Canada – United States
Air Quality Agreement
Progress Report 2014

The International Joint Commission Requests Your Comments on This Report

The International Joint Commission (IJC) is interested in your views on the important work being carried out under the Canada-U.S. Air Quality 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; and what do you think about the information provided in this report?

Under the Air Quality Agreement, the IJC invites public comment and provides a synthesis of comments to the governments of Canada and the United States, to assist them with implementing the Agreement. The IJC invites you to send written comments on this report until July 31, 2015, to either address below:

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Canadian spelling is used throughout this report except when referring to U.S. titles.

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INTRODUCTION

In 1991, the United States and Canada established an Air Quality Agreement (AQA) to address transboundary air pollution. The Agreement initially focused on reducing levels of acidic deposition in each country, and in 2000 the Agreement was amended to also address ground-level ozone (O_3). A bilateral Air Quality Committee, established in the Agreement, is required to issue a progress report every two years, highlighting the commitments included in the AQA and describing the continued efforts by both governments to address transboundary air pollution. This document is the twelfth such progress report under the AQA.

In this report, Canada and the United States document the large reductions in sulphur dioxide (SO_2) and nitrogen oxide (NO_x) emissions that have been achieved to date, along with the associated reductions in ecosystem acidification and improvements in air quality. Between 1990 and 2012, emissions of SO_2 declined by 58 percent in Canada and 78 percent in the United States. The report also provides information on successes in reducing emissions of NO_x and volatile organic compounds (VOCs), the precursors to O_3, in the transboundary ozone region. Between 2000 and 2012, Canada's total NO_x emissions in the region decreased by 45 percent, while in the United States total NO_x emissions in the region declined by 47 percent.

The report also describes scientific and technical cooperation and research under way between the two countries, and provides an update on new actions in each country that will help further reduce levels of acid rain, O_3 and particulate matter (PM). These efforts signify the ongoing importance both countries place on cooperation and innovation in addressing transboundary air pollution issues.

SECTION 1:
COMMITMENTS

Acid Rain Annex

Overview

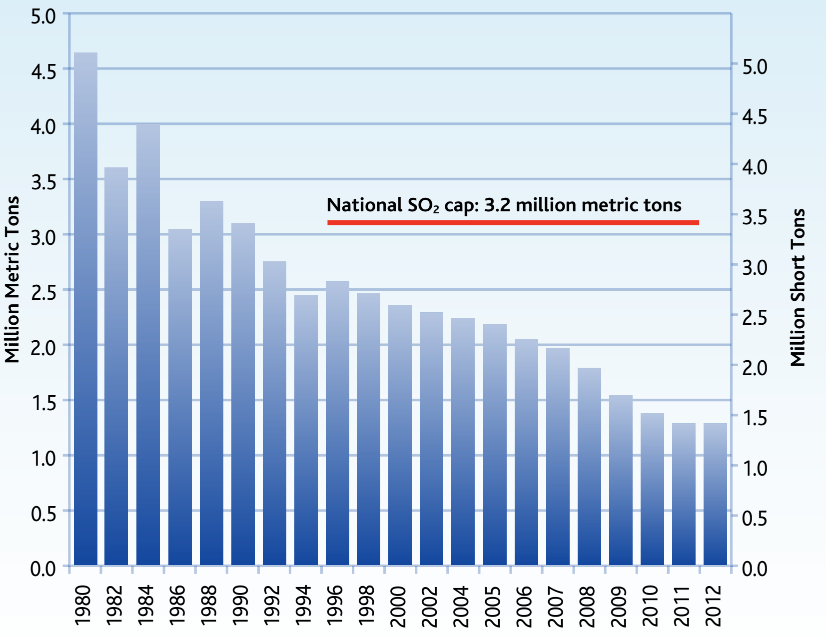
The Acid Rain Annex to the 1991 AQA established commitments for both countries to reduce emissions of SO_2 and NO_x, the primary precursors to acid rain, from stationary and mobile sources. The commitments also include prevention of air quality deterioration, visibility protection, and continuous emission monitoring. Both countries have succeeded in reducing the impact of acid rain on each side of the border. Studies in each country, however, indicate that further efforts are necessary to restore damaged ecosystems.

