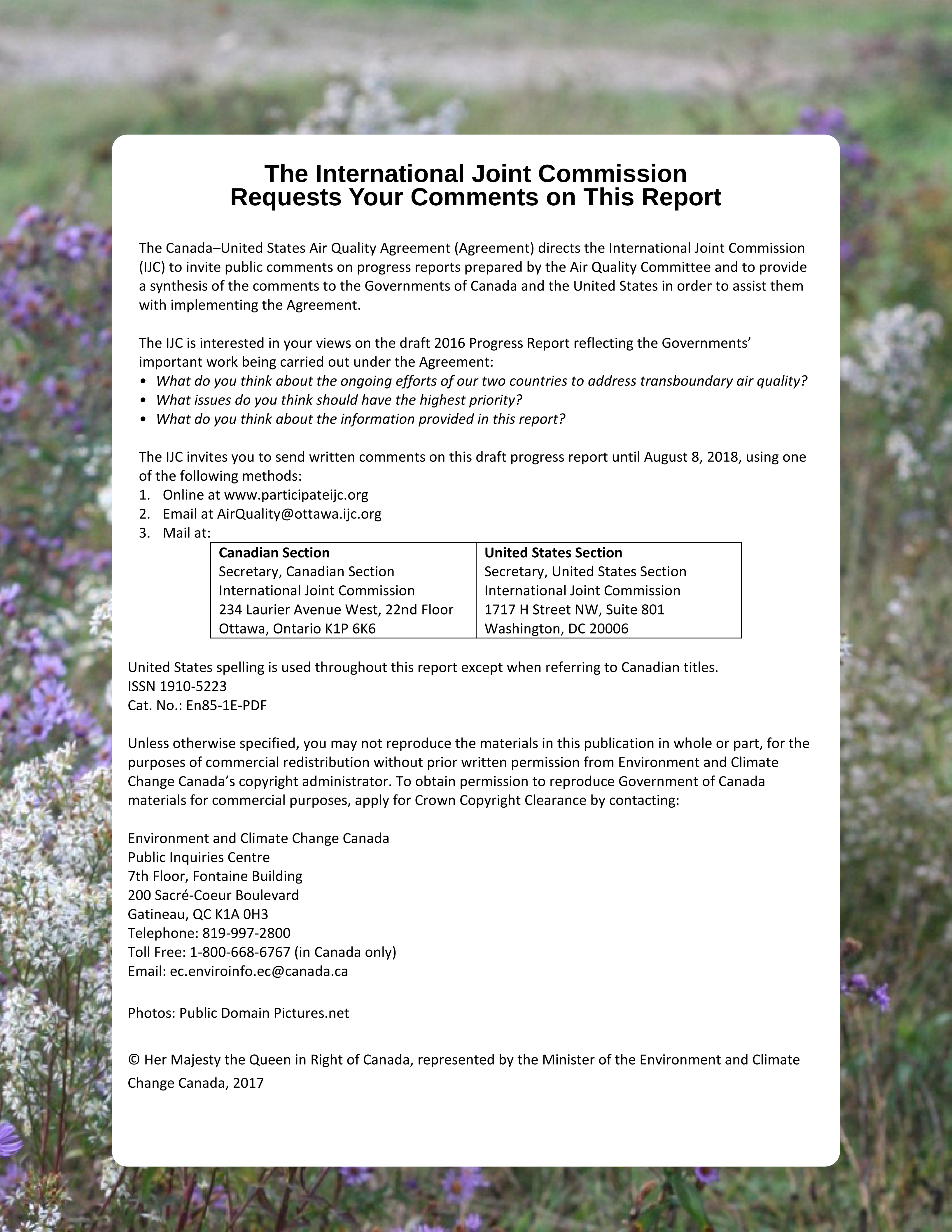
Canada – United States

Air Quality Agreement

Progress Report 2016



The International Joint Commission Requests Your Comments on This Report

The Canada–United States Air Quality Agreement (Agreement) directs the International Joint Commission (IJC) to invite public comments on progress reports prepared by the Air Quality Committee and to provide a synthesis of the comments to the Governments of Canada and the United States in order to assist them with implementing the Agreement.

The IJC is interested in your views on the draft 2016 Progress Report reflecting the Governments' important work being carried out under the Agreement:

- *What do you think about the ongoing efforts of our two countries to address transboundary air quality?*
- *What issues do you think should have the highest priority?*
- *What do you think about the information provided in this report?*

The IJC invites you to send written comments on this draft progress report until August 8, 2018, using one of the following methods:

1. Online at www.participateijc.org
2. Email at AirQuality@ottawa.ijc.org
3. Mail at:

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United States spelling is used throughout this report except when referring to Canadian titles.

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Introduction

In 1991, the United States and Canada established an Air Quality Agreement (Agreement) to address transboundary air pollution. The Agreement initially focused on reducing levels of acid deposition in each country, and in 2000, the Agreement was amended to also address ground-level ozone. A bilateral Air Quality Committee, established in the Agreement, is required to issue a progress report every two years, highlighting progress on the commitments included in the Agreement and describing the continued efforts by both countries to address transboundary air pollution. This document is the 13th such progress report under the Agreement.

The year 2016 marked the 25th anniversary of the Agreement. Working collaboratively under the Agreement, both countries have made remarkable progress in reducing acid rain and controlling ozone in the transboundary region, improving the environment and achieving better air quality for citizens in the United States and Canada. Significant reductions in emissions of sulfur dioxide (SO_2), nitrogen oxides (NO_X), and volatile organic compounds (VOCs) have come about due to regulatory and non-regulatory programs—some of which are specifically designed to meet commitments set in the Agreement—implemented by both countries.

In addition, the Agreement has provided a mechanism, in the form of work plans, for cooperation on the development and implementation of harmonized regulations to reduce vehicle and engine emissions and for addressing emissions from the oil and gas sector.

Acid Rain Annex

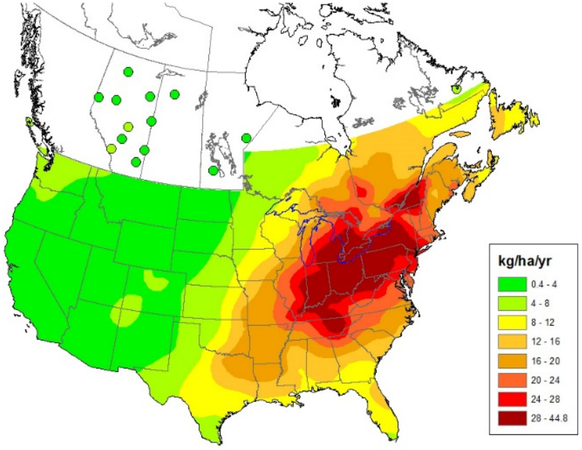
The Acid Rain Annex to the 1991 Agreement established commitments by both countries to reduce emissions of SO_2 and NO_X, the primary precursors to acid rain, from stationary and mobile sources. The commitments also included provisions for prevention of air quality deterioration, protection of visibility, and continuous monitoring of emissions. Reductions in SO_2 and NO_X emissions in both Canada and the United States between 1990 and 2014 have led to major decreases in the wet deposition of sulfate and nitrate over the eastern half of the two countries. Implementation of various regulatory and non-regulatory actions for more than two decades in Canada has significantly reduced emissions of SO_2 and NO_X and ambient concentrations. Similar implementation, especially of regulatory programs in the electric power sector, has significantly reduced emissions of SO_2 and NO_X and ambient concentrations in the United States as well.

Acid deposition, more commonly known as acid rain, occurs when emissions of SO_2 and NO_X, from power plants, vehicles, and other sources, react in the atmosphere (with water, oxygen, and oxidants) to form various acidic compounds that exist in either a wet form (rain, snow, or fog) or a dry form (gases and particles). These acidic compounds can harm aquatic and terrestrial ecosystems (particularly forests); affect human health; impair visibility; and damage automotive finishes, buildings, bridges, and monuments.

Acid Deposition Trends

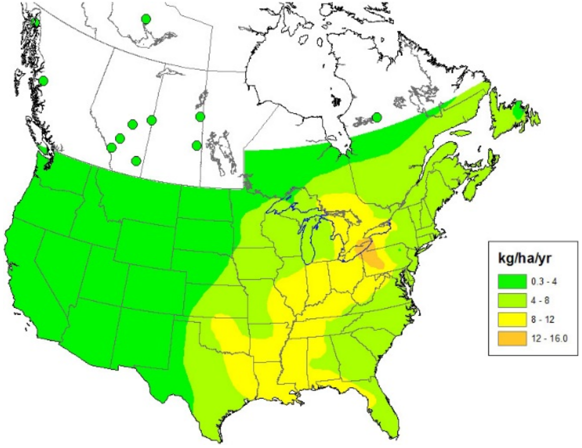
Wet deposition of sulfate and nitrate is measured by precipitation chemistry monitoring networks in Canada and the United States. The measurement data, presented in kilograms per hectare per year (kg/ha/yr), are the basis for binational spatial wet deposition maps.

Figure 1. 1990 Annual Wet Sulfate Deposition



Source: National Atmospheric Chemistry (NAtChem) Database (www.ec.gc.ca/natchem/) and the National Atmospheric Deposition Program (NADP; http://nadp.sws.uiuc.edu), 2014

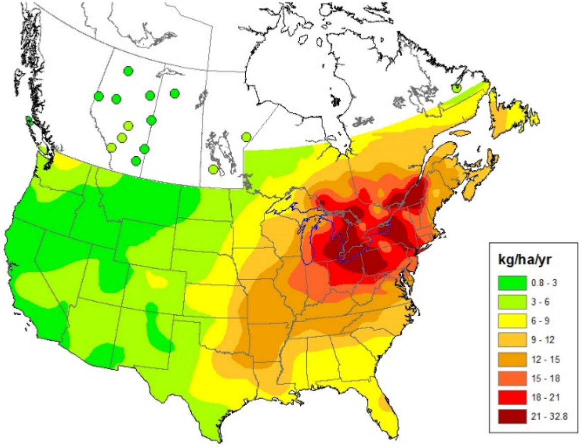
Figure 2. 2014 Annual Wet Sulfate Deposition



Source: NAtChem Database (www.ec.gc.ca/natchem/) and the NADP (nadp.sws.uiuc.edu), 2014

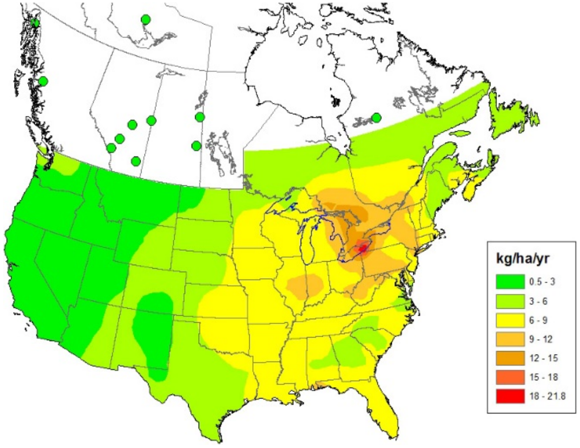
Figures 1 and 2 show the spatial patterns of annual wet sulfate deposition of non-sea-salt sulfate, which is measured sulfate with the contribution of sea salt sulfate removed, in 1990 and 2014, respectively, along with point values at sites in less densely measured regions. Figures 3 and 4 show the patterns of wet nitrate deposition for the same years. The lower Great Lakes region consistently received the highest wet deposition of both sulfate and nitrate in the 25-year period. Sulfate deposition in 1990 exceeded 28 kg/ha/yr over a large area of eastern North America, while in 2014, only a small region around Lake Erie received more than 12 kg/ha/yr of sulfate. Similarly, nitrate deposition exceeded 21 kg/ha/yr in many parts of the northeastern United States and southern Ontario and Quebec in 1990, and it only exceeded 16 kg/ha/yr at a single site in 2014.

