed as the average of the first and fourth quarterly mean values. Annual “warm” season mean values for each site-year were computed as the average of the second and third quarterly mean values. For a given year, all of the seasonal mean values for the monitoring sites located in the CAIR Region were then averaged together to obtain a single year (composite) seasonal mean value.

Figure 1. $PM_{2.5}$ Seasonal Trends

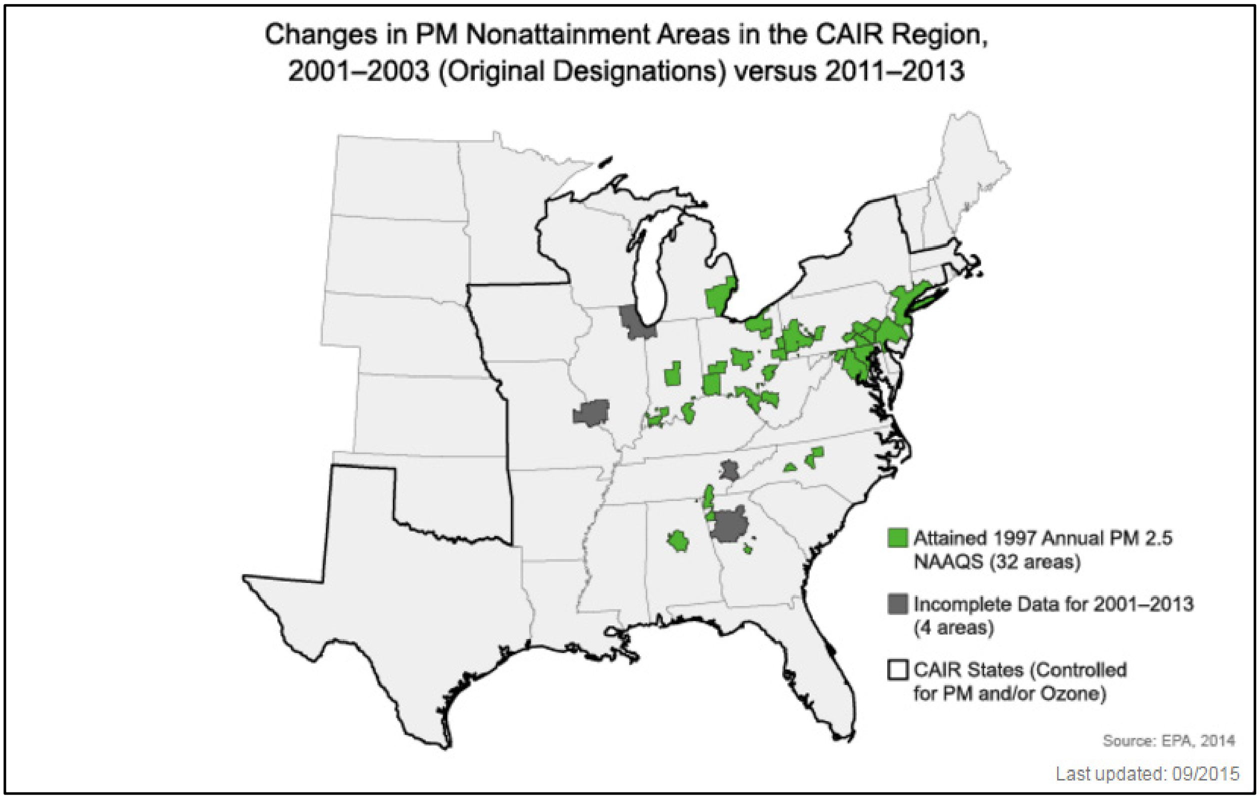


Figure 2. Changes in PM Nonattainment Areas in the CAIR Region, 2001–2003 (Original Designations) versus 2011–2013

Chapter 8: Acid Deposition

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

Analysis and Background Information

Acid Deposition

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

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

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

Monitoring Networks

The Clean Air Status and Trends Network (CASTNET) provides long-term monitoring of regional air quality to determine trends in atmospheric nitrogen, sulfur, ozone concentrations, and deposition fluxes (the rate of particles and gases being deposited to a surface) of sulfur and nitrogen pollutants 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. NADP/NTN provides concentration and wet deposition data on hydrogen ion (acidity as pH), sulfate, nitrate, ammonium, chloride, and base cations. NADP/NTN has grown to more than 200 sites spanning the continental United States, Alaska, Puerto Rico, and the Virgin Islands.