Key Commitments and Progress: SO_2 Emission Reductions

CANADA

For more than two decades, Canada has reduced SO_2 emissions through various actions, including the requirements to reduce sulphur content in fuels and the implementation of the Canada-Wide Acid Rain Strategy for Post-2000. The Strategy serves as the framework for addressing the issues related to acid rain, with the goal 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 2012, Canada's total SO_2 emissions were 1.3 million metric tons (1.4 million short tons[1]), about 60 percent below the national cap of 3.2 million metric tons (3.5 million short tons). This also represents a 58-percent reduction from Canada's total SO_2 emissions in 1990 (see Figure 1).

Figure 1. Total Canadian SO_2 Emissions, 1980-2012



Source: Environment Canada, 2014

The largest contribution of SO_2 emissions originates from industrial sources, which accounted for approximately 66 percent of national SO_2 emissions in 2012. Key sources, such as the non-ferrous smelting and refining industry and the upstream petroleum industry, contributed 27 percent and 21 percent, respectively, to national SO_2 emissions in 2012.

Electric power generation accounted for 22 percent of the national total. The majority of overall reductions in national SO_2 emission levels can be attributed to the SO_2 emission reductions undertaken by the four eastern provinces (New Brunswick, Nova Scotia, Quebec and Ontario) targeted by the Acid Rain Strategy and to recent facility closures.

Although Canada has been successful in reducing emissions of acidifying pollutants, many areas across Canada have a low capacity to withstand acidic deposition and continue to receive levels in excess of critical loads, most notably

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

in eastern Canada. A critical load can be defined as the maximum amount of acidifying deposition an ecosystem can tolerate in the long term without being damaged (see Ecological Effects in Section 2 for further information).

Additional measures to reduce SO_2 and NO_x emissions from certain industrial sectors are being undertaken as part of Canada's Air Quality Management System (see Section 3: New Actions on Acid Rain, Ozone and Particulate Matter).

UNITED STATES ★

The United States succeeded in meeting its commitment to reduce annual SO_2 emissions by 10 million short tons (9.1 million metric tons) from 1980 levels by 2000. Additionally, since 2007, emissions of SO_2 from the electric power sector have been below the 2010 national emission cap of 8.95 million short tons (8.1 million metric tons).

The Acid Rain Program (ARP), established under Title IV of the 1990 Clean Air Act (CAA) Amendments, requires major emission reductions of SO_2 and NO_X, the primary precursors of acid rain, from the power sector. The SO_2 program sets a permanent cap on the total amount of SO_2 that can be emitted by electric generating units (EGUs) in the contiguous United States, and uses a market-based cap and trade program to achieve emission reductions. The program was phased in, with the final 2010 SO_2 cap set at 8.95 million short tons (8.1 million metric 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 program that applies to a subset of coal-fired EGUs and is closer to a traditional, rate-based regulatory system.

In 2012, the SO_2 requirements under the ARP applied to 3652 fossil-fuel-fired combustion units that served large generators greater than 25 megawatts (MW) at 1 249 facilities across the country providing electricity for sale. ARP units emitted 3.3 million short tons (3.0 million metric tons) of SO_2 in 2012, meaning that ARP sources reduced emissions by 12.4 million short tons (11.3 million metric tons, or 79 percent) from 1990 levels and 14 million short tons (12.7 million metric tons, or 81 percent) from 1980 levels. The vast majority of ARP SO_2 emissions result from coal-fired EGUs, although the program also applies to oil and gas units.

These reductions occurred while electricity demand (measured as heat input) remained relatively stable, indicating that the reduction in emissions was not driven by decreased electric generation. Instead, there was a drop in emission rate. A drop in emission rate represents an overall increase in the environmental efficiency of these sources as power generators install controls, run controls year-round, switch to different fuels, or otherwise cut their SO_2 emissions while meeting relatively steady demand for power.