Figure 3. 1990 Annual Wet Nitrate Deposition



Source: NAtChem Database (www.ec.gc.ca/natchem/) and the NADP (nadp.sws.uiuc.edu), 2014

Figure 4. 2014 Annual Wet Nitrate Deposition



Source: NAtChem Database (www.ec.gc.ca/natchem/) and the NADP (nadp.sws.uiuc.edu), 2014

Acid Rain Commitments and Emission Reductions

SO_2 Emission Reductions

CANADA

Actions driving SO_2 emission reductions include the implementation of the Canada-Wide Acid Rain Strategy for Post-2000, which serves as the framework for addressing the issues related to acid rain. The goal of the strategy is to ensure that the deposition of acidifying pollutants does not further deteriorate the environment in eastern Canada and that new acid rain problems do not occur elsewhere in Canada.

In 2014, Canada's total SO_2 emissions were 1.1 million metric tons (1.3 million short tons[1]), about 64 percent below the national cap of 3.2 million metric tons (3.5 million short tons). The 2014 emissions level also represents a 63 percent reduction from Canada's total SO_2 emissions of 3.1 million metric tons (3.4 million short tons) in 1990 (see Figure 5).

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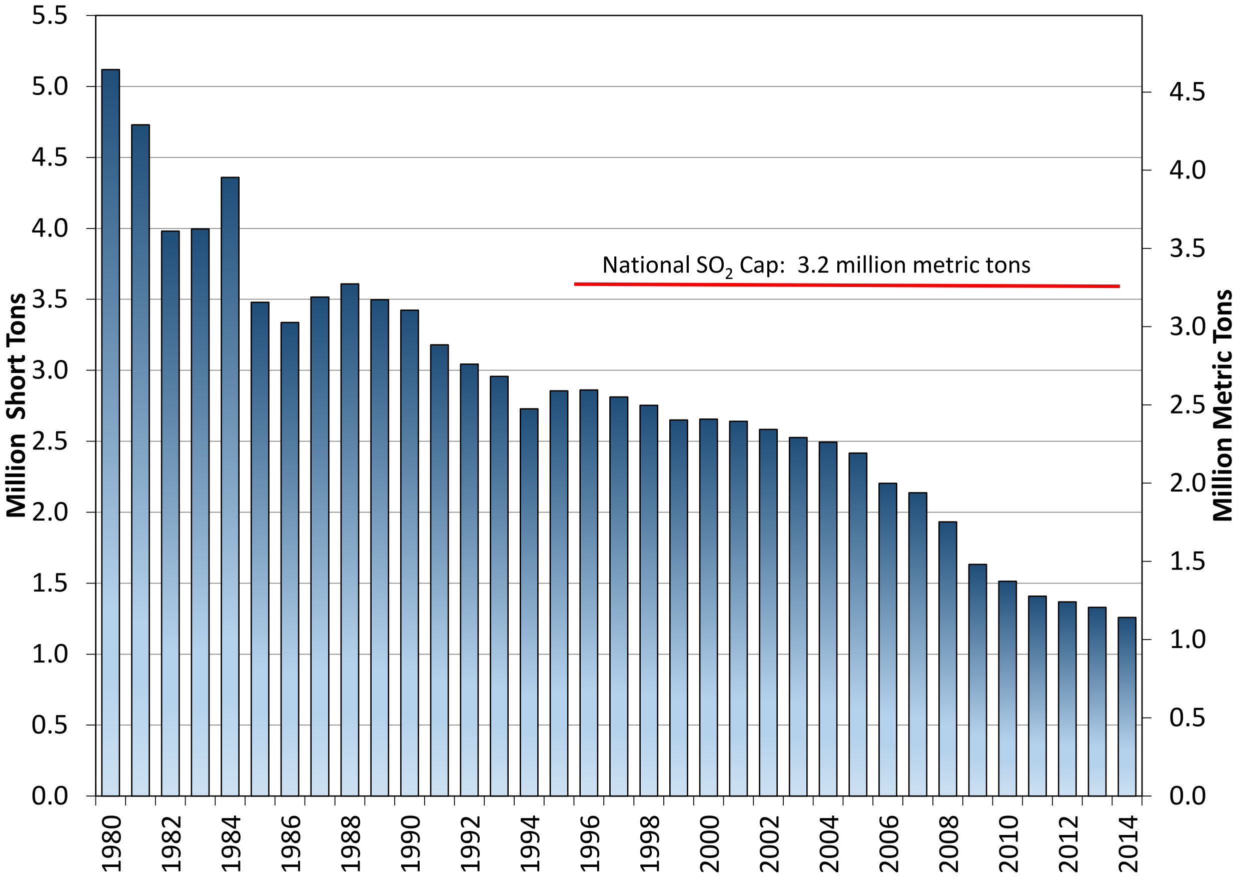
[1] One metric ton is equal to 1.1 short tons.

Figure 5. Total Canadian SO_2 Emissions, 1980–2014



Source: ECCC, 2016

The largest contribution of SO_2 emissions originates from three industrial sectors: the non-ferrous smelting and refining industry; the upstream petroleum industry, which includes the exploration and production of crude oil; and electric power generation. These three sectors accounted for 76 percent of national SO_2 emissions in 2014. The majority of overall reductions in national SO_2 emission levels can be attributed to the SO_2 emission reduction actions undertaken by the province of Ontario, mainly from the permanent closure of coal-fired electric power generation facilities.

Although Canada has been successful in reducing these acidifying pollutants, many areas across Canada are still exposed to concentrations that exceed the capacity of the soils and surface waters to neutralize the acidic deposition, most notably in eastern Canada. A number of measures are being undertaken to reduce SO_2 and NO_X emissions from certain industrial sectors as part of Canada's Air Quality Management System (AQMS), which will also reduce the impact of acidifying pollutants on soils and surface waters.

UNITED STATES ★

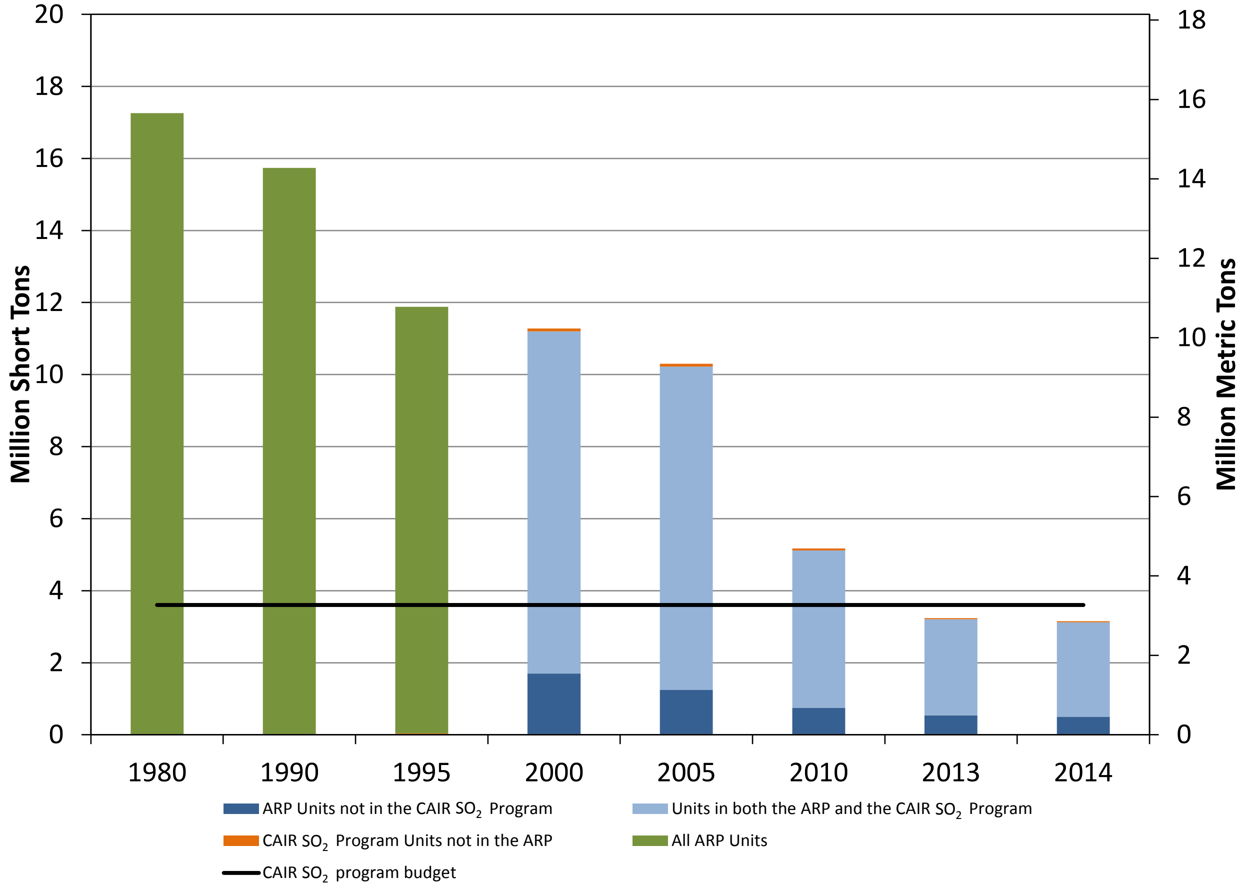
The United States has met its commitment to reduce SO_2 emissions. The national Acid Rain Program (ARP) and the regional Clean Air Interstate Rule (CAIR) were designed to reduce emissions of SO_2 and NO_X from the electric power sector. Since 1995, SO_2 emissions have fallen significantly under these programs. These reductions occurred while the demand for electricity remained relatively stable and were the result of continued increases in efficiency, installation of state-of-the-art pollution controls, and the switch to lower emitting fuels. Most of the power sector emission reductions since 2005 were from early reduction incentives and stricter emission cap levels under CAIR.

The CAIR SO_2 program began on January 1, 2010, and was replaced by the Cross-State Air Pollution Rule (CSAPR) SO_2 program on January 1, 2015.[2]

Electric generating units in the ARP emitted 3.1 million short tons (2.8 million metric tons) of SO_2 in 2014, well below the ARP's statutory annual cap of 8.95 million short tons (8.1 million metric tons). ARP sources reduced emissions by 12.6 million short tons (11.4 million metric tons) or 80 percent from 1990 levels and 14.1 million short tons (12.8 million metric tons) or 82 percent from 1980 levels (see Figure 6).

In 2014, sources in the CAIR SO_2 program and the ARP collectively reduced SO_2 emissions by 8.1 million short tons (7.4 million metric tons) or 72 percent from 2000 levels and 7.1 million short tons (6.5 million metric tons) or 69 percent from 2005 levels (before implementation of CAIR). All ARP and CAIR sources emitted a total of 3.2 million short tons (2.9 million metric tons) of SO_2 in 2014. Annual SO_2 emissions from sources in the regional CAIR SO_2 program alone fell from 9.1 million short tons (8.2 million metric tons) in 2005 to 2.7 million short tons (2.4 million metric tons) in 2014, a 71 percent reduction. Between 2013 and 2014, SO_2 emissions fell 48,000 short tons (44,000 metric tons) or 2 percent and were about 970,000

Figure 6. SO_2 Emissions from ARP and CAIR Sources, 1980–2014



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

There are a small number of sources in CAIR but not in the ARP. Emissions from these sources compose about 1 percent of the total emissions and are not easily visible on the chart.