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

Key Points

Wet Sulfate Map

- The Northeast and Mid-Atlantic have shown the greatest improvement with an overall 64 percent reduction in wet sulfate deposition from 1989-1991 to 2011-2013.
- A decrease in both SO_2 emissions from sources in the Ohio River Valley and the formation of sulfates which are transported long distances have resulted in reduced sulfate deposition in the Northeast. The reductions in sulfate documented in the region, particularly across New England and portions of New York, were also affected by lowered SO_2 emissions in eastern Canada.[10]

Wet Inorganic Nitrogen Map

- Wet deposition of inorganic nitrogen decreased an average of 27 percent in the Mid-Atlantic and Northeast but decreased only 5 percent in the Midwest from 1989-1991 to 2011-2013.
- Reductions in nitrogen deposition recorded since the early 1990s have been less pronounced than those for sulfur. Emission changes from other source categories (e.g., mobile sources and manufacturing) contribute to changes in air concentrations and deposition of nitrogen.

Regional Trends in Deposition

- Between 1989-1991 and 2011-2013, the Northeast and Mid-Atlantic experienced the largest reductions in wet sulfate deposition, 65 percent and 63 percent, respectively.
- The reduction in total sulfur deposition (wet plus dry) has been of similar magnitude as that of wet deposition with an overall average reduction of 68 percent from 1989-1991 to 2011-2013.
- Decreases in dry and total inorganic nitrogen deposition have generally been greater than that of wet deposition with average reductions of 52 percent and 29 percent, respectively. In contrast, wet deposition from inorganic nitrate reduced by an average of 19 percent from 1989-1991 to 2011-2013.

More Information

Acid Rain http://www.epa.gov/acidrain/what/index.html
Clean Air Status and Trends Network (CASTNET) http://epa.gov/castnet/javaweb/index.html
National Atmospheric Deposition Program (NADP) http://nadp.isws.illinois.edu/

References

10. 2014 Canada-United States Air Quality Agreement Progress Report; ISSN 1910-5223 Cat. No.: En85-1/2014E-PDF