Clean Air Interstate Rule

In 2005, the United States promulgated the Clean Air Interstate Rule (CAIR) to address regional interstate transport of O_3 and fine particle ($PM_{2.5}$) pollution. CAIR requires 24 eastern states and the District of Columbia (D.C.) to limit annual emissions of NO_x and SO_2, which contribute to the formation of $PM_{2.5}$ (particulate matter less than or equal to 2.5 microns). CAIR also requires 25 states and D.C. to limit ozone-season NO_x emissions, which contribute to the formation of smog during the summer ozone season (May to September).

However, in July 2008 the U.S. Court of Appeals for the D.C. Circuit granted several petitions for review of CAIR, finding significant flaws in the rule. In December 2008 the court issued a ruling to keep CAIR and the CAIR Federal Implementation Plans (FIPs), including the CAIR trading programs, in place temporarily until the U.S. Environmental Protection Agency (EPA) issued new rules to replace CAIR and the CAIR FIPs. On July 6, 2011, the EPA finalized the Cross-State Air Pollution Rule (CSAPR) to replace CAIR beginning in 2012. However, prior to implementation, the court stayed CSAPR pending judicial review on December 30, 2011. On August 21, 2012, the court issued an opinion vacating CSAPR. In its August opinion, the court also ordered the EPA to continue administering CAIR. The U.S. Supreme Court subsequently granted petitions from the EPA and several environmental and public health organizations to review the D.C. Circuit Court's decision. On April 29, 2014, the U.S.

Supreme Court reversed the D.C. Circuit opinion vacating CSAPR. On June 26, 2014, EPA requested that the D.C. Circuit lift the CSAPR stay and toll the CSAPR compliance deadlines by three years, to allow implementation of Phase 1 for 2015 and Phase 2 for 2017. On October 23, 2014, the D.C. Circuit granted EPA's request. CSAPR Phase 1 implementation is now beginning in 2015, with Phase 2 beginning in 2017.

CAIR includes three separate cap and trade programs to achieve the rule's required reductions: the CAIR NO_x ozone season trading program, the CAIR NO_x annual trading program, and the CAIR SO_2 annual trading program. The CAIR NO_x ozone season and annual programs began in 2009, while the CAIR SO_2 annual program began in 2010.