Source: EPA, 2016

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[2] See https://www.epa.gov/csapr for more information on the CSAPR program.

short tons (880,000 metric tons) below the regional CAIR emission budget.

In addition to the electric power generation sector, emission reductions from other sources not affected by the ARP or CAIR, including industrial and commercial boilers and refining, have contributed to an overall reduction in annual SO_2 emissions. National SO_2 emissions from all sources fell from 23.1 million short tons (20.9 million metric tons) in 1990 to 4.7 million tons (4.3 million metric tons) in 2014, a reduction of 79 percent.

NO_X Emission Reductions

CANADA

Canada has met its commitment to reduce NO_X emissions from power plants, major combustion sources, and metal smelting operations by 100,000 metric tons (110,000 short tons) below the forecasted level of 970,000 metric tons (1.1 million short tons). This commitment is based on a 1985 forecast of 2005 NO_X emissions.

Emissions of NO_X from all industrial sources, including emissions from electric power generation, totaled 782,529 metric tons (860,782 short tons) in 2014. Transportation sources contributed the majority of NO_X emissions in 2014, accounting for almost 55 percent of total Canadian emissions, with the remainder produced by the upstream petroleum industry (22 percent), electric power generation facilities (9 percent), and other sources. Canada continues to develop programs to further reduce NO_X emissions nationwide. On June 29, 2016, Canada published the *Multi-sector Air Pollutants Regulations* to limit NO_X emissions from industrial boilers, heaters, and stationary engines and to limit NO_X and SO_2 emissions from cement manufacturing facilities. The regulations establish Canada's first ever mandatory national air pollutant emissions standards for major industrial facilities. The regulations will significantly reduce emissions that contribute to acid rain and smog. ECCC analysis predicts that the regulations will result in a reduction of 2.0 million metric tons (2.2 million short tons) of NO_X emissions in the first 19 years (equivalent to taking all passenger cars and trucks off the road for about 12 years). These industrial emission requirements are a key element of Canada's AQMS.

UNITED STATES

The United States has met its commitment to reduce NO_X emissions. To address NO_X emissions, the ARP NO_X program requires emission reductions through a rate-based approach on certain coal-fired power plants, while CAIR[3] achieves emission reductions through a market-based, emission trading program from fossil fuel-fired power plants. Overall, NO_X emissions have declined dramatically under the ARP, the former NO_X Budget Trading Program (NBP), and the CAIR NO_X program, with the majority of reductions coming from coal-fired units. Other programs—such as regional and state NO_X emission control programs—also contributed significantly to the annual NO_X emission reductions achieved by sources in 2014.

In 2014, sources in both the CAIR NO_X program and the ARP reduced NO_X emissions by 4.7 million short tons (4.3 million metric tons) or 73 percent from 1990 levels, 3.5 million short tons (3.1 million metric tons) or 67 percent from 2000 levels, and 2 million short tons (1.8 million metric tons) or 54 percent from 2005 levels. Together, all ARP and CAIR sources emitted a total of 1.7 million short tons of NO_X in 2014 (see Figure 7).

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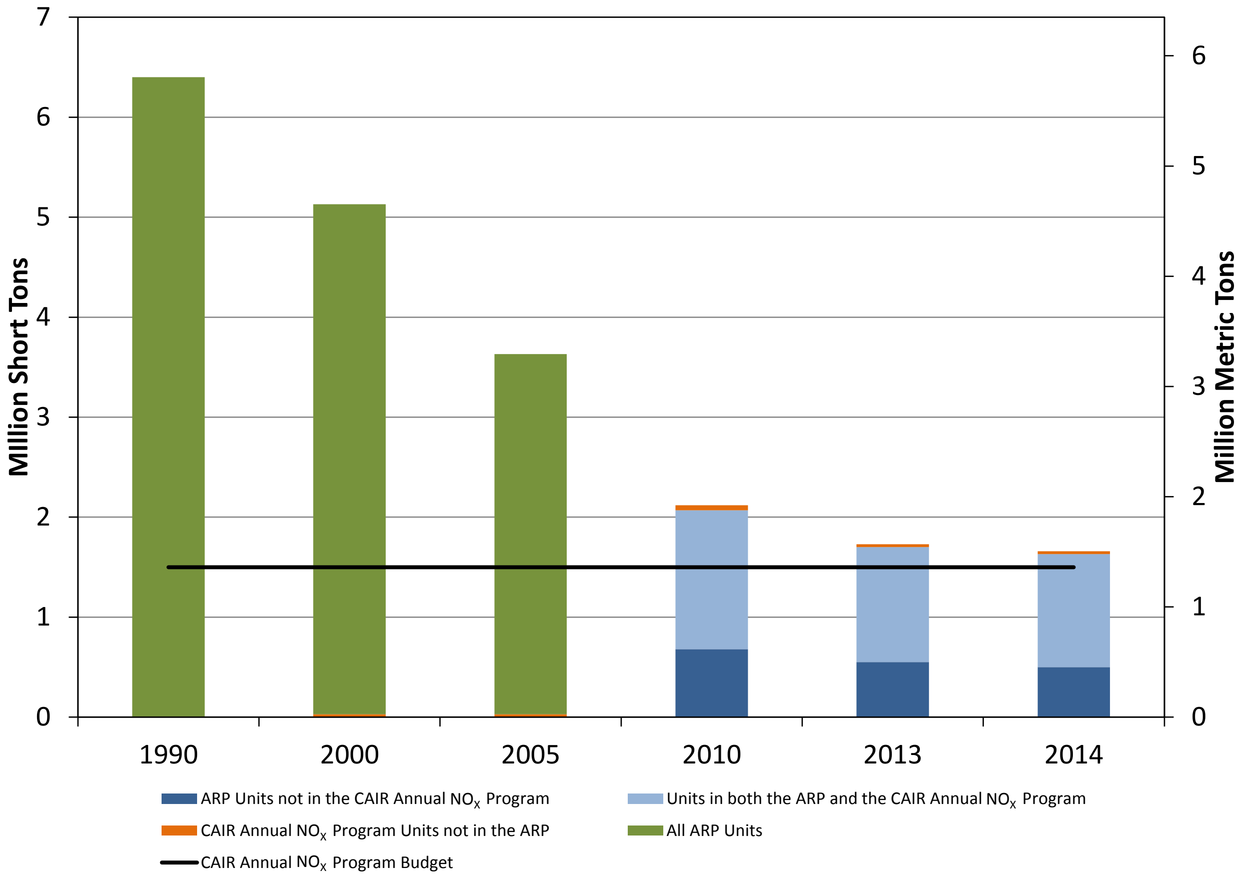
[3] The CSAPR annual NO_X program replaced the CAIR annual NO_X program starting on January 1, 2015.

Annual NO_X emissions from sources in the CAIR NO_X program alone fell from 2.7 million short tons (2.4 million metric tons) in 2005 to 1.2 million short tons (1.1 million metric tons) in 2014, a 56 percent reduction. Between 2013 and 2014, NO_X emissions fell 12,000 short tons (11 thousand metric tons) or 1 percent. For more detailed information on the United States NO_X programs, see www.epa.gov/airmarkets.

In addition to ARP and CAIR, other NO_X ozone season and annual programs, as well as state NO_X emission control programs, contributed significantly to the NO_X reductions that sources achieved in 2014. Annual NO_X emissions from the power sector as well as all other sources fell from 25.2 million short tons (22.8 million metric tons) in 1990 to 12.5 million short tons (11.3 million metric tons) in 2014, a reduction of 50 percent.

Figure 7. Annual NO_X Emissions from ARP and CAIR Sources, 1990–2014



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

There are a small number of sources in CAIR but not in the ARP. Emissions from these sources compose about 1 percent of the total emissions and are not easily visible on the chart.

Source: EPA, 2016

Preventing Air Quality Deterioration and Protecting Visibility

CANADA

Canada has continued addressing the commitment to prevent air quality deterioration and ensure visibility protection by implementing the *Canadian Environmental Protection Act, 1999* (CEPA 1999) and the *Canadian Environmental Assessment Act, 2012* and by following the continuous improvement and keeping clean areas clean principles. These principles are included in Canada's AQMS and the associated Canadian Ambient Air Quality Standards (CAAQS).

The British Columbia Visibility Coordinating Committee (BCVCC) continues to work towards developing a visibility management framework for the Lower Fraser Valley (LFV) in southwest British Columbia. Modeling work by Environment and Climate Change Canada (ECCC) has further strengthened scientific understanding of visual air quality, including the development of a statistical model to estimate light extinction from routine air quality measurements and investigations of the visibility impact of emission reduction scenarios. This modeling work has guided policy decisions to improve visual air quality.

The Visual Air Quality Rating (VAQR) is a new tool to inform residents and visitors about how air pollution can degrade scenic views in the LFV. The VAQR uses air quality measurements to categorize and report visual air quality and was launched through the BCVCC website (http://www.clearairbc.ca/Pages/default.aspx) in August 2015. Other public outreach activities include the development of a brochure outlining the sources and effects of visual air quality degradation and the creation of outreach displays on signs in public parks highlighting the links between haze and the natural environment.

ECCC contributed to BCVCC science activities, including a recently completed comprehensive photochemical modeling effort to test the potential impacts of possible future emission changes on visibility in the LFV region.

Additional activities have been undertaken in other parts of Canada as part of ECCC's National Visibility Monitoring Pilot Study. Visibility monitoring pilot sites that were established in 2011 at Barrier Lake, Alberta and Wolfville, Nova Scotia continue to operate, as does the Abbotsford, British Columbia visibility supersite, which collects the full suite of visibility monitoring measurements including aerosol speciation, optical point measurements, and digital camera imagery. Data collection for inter-comparison studies has recently been completed at the Barrier Lake site. A National Air Pollutant Surveillance (NAPS) speciation sampler that operated at the Barrier Lake site from 2013–2015 allowed comparison with the co-located U.S. Interagency Monitoring of Protected Visual Environments (IMPROVE) sampler. At Egbert, Ontario, IMPROVE speciation data are being compared with data obtained from the Canadian Air and Precipitation Monitoring Network (CAPMoN) from 2005–2015. Analysis of the data will be completed in the coming year. If the Canadian methodology is found to be sufficiently sound for visibility measurements, it would open up the potential for expansion of visibility monitoring at speciation sites across Canada. In addition, an updated assessment of visibility conditions across Canada, using data from the NAPS speciation network from 2003–2012, has been completed and more recent data will be added as it becomes available.