Figures

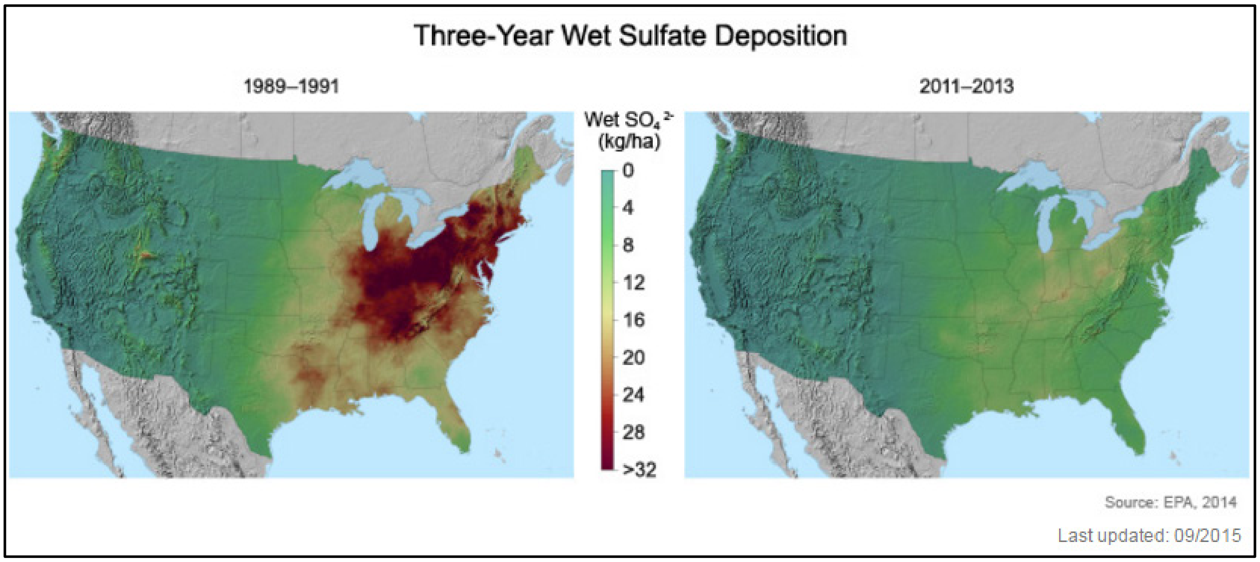


Figure 1. Three-Year Wet Sulfate Deposition

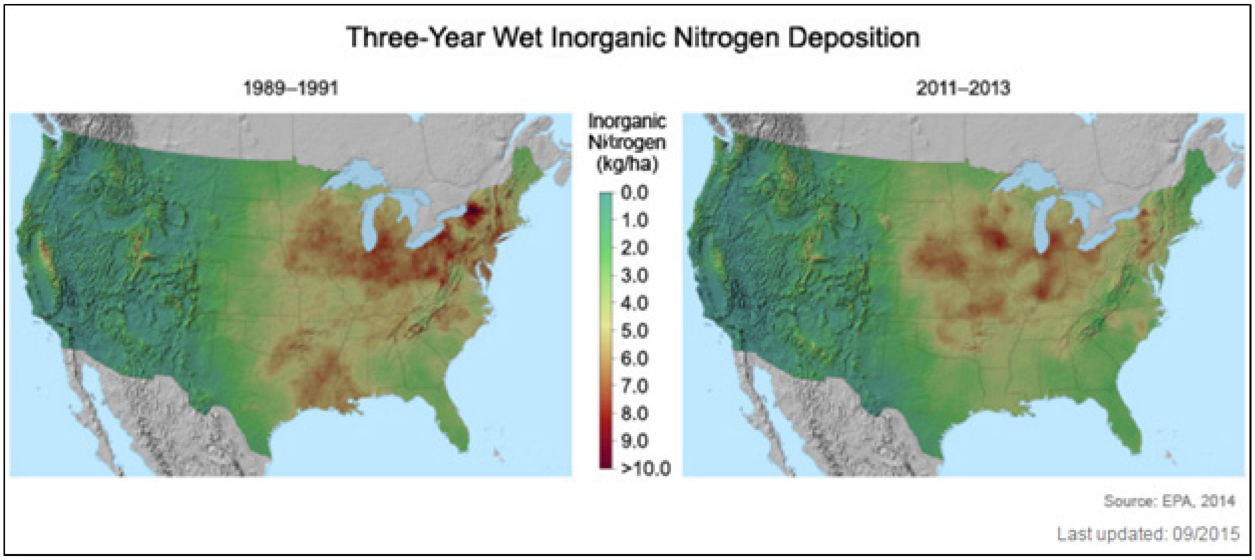


Figure 2. Three-Year Wet Inorganic Nitrogen Deposition

Regional Trends in Deposition

Measurement	Region	Annual Average, 1989-1991	Annual Average, 2011-2013	Percent Change	Number of Sites	Statistical Significance
Dry inorganic nitrogen deposition (kg-N/ha)	Mid-Atlantic	2.5	1.1	-56	12	***
	Midwest	2.4	1.4	-42	9	***
	Northeast	1.3	0.5	-62	3	
	Southeast	1.7	0.9	-47	8	***
Dry sulfur deposition (kg-S/ha)	Mid-Atlantic	7.0	1.2	-83	12	***
	Midwest	6.5	1.6	-75	9	***
	Northeast	2.6	0.5	-81	3	
	Southeast	3.1	0.7	-77	8	***
Total inorganic nitrogen deposition (kg-N/ha)	Mid-Atlantic	8.8	5.6	-36	12	***
	Midwest	8.6	7.0	-19	9	***
	Northeast	6.6	4.4	-33	3	
	Southeast	6.4	4.7	-27	8	***
Total sulfur deposition (kg-S/ha)	Mid-Atlantic	16.0	5.0	-69	12	***
	Midwest	15.0	5.0	-67	9	***
	Northeast	9.5	2.9	-69	3	
	Southeast	10.4	3.5	-66	8	***
Wet nitrogen deposition from inorganic nitrogen (kg-N/ha)	Mid-Atlantic	6.2	4.6	-26	11	***
	Midwest	5.8	5.5	-5	27	***
	Northeast	5.7	4.1	-28	16	***
	Southeast	4.4	3.6	-18	23	***
Wet sulfur deposition from sulfate (kg-S/ha)	Mid-Atlantic	9.2	3.4	-63	11	***
	Midwest	7.1	3.3	-54	27	***
	Northeast	7.5	2.6	-65	16	***
	Southeast	6.1	2.6	-57	23	***

Source EPA, 2014

Last updated: 09/2015

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 ($p < 0.05$). Changes that are not statistically significant may be unduly influenced by measurements at only a few locations or large variability in measurements.