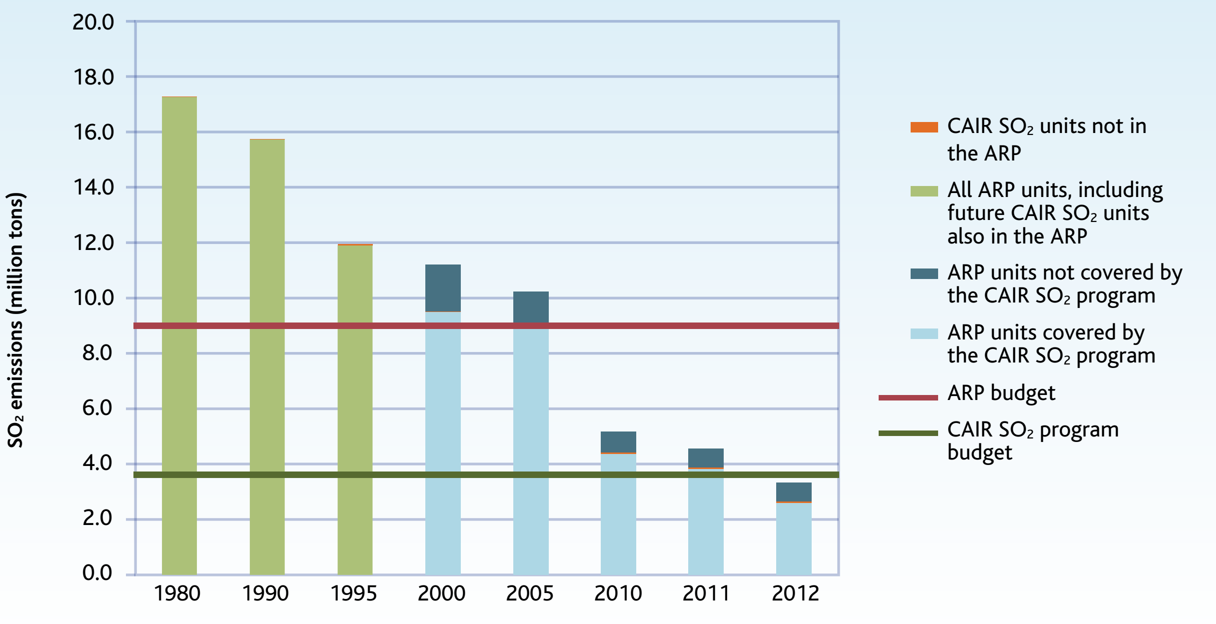
In 2012, there were 3336 affected EGUs at 952 facilities in the CAIR SO_2 and NO_x annual programs. The CAIR programs cover a range of unit types, including units that operate year-round to provide baseload power to the electric grid as well as units that provide power on peak demand days only and may not operate at all during some years. Annual SO_2 emissions from sources in the CAIR SO_2 program alone fell from 9.1 million short tons (8.2 million metric tons) in 2005 when CAIR was promulgated to 2.8 million short tons (2.5 million metric tons) in 2012, a 69 percent reduction. Between 2011 and 2012, SO_2 emissions fell 1.1 million short tons (1.0 million metric tons), or 28 percent. In 2012, the total SO_2 emissions from participating sources were about 855 000 short tons (776 000 metric tons) below the regional CAIR emission budget.

The EPA's Emissions Tracking Highlights site contains the most up-to-date emission and control data for sources subject to the ARP and CAIR: www.epa.gov/airmarkets/quarterlytracking.html.

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 the metals and refining industries, and the use of cleaner fuels in residential and commercial boilers, have contributed to an overall reduction in annual SO_2 emissions. National SO_2 emissions from all sources have fallen from nearly 26 million short tons (23.6 million metric tons) in 1980 to just over 5 million short tons (4.8 million metric tons) in 2012 (see www.epa.gov/ttn/chief/trends).

Figure 2 combines emission and compliance data for ARP and CAIR to more holistically show reductions in power sector emissions of SO_2 from these national and regional programs, as of 2012.

Figure 2. SO_2 Emissions from CAIR SO_2 Annual Program Sources, 1980–2012



Note: 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.

Source: U.S. EPA, 2013

Key Commitments and Progress: 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. In 2012, industrial emissions of NO_x totaled 612 885 metric tons (674 174 short tons). Emissions of NO_x from all industrial sources, including emissions from electric power generation, totaled 778 658 metric tons (856 524 short tons) in 2012.

Transportation sources contributed the majority of NO_x emissions in 2012, accounting for almost 54 percent of total Canadian emissions, with the remainder produced by the upstream petroleum industry (23 percent), electric power generation facilities (9 percent), and other sources (see Figure 25). Canada continues to develop programs to further reduce NO_x emissions nationwide.[2]

UNITED STATES

The United States has exceeded its goal under the Acid Rain Annex to reduce total annual NO_x emissions by 2 million short tons (1.8 million metric tons) below projected annual emission levels for 2000 without the ARP (8.1 million short tons, or 7.4 million metric tons).

Title IV of the CAA requires NO_x emission reductions from certain coal-fired EGUs. Unlike the market-based NO_x programs in CAIR, the ARP requires NO_x emission reductions for older, larger coal-fired EGUs by limiting their NO_x emission rate (expressed in pounds per million British thermal units [lbs./mmBtu]). In 2012, 900 units at 368 facilities were subject to the ARP NO_x program.