UNITED STATES ★

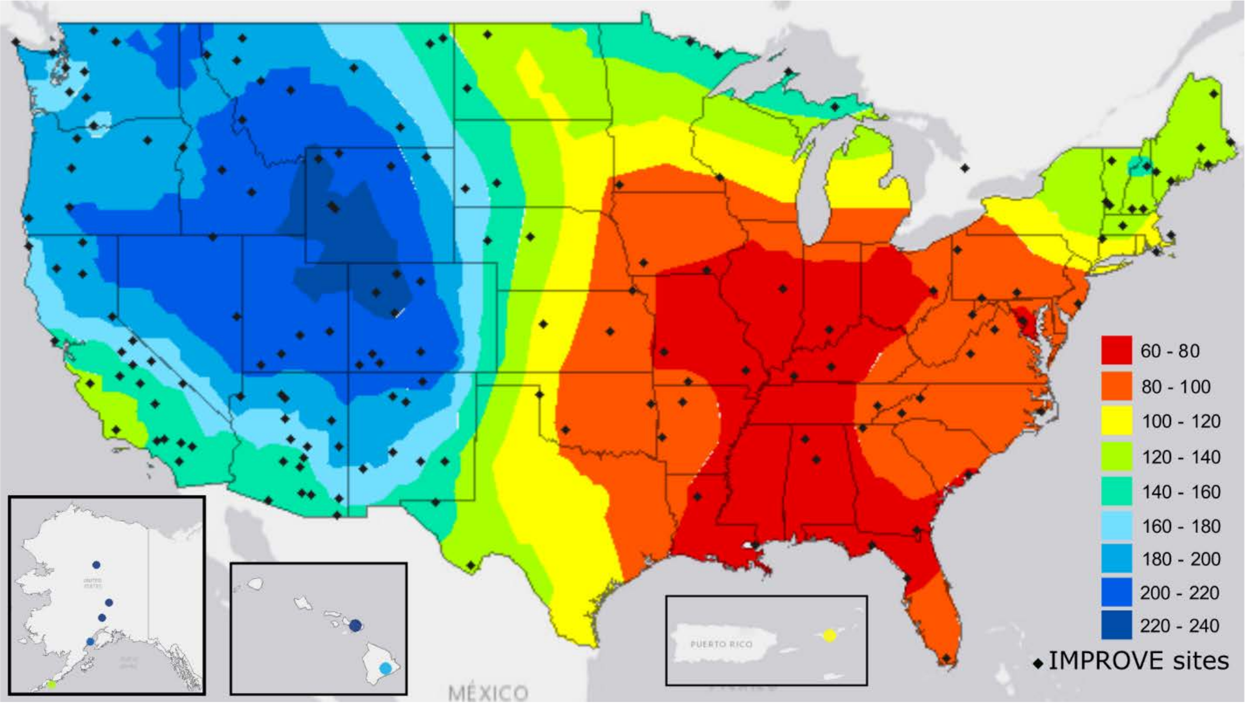
The United States continues to address its commitment to air quality and visibility protection through several ongoing programs, including New Source Review (NSR) and the Regional Haze Rule. NSR pre-construction permitting programs apply both to areas that meet the National Ambient Air Quality Standards (NAAQS), i.e., attainment areas, and to areas that exceed the NAAQS, i.e. nonattainment areas. Nonattainment area permits for new or modified sources require air pollution controls that represent the lowest achievable emission rate (LAER), plus emissions offsets. Emissions offsets are actual emission reductions, generally obtained from sources in the vicinity of a proposed source or modification that offset the emission increase and provide a net air quality benefit.

Permits for new or modified sources in attainment areas are known as prevention of significant deterioration (PSD) permits and require air pollution controls that represent the best available control technology (BACT), as well as a demonstration that the project's emissions will not cause or contribute to a violation of the NAAQS or PSD increments. The PSD program also protects the air quality and visibility in Class I areas (i.e., national parks exceeding 6,000 acres and wilderness areas exceeding 5,000 acres).

The Clean Air Act established the goal of improving visibility in the nation's 156 Class I areas and returning these areas to visibility conditions that existed before human-caused air pollution. The 1999 Regional Haze Rule requires that states reach that goal by 2064. In July 2005, the U.S. Environmental Protection Agency (EPA) finalized amendments to the Regional Haze Rule, which required the installation of emission controls known as best available retrofit technology (BART) to existing major stationary sources. In addition to BART, the rule also requires states to assess progress toward visibility improvement that could be made by controlling other non-BART emission sources, referred to as "reasonable progress." Additional information on EPA's Regional Haze Program can be found at https://www.epa.gov/visibility.

Figure 8 shows the annual average "standard visual range" (the farthest distance a large, dark object can be seen during daylight hours) within the United States for the period 2010–2014. This distance is calculated using fine and coarse particle data from the IMPROVE network. Increased particle pollution reduces the visual range. The visual range under naturally occurring conditions without human-caused

Figure 8. Annual Average Standard Visual Range (km) 2010–2014



Source: U.S. National Park Service, 2016 (data from IMPROVE website: vista.cira.colostate.edu/improve/)

pollution in the United States is typically 45–90 miles (75–140 kilometers [km]) in the east and 110–150 miles (180–240 km) in the west. Additional information on the IMPROVE program and visibility in U.S. National Parks can be found at vista.cira.colostate.edu/improve/.

Emissions/Compliance Monitoring

Commitments in the Agreement require Canada and the United States to apply continuous emissions monitoring or methods of comparable effectiveness to certain electric utility units. Both countries meet these commitments by using continuous emissions monitoring systems (CEMS) and rigorous reporting programs. Canada and the United States each monitor more than 90 percent of eligible SO_2 emissions with CEMS.

CANADA

Canada continues to meet its commitment to monitor and estimate emissions of NO_X and SO_2 from new and existing electric utility units with a capacity rating greater than 25 megawatts. CEMS, or other comparable monitoring methods, have had widespread use in Canada's electric utility sector since the late 1990s. Currently, most new and existing base-load fossil steam plants and natural gas turbines with high emission rates operate CEMS technology. Coal-fired facilities, which are the largest source of emissions from the sector, have SO_2 and NO_X CEMS installed at more than 92 percent of their total capacity. In addition, under Canada's National Pollutant Release Inventory, a mandatory reporting program, electric power generating facilities are required to report their air pollutant emissions (including NO_X and SO_2) annually. CEMS also serves as a testing approach to demonstrate compliance with the *Multi-Sector Air Pollutants Regulations*.

UNITED STATES

EPA has developed detailed procedures to ensure that sources monitor and report emissions with a high degree of precision, accuracy, reliability, and consistency. Most emissions of SO_2, carbon dioxide, and NO_X are measured with CEMS, which monitor important information such as the amount of pollution emitted from a smokestack (pollutant concentration) and how fast the emissions occur. In 2014, CEMS monitored over 99 percent of SO_2 emissions from CAIR sources, including 100 percent from coal-fired units.

Additionally, other large emission sources that are equipped with pollution control devices are regulated under the Compliance Assurance Monitoring (CAM) rule. The CAM rule includes criteria that define the monitoring, reporting, and record keeping that should be conducted by a source to provide a reasonable assurance of compliance with emission limitations and standards. EPA rigorously checks the completeness, quality, and integrity of monitoring data. In addition to electronic audits, EPA conducts targeted field audits on sources that report suspect data.

Ozone Annex

The Ozone Annex, added to the Agreement in 2000, commits the United States and Canada to address transboundary ground-level ozone by reducing emissions of NO_X and VOCs, the precursors to ozone, from stationary and mobile sources and from solvents, paints, and consumer products. The commitments apply to a defined region in both countries known as the Pollutant Emission Management Area (PEMA), which includes central and southern Ontario, southern Quebec, 18 states, and the District of Columbia, where emission reductions are most important for reducing transboundary ozone (See Figure 9).

Figure 9. Ozone Annex Pollutant Emission Management Area (PEMA)

Ground-level ozone is a pollutant that forms when emissions of NO_X and VOCs react in the atmosphere in the presence of sunlight. Cars, trucks, buses, engines, industries, power plants, and products such as solvents and paints are among the major man-made sources of ozone-forming emissions. Ground-level ozone, a key component of smog, can cause or exacerbate respiratory illnesses and is especially harmful to young children, the elderly, and those suffering from chronic asthma and/or bronchitis. Exposure to ground-level ozone can damage vegetation, reduce growth, and have other harmful effects on plants and trees. This can make them more susceptible to attack from insects and diseases and reduce their ability to withstand droughts, windstorms, and man-made stresses such as acid rain.

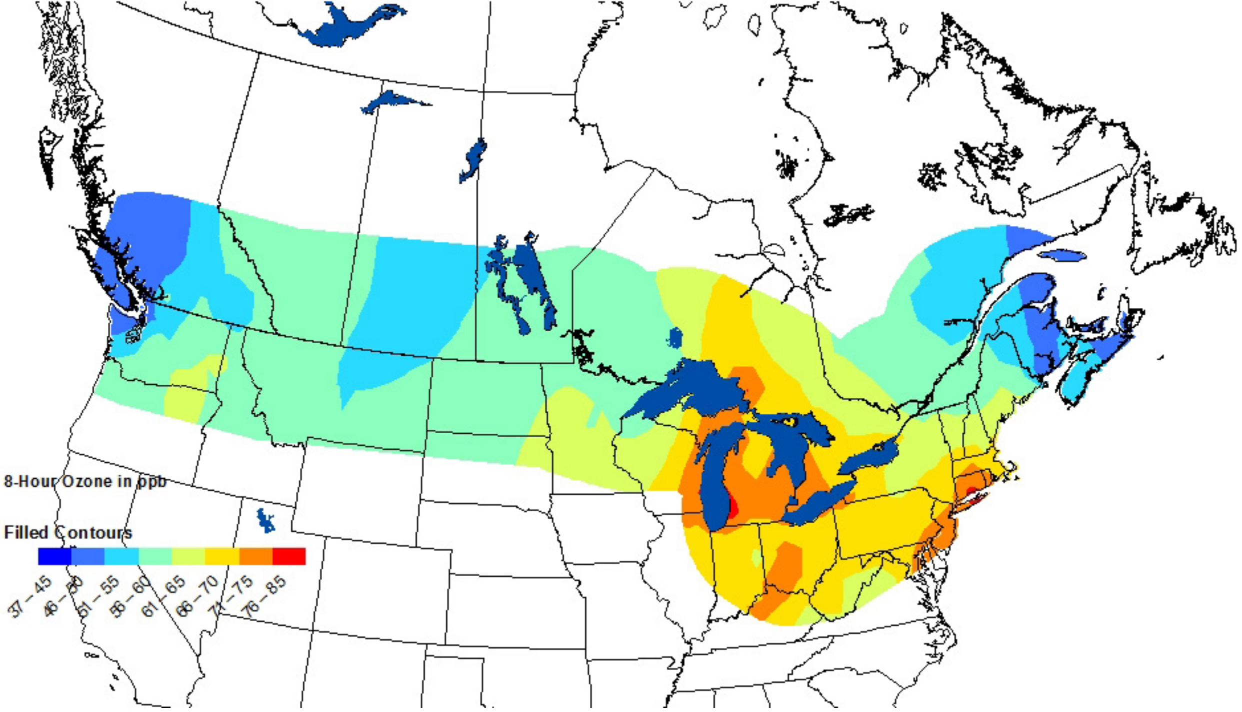
Ambient Levels of Ozone in the Border Region

Levels of ambient ozone in the PEMA have a decreasing trend since 1995. Similarly decreasing trends in concentrations are found for both NO_X and VOCs. Regulatory and non-regulatory programs designed to meet emissions commitments in the Ozone Annex, as well as programs designed to meet program goals for Canada and the United States individually, have contributed to the reductions in ozone concentrations.

Figure 10 illustrates ozone concentrations in the border region—sites within 500 km (310 miles) of the United States–Canada border. The figure shows that higher ozone levels occur in the Great Lakes and Ohio Valley regions and along the United States' eastern coast. The lowest values are generally found in western and eastern Canada. Levels are generally higher within and downwind of urban areas (such as in western portions of lower Michigan). The figure illustrates the regional pattern of ozone concentrations. Ozone is depicted in this figure as a 3-year average (2012–2014) of the annual fourth-highest daily maximum 8-hour concentration, in parts per billion (ppb), by volume. Only sites that met data completeness requirements (based upon 75 percent or more of all possible daily values during the EPA-designated ozone monitoring seasons) were used to develop this map.

Figure 11 shows the decreasing trend of ozone concentrations reported as the annual average fourth-highest daily maximum 8-hour ozone concentration for sites within 500 km of the United States–Canada Border for 1995–2014.