Figure 3. Regional Trends in Deposition

Chapter 9: Ecosystem Response

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

Ecosystem Health

Analysis and Background Information

Acidified Surface Water Trends

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

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

Highly weathered soils of the Central Appalachians are able to store deposited sulfate, such that the decrease in acidic deposition has not yet resulted in lower sulfate concentrations in many of the monitored streams. However, as long-term sulfate deposition exhausts the soil’s ability to store additional sulfate, a decreasing proportion of the deposited sulfate will be retained in the soil and an increasing proportion is exported to surface waters. Thus, sulfate concentrations in some streams in this region are not changing or are still increasing despite reduced sulfate deposition.[11]

Monitoring Networks

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

Key Points

Regional Trends in Water Quality

- Significant improving trends in sulfate concentrations are found at nearly all LTM monitoring lakes and streams in New England, the Adirondacks, and the Catskill mountains/Northern Appalachian Plateau.
- On the other hand, lakes and streams in the Central Appalachian region have experienced mixed results with only 21 percent of monitored streams showing lower sulfate concentrations (and statistically significant trends), while 20 percent show increased sulfate concentrations.
- Nitrate concentrations and trends are highly variable and many sites do not show improving trends, despite reductions in NO_x emissions and inorganic nitrogen deposition.
- Levels of Acid Neutralizing Capacity (ANC), a key indicator of ecosystem recovery, have increased significantly from 1990 in lake and stream sites in the Adirondack Mountains, New England and the Northern Appalachian Plateau.

More Information

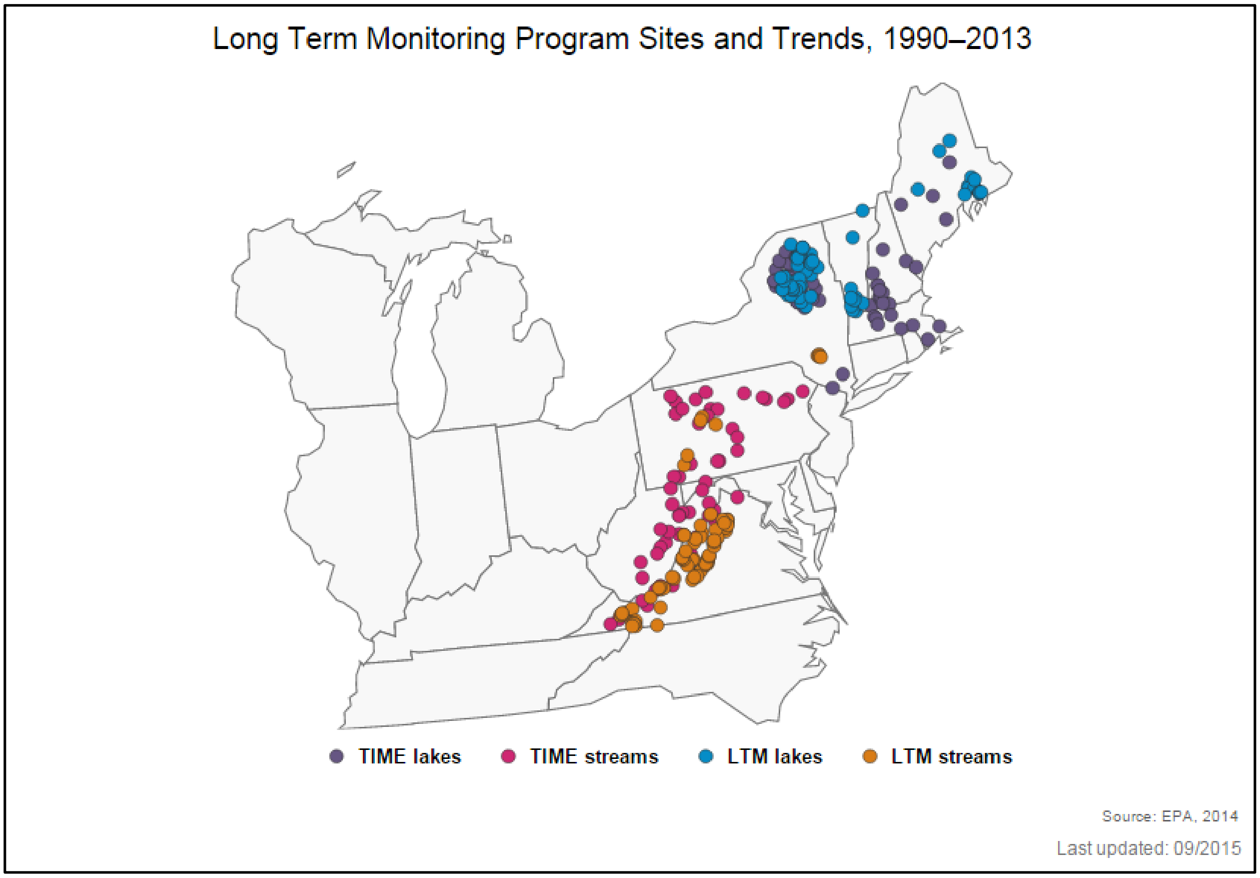
Surface Water Monitoring at EPA http://www.epa.gov/airmarkets/monitoring-surface-water-chemistry
Acid Rain http://www.epa.gov/acidrain/