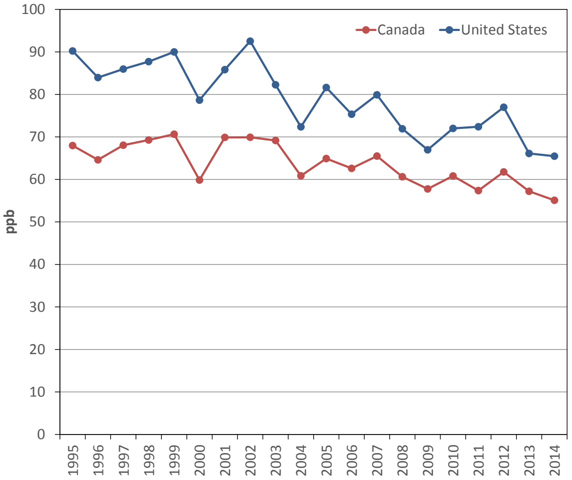
Figure 10. Ozone Concentrations along the United States–Canada Border (3-year Average of the Fourth-highest Daily Maximum 8-hour Concentration), 2012–2014



Note: Data are the 2012–2014 averages of annual fourth-highest daily values, where the daily value is the highest running 8-hour average for the day.

Sources: ECCC NAPS Network Canada-wide Database, 2014; EPA Air Quality System Data Mart (www.epa.gov/airdata).

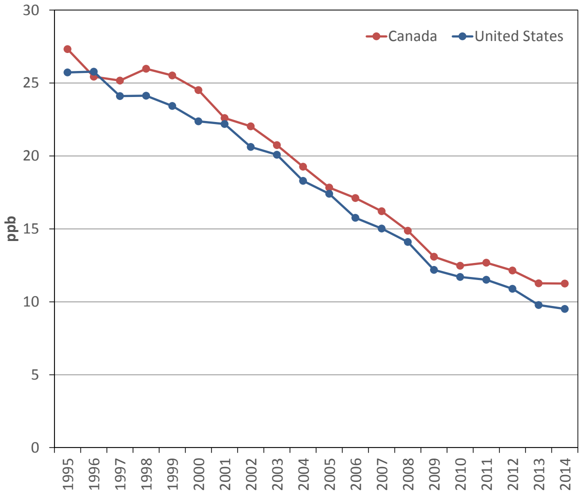
Figure 11. Annual Average Fourth-highest Daily Maximum 8-hour Ozone Concentration for Sites within 500 km of the United States–Canada Border, 1995–2014



Source: EPA and ECCC, 2014

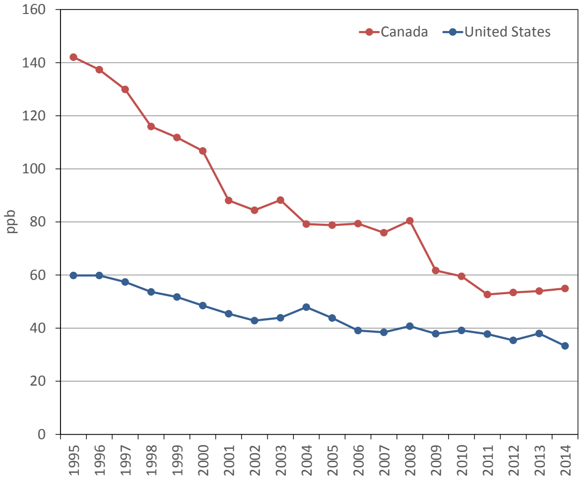
Downward trends in concentrations of ozone-season NO_X and VOCs are shown in Figures 12 and 13. Ambient concentrations of NO_X and VOCs reflect the significant reductions in emissions of these ozone precursors. Ozone concentrations reflect not only precursor concentrations, but also meteorological conditions for ozone formation. While some of the lowest ozone concentration levels are associated with cool, rainy summers (2004, 2009, 2014), ozone concentration levels are mainly due to the emission reductions programs described in this report.

Figure 12. Average Ozone Season (May–September) 1-hour NO_X Concentrations for Sites within 500 km of the United States–Canada Border, 1995–2014



Source: EPA and ECCC, 2014

Figure 13. Average Ozone Season (May–September) 24-hour VOC Concentrations for Sites within 500 km of the United States–Canada Border, 1995–2014



Source: EPA and ECCC, 2014

Emissions and Emission Trends in the PEMA

Table 1 shows 2014 United States and Canadian emissions in the PEMA. In the Canadian PEMA, the sectors that contribute the most to the area's annual NO_X emissions are on-road and non-road transportation. The predominant sectors that contribute to annual VOC emissions in the Canadian PEMA are solvent utilization processes, non-industrial fuel combustion, and non-road transportation. The sectors that contribute most to NO_X emissions in the United States PEMA are transportation, electric power generation, and industrial sources. Transportation and solvent utilization are the predominant sectors for VOC emissions in the United States PEMA.

Table 1. PEMA Emissions during 2014

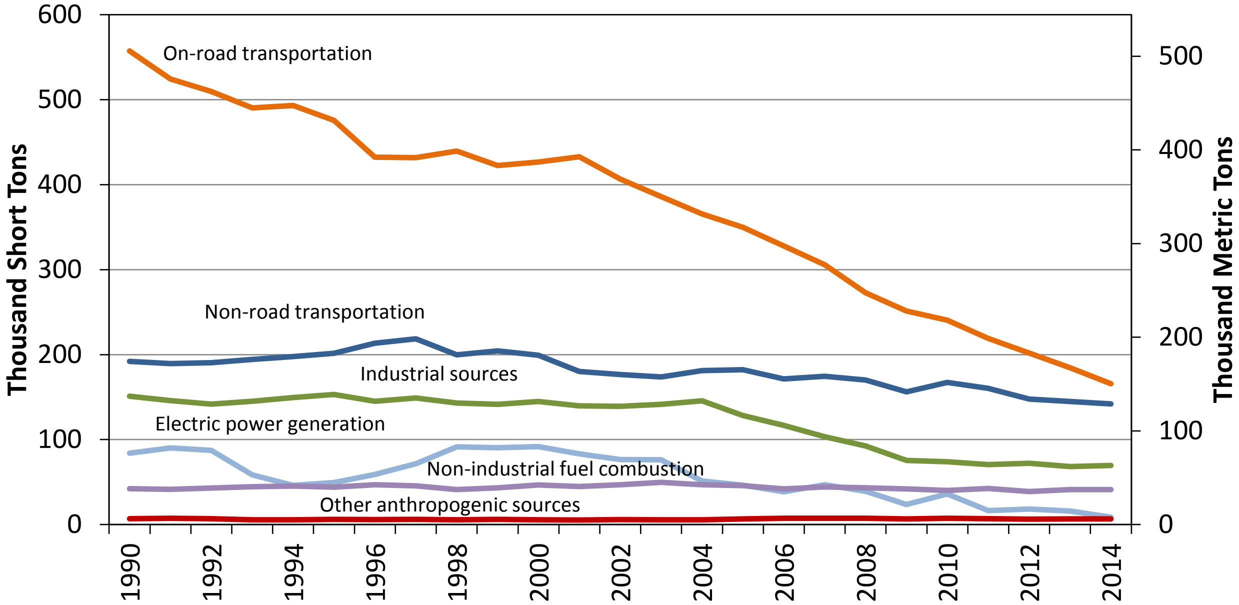
	2014 Annual				2014 Ozone Season			
	NO_X		VOCs		NO_X		VOCs	
Emissions Category	1000 Short Tons	1000 Metric Tons	1000 Short Tons	1000 Metric Tons	1000 Short Tons	1000 Metric Tons	1000 Short Tons	1000 Metric Tons
Canadian PEMA Region: Annual and Ozone Season Emissions								
Industrial Sources	70	64	72	65	34	31	30	27
Non-industrial Fuel Combustion	41	37	92	83	10	9	8	7
Electric Power Generation	9	8	0	0	3	3	0	0
On-road Transportation	166	151	70	64	65	59	27	24
Non-road Transportation	142	129	85	77	70	64	30	27
Solvent Utilization	0	0	205	186	0	0	87	79
Other Anthropogenic Sources	7	6	87	79	4	4	38	34
Forest Fires	n/a	n/a	n/a	n/a	0.008	0.009	0.720	0.653
Biogenic Emissions	12	11	560	508	10	9	451	409
TOTALS	**447**	**406**	**1171**	**1062**	**196**	**179**	**672**	**608**
TOTALS without Forest Fires and Biogenics	**435**	**395**	**611**	**554**	**186**	**170**	**220**	**198**
United States PEMA States: Annual and Ozone Season Emissions								
Industrial Sources	608	551	487	442	253	230	203	184
Non-industrial Fuel Combustion	310	281	192	174	129	117	80	73
Electric Power Generation	662	600	13	12	276	250	5	5
On-road Transportation	1474	1337	747	678	615	558	312	283
Non-road Transportation	812	736	671	609	338	307	280	254
Solvent Utilization	0	0	1044	947	0	0	435	395
Other Anthropogenic Sources	61	55	363	329	25	23	151	137
Forest Fires	6	6	109	99	3	3	45	41
Biogenic Emissions	145	132	4671	4237	60	55	1948	1767
TOTALS	**4078**	**3698**	**8297**	**7527**	**1699**	**1542**	**3459**	**3139**
TOTALS without Forest Fires and Biogenics	**3926**	**3560**	**3517**	**3191**	**1636**	**1485**	**1466**	**1331**

Notes: Short tons and metric tons are rounded to the nearest thousand. Totals in rows may not equal the sum of the individual columns.

Source: ECCC and EPA, 2016.

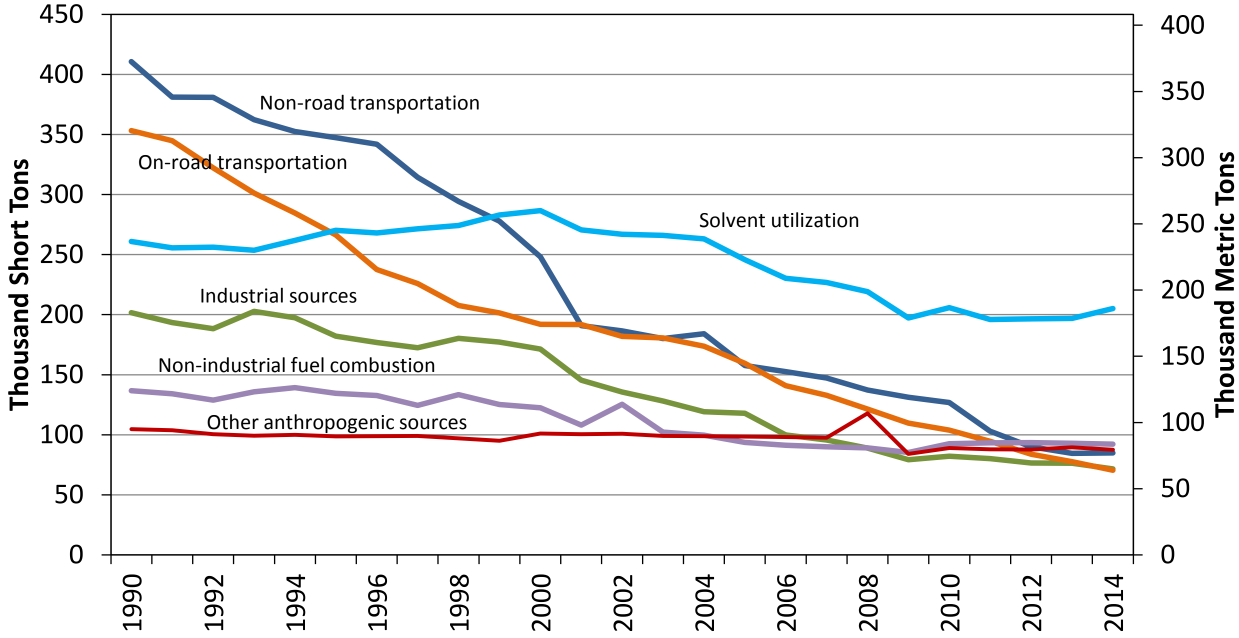
Figures 14 and 15 show Canadian NO_X and VOC PEMA emission trends for the years 1990 through 2014. For NO_X, each source category shows an overall decrease in emissions with most of the reductions originating from on-road mobile sources, industrial sources, and electric power generation. Similarly, over the same time period, each category of VOC sources shows an overall decrease with most of the reductions coming from non-road mobile sources, on-road mobile sources, and industrial sources. The sharp increase in NO_X emissions for on-road transportation in 2002 is due to a different estimation method beginning with that year.