References

11. Burns, D.A., Lynch, J.A., Cosby, B.J., Fenn, M.E., Baron, J.S., US EPA Clean Air Markets Div., 2011, *National Acid Precipitation Assessment Program Report to Congress 2011: An Integrated Assessment*, National Science and Technology Council, Washington, DC, 114 p.

Figures

Subtopic: Ecosystem Health



Notes:

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

Figure 1. Long Term Monitoring Program Sites and Trends, 1990–2013

Regional Trends in Sulfate, Nitrate, ANC, and Base Cations at Long-term Monitoring Sites, 1990–2013

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	50 lakes in NY	100%	56%	86%	88%
New England	26 lakes in ME and VT	100%	25%	58%	74%
Catskills/N. Appalachian Plateau*	9 streams in NY and PA	80%	40%	58%	90%
Central Appalachians	66 streams in VA	21%	59%	12%	14%

Source EPA, 2014

Last updated: 09/2015

Notes:

- Trends are statistically significant at the 95 percent confidence interval ($p < 0.05$).
- Base cations are calculated as the sum of calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na) ions.
- Trends are determined by multivariate Mann-Kendall tests.
- *Data for PA streams in N. Appalachian Plateau is only through 2011.

Figure 2. Regional Trends in Sulfate, Nitrate, ANC, and Base Cations at Long-term Monitoring Sites, 1990–2013

Critical Loads Analysis

Analysis and Background Information

A critical load is an assessment tool used to provide a quantitative estimate of whether acid deposition levels resulting from reduction in 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 anticipated, and ecosystems damaged by past exposure are expected to eventually recover.[12]

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 annual deposition load of sulfur and nitrogen to which a lake or stream and its watershed could be subjected and still support a moderately healthy ecosystem (i.e., having an ANC greater than 50 µeq/L). Surface water samples from 6,000 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.[13, 14]

Key Points

Critical Loads and Exceedances

- For the period from 2011–2013, 20 percent of all studied lakes and streams were shown to still receive levels of combined total sulfur and nitrogen deposition in excess of their calculated critical load. This is a 42 percent improvement over the period from 2000–2003 when 34 percent of all studied lakes and streams were in excess of their calculated critical load.
- Emission reductions achieved since 2000 are anticipated to contribute to broad surface water improvements and increased aquatic ecosystem protection across the five regions along the Appalachian Mountains.
- Current sulfur and nitrogen deposition loadings still fall short for recovery of many modeled lakes and streams, which indicates that additional emission reductions would be necessary for some acid-sensitive aquatic ecosystems along the Appalachian Mountains to recover and be protected from acid deposition.

More Information

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

References

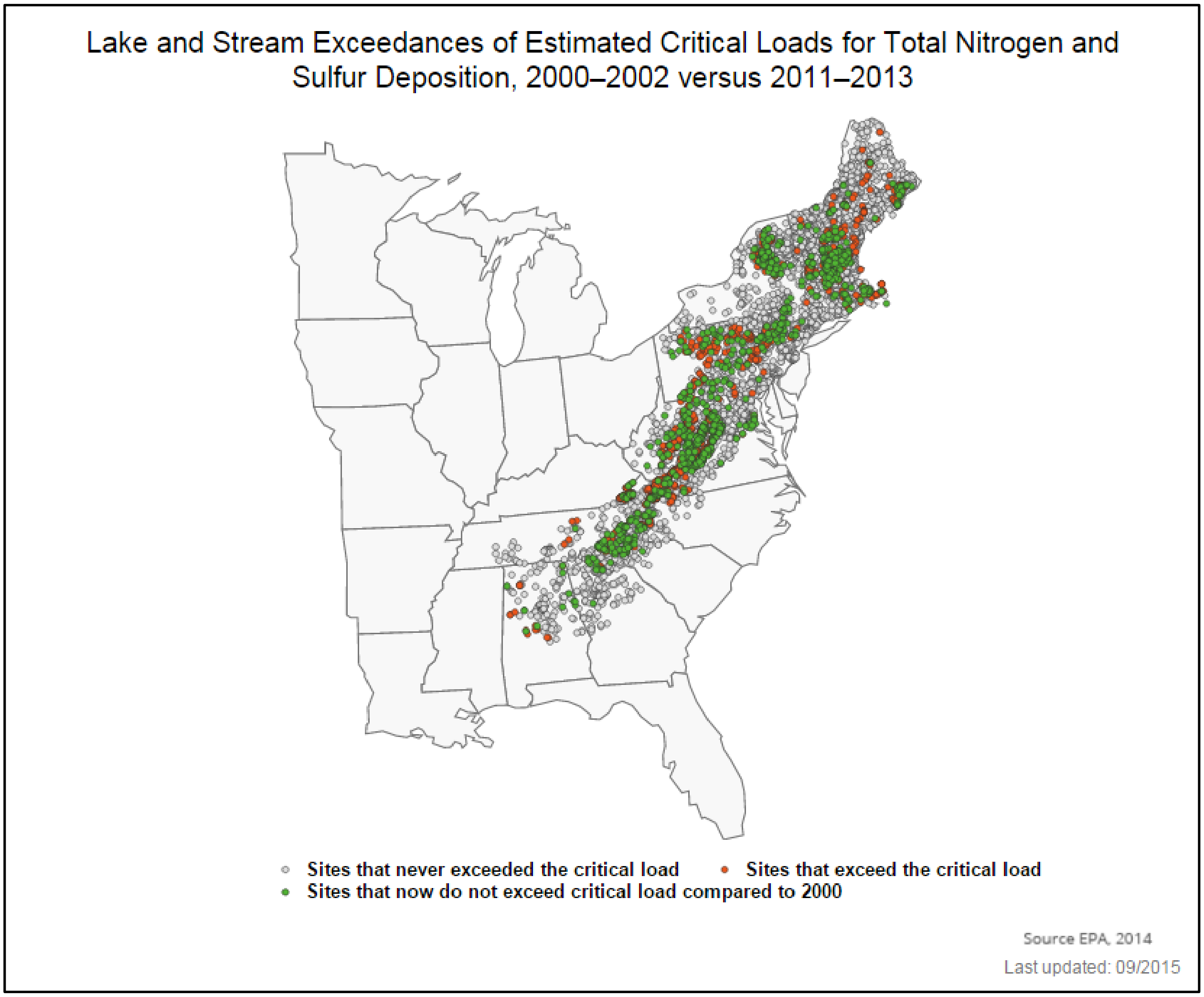
12. Dupont, J., T.A. Clair, C. Gagnon, D.S. Jeffries, J.S. Kahl, S.J. Nelson, and J.M. Peckenham. 2005. Estimation of critical loads of acidity for lakes in the northeastern United States and eastern Canada. Environmental Monitoring and Assessment 109:275-291.

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

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

Figures

Subtopic: Critical Loads Analysis



Notes:

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

Figure 1. Lake and Stream Exceedances of Estimated Critical Loads for Total Nitrogen and Sulfur Deposition, 2000–2002 versus 2011–2013

Critical Load Exceedances by Region

Region	Number of Water Bodies Modeled	Water Bodies in Exceedance of Critical Load				Percent Reduction
		2000-2003		2011-2013		
		Number of Sites	Percent of Sites	Number of Sites	Percent of Sites	
New England (ME, NH, VT, RI, CT)	2,027	461	23%	242	12%	48%
Adirondack Mountains (NY)	315	144	46%	69	22%	52%
Northern Mid-Atlantic (PA, NY, NJ)	1,166	279	24%	148	13%	47%
Southern Mid-Atlantic (VA, WV, MD)	1,597	856	54%	562	35%	34%
Southern Appalachian Mountains (NC, TN, SC, GA, AL)	896	286	32%	150	17%	48%
Total Units	**6,001**	**2,026**	**34%**	**1,171**	**20%**	**42%**

Source EPA, 2014

Last updated: 09/2015

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 $meq/m^2/yr$.

Figure 2. Critical Load Exceedances by Region