Figure 14. Canada NO_X Emission Trends in the PEMA Region, 1990–2014



Source: ECCC, 2016

Figure 15. Canada VOC Emission Trends in the PEMA Region, 1990–2014

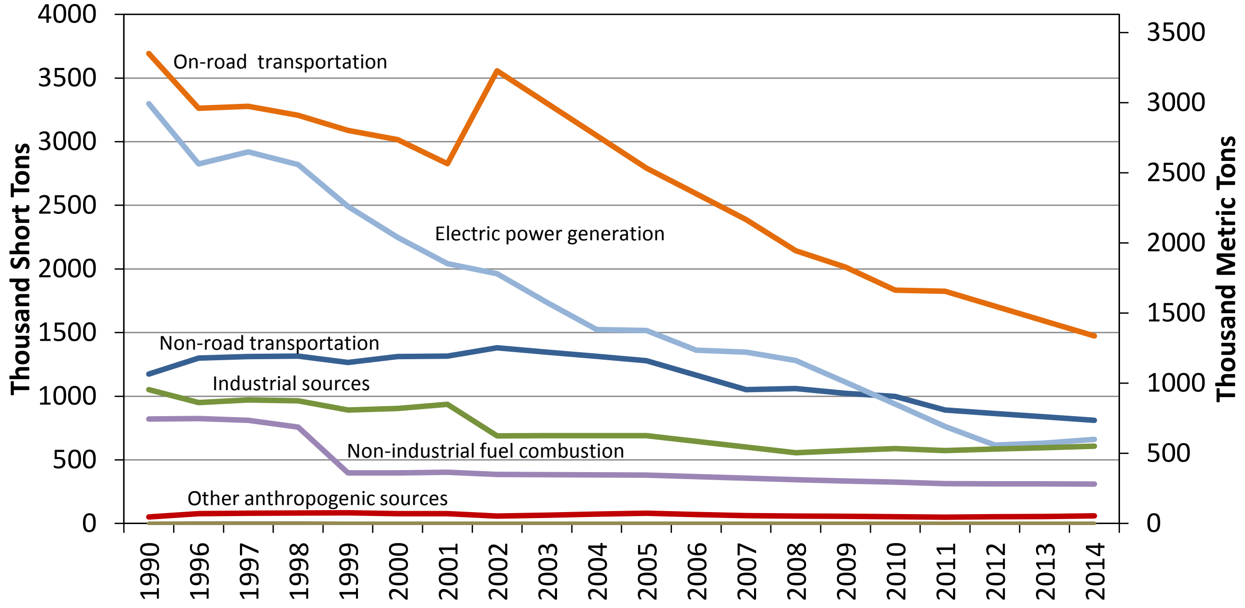


Source: ECCC, 2016

Figures 16 and 17 show United States PEMA emission trends for 1990 through 2014. There is an overall trend of emission reductions for NO_X and VOCs. The percent decrease in emissions from 1990 to 2014 for NO_X is 51 percent and for VOCs is 38 percent. For NO_X emissions, the on-road and non-road transportation sources account for the greatest portion of the emissions in 2014, followed by fuel combustion for electrical power generation and industrial and non-industrial boilers. The largest NO_X emission reductions from these sources have occurred over the last 12 years. The sharp increase in NO_X emissions for on-road transportation in 2002 is due to a different estimation method beginning with that year.

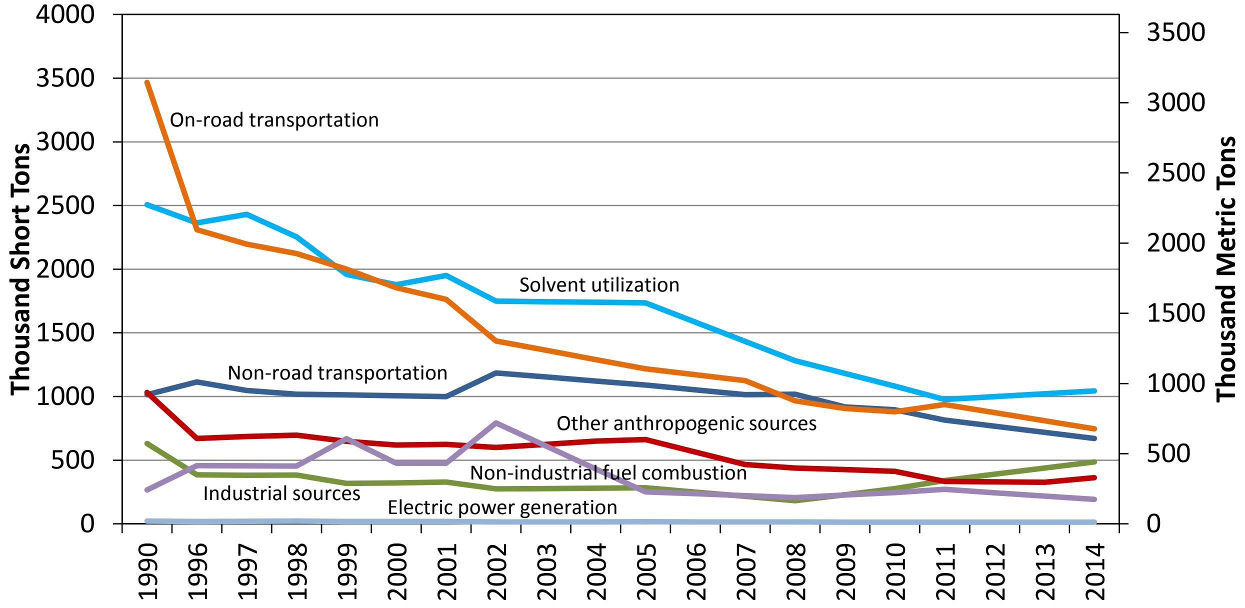
The greatest contributions of VOC emissions since 2012 are predominantly from solvent utilization,

Figure 16. United States NO_X Emission Trends in PEMA States, 1990–2014



Source: EPA, 2016

Figure 17. United States VOC Emission Trends in PEMA States, 1990–2014



Source: EPA, 2016

transportation, and industrial sources. Over the period shown in Figure 17, the largest VOC emission reductions have occurred in on-road mobile sources and solvent utilization. While there is an overall decrease in VOC emissions, there have been increases for petroleum and related industries, including oil and gas production, and for prescribed fires. Emission estimation methods and reporting for these sources has also improved significantly in recent years.

Actions to Address Ozone

Canada and the United States continue to implement programs designed to reduce emissions of NO_X and VOCs. Emissions from power plants and from vehicles remain a focus of these programs.

CANADA

Canada has implemented a series of regulations to align Canadian emission standards for vehicles, engines, and fuels with corresponding standards in the United States.

Four regulations concerning on-road and off-road vehicles are in effect and have been subject to various amendments. They include: *On-Road Vehicle and Engine Emission Regulations; Off-Road Small Spark-Ignition Emission Regulations; Off-Road Compression-Ignition Engine Emission Regulations; and Marine-Spark Ignition Engine, Vessel, and Off-Road Recreational Vehicle Emission Regulations*.

Regulatory initiatives for gasoline include *Sulphur in Gasoline Regulations* and *Benzene in Gasoline Regulations*, which have limited the level of sulfur and benzene content in gasoline. In addition, *Sulphur in Diesel Fuel Regulations* set maximum limits for sulfur in diesel fuels. Sulfur in gasoline impairs the effectiveness of emission control systems and contributes to air pollution. Reducing the sulfur content in gasoline enables advanced emission controls and reduces air pollution.

On July 29, 2015, ECCC published final *Regulations Amending the Sulphur in Gasoline Regulations* (SiGR Amendments), which introduced lower limits on the sulfur content of gasoline from an average of 30 milligrams per kilogram (mg/kg) to 10 mg/kg, in alignment with the EPA Tier 3 fuel standards. The SiGR Amendments were published with *Regulations Amending the On-Road Vehicle and Engine Emission Regulations and Other Regulations Made Under the Canadian Environmental Protection Act, 1999* (ORVEER). The ORVEER Amendments introduce stricter limits on air pollutant emissions from new passenger cars, light-duty trucks, and certain heavy-duty vehicles beginning with the 2017 model year in alignment with the EPA Tier 3 vehicle standards. These two regulatory initiatives work in concert to reduce vehicle air pollutant emissions.

On June 11, 2016, ECCC published proposed amendments to the *Off-Road Small Spark ignition Emission Regulations* for public comment. These regulations apply to small spark-ignition (SSI) engines found in lawn and garden machines, light-duty industrial machines, and light-duty logging machines. The proposed amendments would incorporate the more stringent EPA Phase 3 exhaust emission standards for machines powered by SSI engines and include new evaporative emission standards for SSI engines that have complete fuel systems attached. The proposed amendments would introduce tighter air pollutant emission standards for the 2018 and later model year SSI engines in Canada.

The federal government continues to address VOC emissions through various regulations. The *Tetrachloroethylene (Use in Dry Cleaning and Reporting Requirements) Regulations* were published in March 2003 with two goals: (1) reducing the ambient tetrachloroethylene (PERC) concentration in the air to below 0.3 micrograms per cubic meter and (2) reducing PERC use in dry cleaning in Canada to less than 1,600 metric tons per year. Both goals have been achieved. In 2014, dry cleaners reporting under the regulations used less than 600 metric tons (661 short tons) of PERC.

The *Solvent Degreasing Regulations*, which took effect in July 2003, required a 65 percent reduction in annual consumption of trichloroethylene (TCE) and PERC from affected facilities by 2007. This usage has continued to decline. Under the regulations, ECCC issues annual allowances (consumption units) for use of PERC or TCE to qualifying facilities. Consumption units issued for 2015 represented a reduction of 88 percent for both TCE and PERC relative to the baseline.

ECCC has taken action to reduce VOC emissions from consumer and commercial products. Two regulations, one setting VOC concentration limits for automotive refinishing products and another for architectural coatings, came into effect in 2009. The department is also developing proposed *Volatile Organic Compound (VOC) Concentration Limits for Certain Products Regulations*, which would establish concentration limits for VOCs in 130 product categories, including personal care, automotive, and household maintenance products; adhesives, adhesive removers, sealants, and caulks; and other miscellaneous products.

The final *Code of Practice for the Reduction of Volatile Organic Compound (VOC) Emissions from the Use of Cutback and Emulsified Asphalt* was published in the *Canada Gazette*, Part I on February 25, 2017. The main objective of the Code is to protect the environment and health of Canadians while maintaining road safety by recommending best practices that encourage, when suitable, the use of low VOC-emitting asphalt. It is anticipated that compliance with the Code would result in annual VOC emission reductions of up to 5,000 metric tons from the use of asphalt.

ECCC continues to take action to reduce emissions of smog-forming pollutants. On May 28, 2016, the *Code of Practice to Reduce Fugitive Emissions of Total Particulate Matter and Volatile Organic Compounds from the Iron, Steel, and Ilmenite Sectors* was published along with a Code of Practice to Reduce Emissions of Fine Particulate Matter ($PM_{2.5}$) from the Aluminium Sector.

New ambient air quality standards for $PM_{2.5}$ and ground-level ozone were implemented in 2013 under the CEPA 1999 as approved by federal, provincial, and territorial Ministers of the Environment. A review of the 2020 ozone and $PM_{2.5}$ standards will be initiated in 2017 and 2018, respectively, to ensure that the standards remain appropriate and reflect the latest scientific information and technological advances. On October 3, 2016, the federal, provincial, and territorial Ministers of the Environment announced new CAAQS for SO_2. In addition, work is underway to establish new, more stringent standards for nitrogen dioxide which is expected to be completed in 2018.

UNITED STATES ★

The EPA implemented the NBP under the NO_X State Implementation Plan Call from 2003 to 2008 to reduce ozone season NO_X emissions in eastern states. Starting in 2009, the NO_X annual and ozone season programs under EPA's CAIR took effect. These programs addressed regional interstate transport of fine particulate matter and ozone by requiring 28 eastern states to make reductions in SO_2 and NO_X emissions that contribute to fine particle and ozone pollution in downwind states. All affected states chose to meet their emission reduction requirements by controlling power plant emissions through the CAIR NO_X annual trading program and the CAIR NO_X ozone season trading program. In addition to the CAIR NO_X ozone season program and the former NBP, prior programs, such as the Ozone Transport Commission's NO_X Budget Program, and current regional and state NO_X emission control programs (i.e., CSAPR) have contributed significantly to the ozone season NO_X reductions.

From 2013 to 2014, ozone season NO_X emissions from sources in the CAIR NO_X ozone season program decreased by 25,000 short tons (23,000 metric tons) or 5 percent. NO_X ozone season program emissions decreased from 1.5 million short tons (1.4 million metric tons) in 2000 to 450,000 short tons (410,000 metric tons) in 2014, a decrease of 69 percent. CSAPR replaced CAIR on January 1, 2015. For more information on the CAIR and CSAPR NO_X programs, see www.epa.gov/airmarkets.

In addition to implementing existing United States vehicle, non-road engine, and fuel quality rules to achieve both VOC and NO_X reductions, EPA continues implementation and updating of New Source Performance Standards to achieve VOC and NO_X reductions from new and modified existing sources. Reductions of NO_X emissions are also being achieved through solid waste incineration unit rules and guidelines that impact new and existing incineration units. EPA finalized standards that have significantly reduced NO_X, particulate matter (PM), and VOCs from on-highway light-duty and heavy-duty vehicles.

Scientific and Technical Cooperation and Research - Emission Inventories and Trends

The United States and Canada have updated and improved their emission inventories and projections for a number of important pollutants, including particulate matter less than or equal to 10 microns (PM_{10}), $PM_{2.5}$, VOCs, NO_X, and SO_2, to reflect the latest information available. In Canada, the emission inventory data are for the year 2014. The United States emissions data are based on national and state-level trend information from the 2014 National Emission Inventory (https://www.epa.gov/air-emissions-inventories/air-pollutant-emissions-trends-data).

Figure 18 shows the distribution of emissions by source category grouping for SO_2, NO_X, and VOCs. The following observations can be made about this figure:

- Canadian SO_2 emissions originate mostly from the non-ferrous smelting and refining industry, upstream petroleum industry, and coal-fired electric power generation. The relative contribution from electric power generation utilities is lower in Canada due to the large hydroelectric and nuclear capacity in place.
- SO_2 emissions in the United States originate primarily from coal-fired combustion in the electric power sector and from industrial boilers.
- In Canada, non-road and on-road vehicles account for the greatest portion of NO_X emissions, followed by the upstream petroleum industry.
- Similarly, in the United States, non-road and on-road vehicles account for the greatest portion of NO_X emissions, followed by industrial sources.
- Solvent utilization and industrial sources contribute more than half of the total VOC emissions in both Canada and the United States.

Figures 19, 20, and 21 show emissions from 1990 through 2014 in Canada and the United States, for SO_2, NO_X, and VOCs, respectively. Both countries have seen major reductions in emissions.

In Canada, the reductions in SO_2 emissions came from the non-ferrous smelting and refining industry, coal-fired electric power generation, and the upstream petroleum industry. For NO_X, the reductions were from coal-fired electric power generation and transportation-related sources. The VOC reductions came from transportation-related sources such as off-road and on-road vehicles.

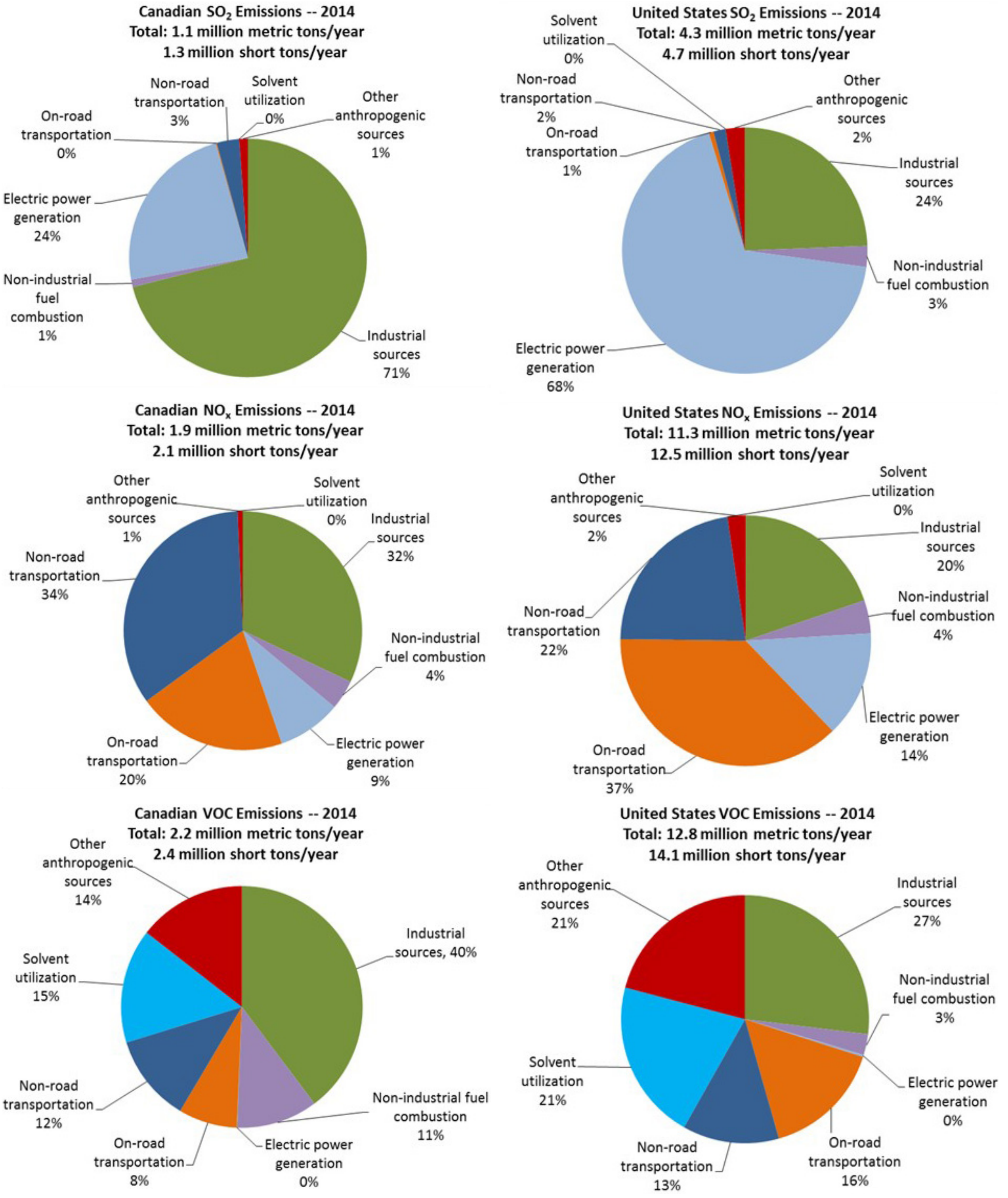
In the United States, the reductions in SO_2 emissions came mostly from electric power generation and industrial sources. Reductions in NO_X emissions came from on-road and off-road transportation, and from electric power generation. Reductions in VOC emissions came from on-road and off-road transportation as well as from other anthropogenic sources.

Scientific Cooperation

Air Quality Model Evaluation International Initiative

Since its start in 2008, the Air Quality Model Evaluation International Initiative (AQMEII) has been coordinated by the European-Commission Joint Research Center (JRC) and the EPA. The primary goal of this project is to promote the collaboration of the European and North American regional scale air quality modeling communities on evaluation of air quality models. The key elements driving the AQMEII process are regular, dedicated workshops; the organization of international model evaluation studies; and the dissemination of findings from these studies in the peer-reviewed literature.

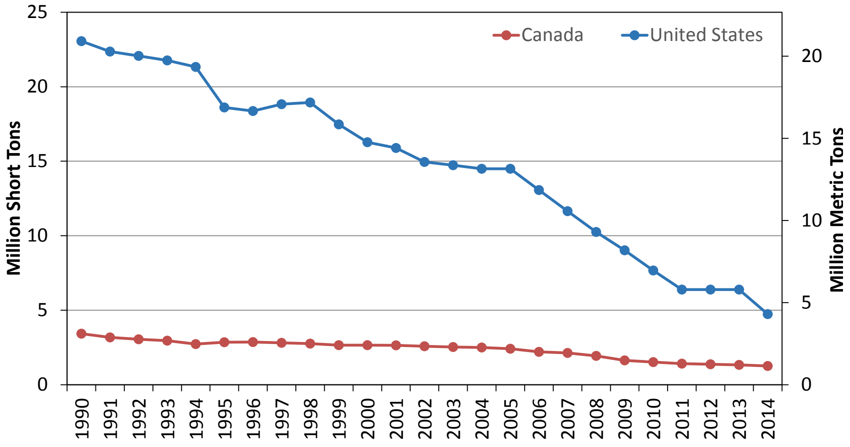
Figure 18. Canada and the United States National Emissions by Sector for Selected Pollutants, 2014



Notes: Emissions exclude natural sources (biogenics and forest fires).
Percentages may not add up to 100 due to rounding.

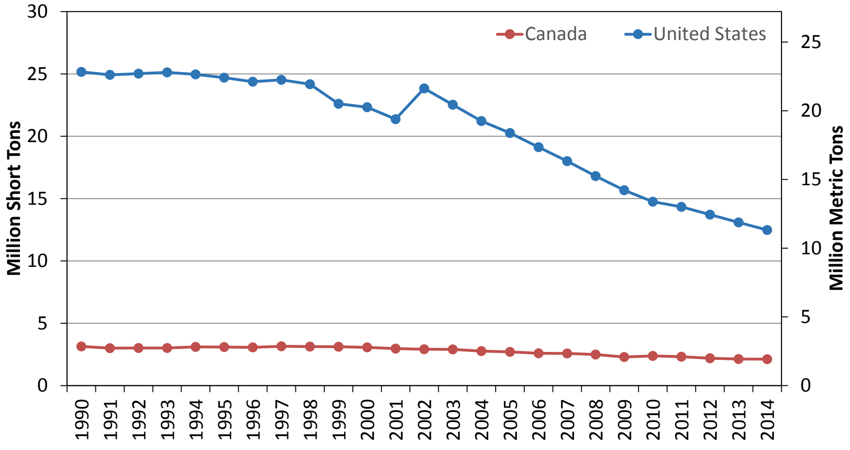
Sources: ECCC, 2016; EPA, 2016

Figure 19. National SO_2 Emissions in Canada and the United States from All Sources, 1990–2014



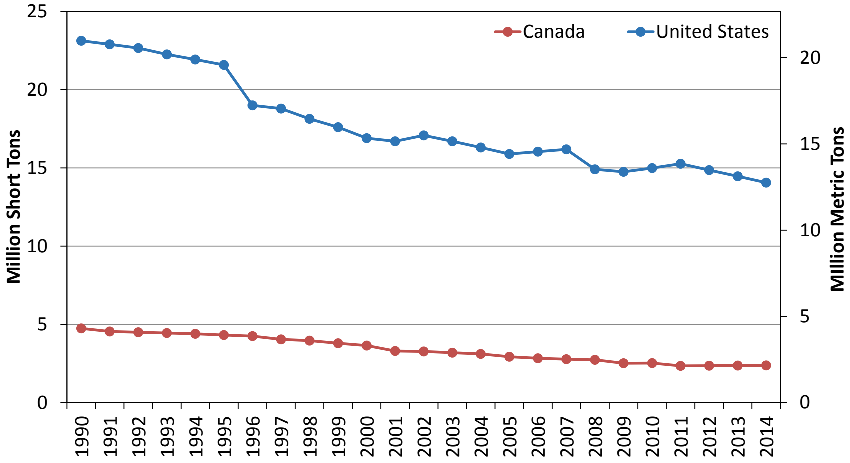
Source: ECCC and EPA, 2016

Figure 20. National NO_X Emissions in Canada and the United States from All Sources, 1990–2014



Source: ECCC and EPA, 2016

Figure 21. National VOC Emissions in Canada and the United States from All Sources, 1990–2014



Phase 2 of AQMEII began in 2012 and focused on applying and evaluating online coupled or integrated chemistry transport models and meteorological models. It is well known that atmospheric dynamics and composition are interconnected, that variations in heat distribution affect atmospheric flows and physics, and that atmospheric optical and heat properties depend on atmospheric composition. An online coupled model is a model in which all these feedback loops are partially or completely closed. This online coupled or integrated modeling approach leads to a higher level of complexity in model development, application, and evaluation, but at the same time also yields intrinsic consistency in the model results.

The primary focus of Phase 2 was on simulating air quality for the year 2010, but updated inputs were also prepared for 2006 for North America to facilitate dynamic evaluation studies. A common set of anthropogenic emissions and chemical boundary conditions was prepared and used by all modeling groups. Over 20 groups took part in this project, including EPA and ECCC. JRC and ECCC collected, compiled, and harmonized a massive amount of monitoring and observation data for model evaluation. The analysis of model results and comparison with observations was distributed throughout the community of participants. Over 24 papers were included in a special journal issue in *Atmospheric Environment*. Fourteen of these papers were co-authored by researchers from EPA and/or ECCC, including six papers that had an EPA or ECCC lead author. The body of work contained in this special issue represents a first step in the systematic evaluation of online coupled modeling systems through a multi-model intercomparison approach. A key recommendation is that future work should focus on shorter-duration, process-focused sensitivity simulations, in order to better inter-compare process representations and model coupling methodologies. Another important finding is that inter-model variability typically is greater than the feedback effects simulated with a given model. This implies that factors other than feedback effects such as emissions, boundary conditions, and process representations of chemistry and/or transport remain the key determinants for overall model performance. However, within a given model, the feedback effects were shown to be capable of improving both meteorological and chemical forecasts, especially for specific episodes, and hence, represent a fruitful direction for future research.

Some of the other highlights of findings from Phase 2 of AQMEII include:

- It is important to include interactions between meteorology and chemistry (especially aerosols and ozone) in online coupled models;
- Aerosol indirect and direct effects often counteract each other - direct effects are weaker on the annual scale;
- The aerosol indirect effect (cloud microphysics implementation) is a prime cause of model differences; and
- The representation of aerosol indirect effects is incomplete/poor and needs to be further developed and improved in online coupled models.

A key finding from AQMEII Phase 2 (as well as previous global model simulations under the Task Force on the Hemispheric Transport of Air Pollution (TF-HTAP) model intercomparison) was that global transport of certain pollutants may exert a significant seasonal influence on simulated regional scale concentrations. The influence of global scale background concentrations on regional scale air quality simulations is the primary focus of the next phase of AQMEII that will contribute to the activities of TF-HTAP. EPA is an active participant in the ongoing AQMEII Phase 3 effort.

Global Assessment of Precipitation Chemistry and Deposition

The atmospheric deposition of nitrogen, sulfur, and other chemical species to underlying surfaces is an important exposure pathway that can contribute or lead to the degradation of air, land, and water quality as well as reductions in the benefits humans may derive from ecosystems. Understanding the processes and outcomes associated with atmospheric deposition is needed to characterize progress toward meeting targeted reductions in deposition in the United States and Canada.

Scientists at the EPA actively participate in the NADP’s Total Deposition Science Committee (TDEP). The mission of TDEP is to improve estimates of atmospheric deposition by advancing the science of measuring and modeling atmospheric wet, dry, and total deposition of species such as sulfur, nitrogen, and mercury. TDEP provides a forum for the exchange of information on current and emerging issues within a broad multi-organization context including atmospheric scientists, ecosystem scientists, resource managers, and policy makers. One of the goals of the NADP's TDEP is to provide estimates of total sulfur and nitrogen deposition for use in critical loads and other assessments, where loading results in the acidification and eutrophication of ecosystems.

Gridded total deposition values provided by TDEP were developed using a hybrid approach that combines measured air concentration and wet deposition data with modeled unmeasured air concentration estimates and deposition velocities. Wet deposition values are obtained from combining the National Trends Network (NTN) measured values of precipitation chemistry with precipitation estimates from the Parameter-elevation Regression on Independent Slopes Model (PRISM). Dry deposition values are estimated by combining air concentration data from the Clean Air Status and Trends Network (CASTNET) and modeled deposition velocities. Modeled data were obtained from the Community Multiscale Air Quality model. Details of the methodology for developing the data set, as well as comparisons of these data to other deposition estimates, are provided in Schwede and Lear (2014). Total sulfur and nitrogen deposition data and maps are available for 2000 through 2015 on the NADP website.

EPA has been coordinating with ECCC to apply the same deposition approach of fusing measurement and modeling data with the goal of producing mutually-agreed-upon maps of total atmospheric deposition across North America. The Atmospheric Deposition Analysis Generated by Optimal Interpolation from Observations (ADAGIO) system being developed by ECCC will produce annual wet, dry, and total deposition maps for sulfur and nitrogen. The CAPMoN and NAPS network are providing observational data for air and precipitation concentrations in addition to the data from NTN and CASTNET. The Global Environmental Multi-scale – Modeling Air Quality and Chemistry model is being used to provide the modeled estimates. It is anticipated that the first results from ADAGIO for 2010 total deposition of nitrogen and sulfur will be released shortly.

Cooperation on Mobile Transportation Sources

There is a long history of collaboration between ECCC and the EPA to reduce transportation emissions, largely fostered by the framework of the Agreement. A work plan has been developed that supports this ongoing collaboration. EPA and ECCC continue to work closely to align emission standards and coordinate their implementation. For example, EPA and ECCC share information and closely coordinate vehicle and engine compliance verification testing programs between our laboratories in Ann Arbor, Michigan and Ottawa, Canada. EPA and ECCC also coordinate research and testing projects to inform the development of regulations. This collaboration minimizes testing overlap and improves the breadth of compliance monitoring, resulting in program efficiencies in both organizations. EPA and ECCC meet regularly to review progress on their coordination efforts and to discuss any opportunities or obstacles that should be addressed.

Cooperation on Oil and Gas Sector Emissions

In November 2015, a work plan between the EPA and ECCC was approved under the Agreement to support collaboration on oil and gas sector emissions. The oil and gas work plan has facilitated ongoing technical discussions between the two countries on a range of oil and gas issues, including developing equipment standards, addressing regulatory requirements and emissions associated with venting and flaring, designing leak detection and repair programs, fence-line monitoring at refineries, and the sharing of information through WebEx discussions on our respective greenhouse gas inventory and reporting programs. The work plan also served as the foundation for developing joint commitments to reduce methane emissions from the oil and gas sector. The Canada–United States cooperation has also extended to a work exchange with an EPA representative participating in an Embassy Science Fellowship Program in collaboration with ECCC in fall 2016.

Conclusion

Canada and the United States continue to successfully meet their commitments set forth in the 1991 Agreement. Since the establishment of the Agreement, both countries have made significant progress in reducing acid rain and controlling ozone in the transboundary region.

Despite the results achieved under the Agreement, the pollutants covered by the Agreement (SO_2, NO_X, VOCs) remain a concern and continue to have significant impacts on human health and the environment in both countries. Continued bilateral efforts are needed to reduce the transboundary impact of these pollutants and to ensure that transboundary air pollution does not affect each country's ability to attain and maintain its national ambient air quality standards for pollutants such as ozone and $PM_{2.5}$.

The Agreement provides a formal and flexible method for addressing transboundary air pollution and continues to provide a framework under which the two countries can cooperate to address ongoing and future air quality issues.

Appendix A: List of Acronyms

ADAGIO	Atmospheric Deposition Analysis Generated by Optimal Interpolation from Observations
Agreement	Canada–United States Air Quality Agreement
ARP	Acid Rain Program
AQMEII	Air Quality Model Evaluation International Initiative
AQMS	(Canada) Air Quality Management System
BACT	best available control technology
BART	best available retrofit technology
BCVCC	British Columbia Visibility Coordinating Committee
CAAQS	Canadian Ambient Air Quality Standards
CAIR	Clean Air Interstate Rule
CAM	compliance assurance monitoring
CAPMoN	Canadian Air and Precipitation Monitoring Network
CASTNET	Clean Air Status and Trends Network
CEMS	continuous emissions monitoring systems
CEPA 1999	Canadian Environmental Protection Act, 1999
CSAPR	Cross-State Air Pollution Rule
ECCC	Environment and Climate Change Canada
EPA	U.S. Environmental Protection Agency
IMPROVE	Interagency Monitoring of Protected Visual Environments
IJC	International Joint Commission
JRC	(European-Commission) Joint Research Center
kg/ha/yr	kilograms per hectare per year
LAER	lowest achievable emission rate
LFV	Lower Fraser Valley
mg/kg	milligrams per kilogram
NAAQS	National Ambient Air Quality Standards
NADP	National Atmospheric Deposition Program
NAPS	National Air Pollution Surveillance
NAtChem	National Atmospheric Chemistry Database
NBP	NO_x Budget Trading Program
NO_X	nitrogen oxides
NSR	New Source Review
NTN	National Trends Network
ORVEER	*Regulations Amending the On-Road Vehicle and Engine Emission Regulations and Other Regulations Made Under the Canadian Environmental Protection Act, 1999*
PEMA	pollutant emission management area
PERC	tetrachloroethylene
PM	particulate matter
$PM_{2.5}$	particulate matter less than or equal to 2.5 microns, known as fine particles
PM_{10}	particulate matter less than or equal to 10 microns
ppb	parts per billion

Appendix A: List of Acronyms (continued)

PRISM	Parameter-elevation Regression on Independent Slopes Model
PSD	Prevention of Significant Deterioration
SiGR	*Regulations Amending the Sulphur in Gasoline Regulations*
SO_2	sulfur dioxide
SSI	small spark-ignition
TCE	trichloroethylene
TDEP	(NADP) Total Deposition Science Committee
TF-HTAP	Task Force on the Hemispheric Transport of Air Pollution
VAQR	Visual Air Quality Rating
VOCs	volatile organic compounds