Emissions of NO_x from all sources covered by the ARP were 1.7 million short tons (1.5 million metric tons) (Figure 3) in 2012. This level is 6.4 million short tons (5.5 million metric tons) less than the projected NO_x level in 2000 without the ARP, and over three times the Title IV NO_x emission reduction commitment under the Acid Rain Annex.

While the ARP is responsible for a large portion of these annual NO_x reductions, other programs, such as the CAIR NO_x ozone season and annual programs as well as state NO_x emission control programs, also contributed significantly to the NO_x reductions that sources achieved in 2012.

Emissions/Compliance Monitoring

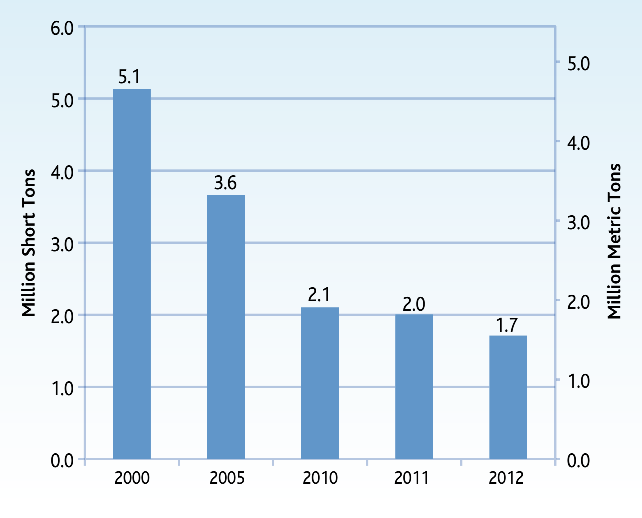
CANADA

Canada continues to meet its commitments to estimate and monitor emissions of NO_x and SO_2 from new electric utility units and existing electricity units with a capacity rating greater than 25 MW. Continuous emission monitoring systems (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-loaded 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 93 percent of their total capacity. In addition, under Canada's National Pollutant Release Inventory (NPRI) mandatory reporting program, electric power generating facilities are required to report their air pollutant emissions (including NO_x and SO_2) annually.

UNITED STATES

The 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 CEMS or other approved methods. Part 75 requires sources to conduct stringent quality assurance tests

Figure 3. U.S. Title IV Utility Unit Annual NO_x Emissions from all ARP Sources, 1990–2012



Source: U.S. EPA, 2014

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[2] For further information on Canadian emissions, consult www.ec.gc.ca/inrp-npri/default.asp?lang=En&n=0EC58C98-1.

of their monitoring systems, such as daily and quarterly calibration tests and a semi-annual or annual relative accuracy test audit. These tests ensure that sources report accurate data and provide assurance to market participants that a ton of emissions measured at one facility is equivalent to a ton measured at another facility.

In 2012, 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. The relatively low percentage for oil-fired units is consistent with the decline in oil-fired heat input, as most of these units were used infrequently and qualified for reduced monitoring. Although some CAIR units with low levels of emissions are not required to use CEMS, the vast majority of NO_x emissions—over 99 percent—were measured by CEMS. Coal-fired units were required to use CEMS for NO_x concentration and stack gas flow rate to calculate and record their NO_x mass emissions. Oil-fired and gas-fired units could use a NO_x CEMS in conjunction with a fuel-flow meter to determine NO_x mass emissions. Alternatively, for oil-fired and gas-fired units that either operated infrequently or had very low NO_x emissions, Part 75 provided low-cost alternatives to conservatively estimate NO_x mass emissions.

Using automated software audits, the EPA rigorously checks the completeness, quality and integrity of monitoring data. The Agency promptly sends results from the audits to the source, and requires correction of critical errors. In addition to electronic audits, the EPA conducts targeted field audits on sources that report suspect data. In 2012, all reporting ARP and CAIR SO_2 facilities were in compliance with both programs, and held enough allowances to cover their SO_2 emissions. Similarly, all reporting covered facilities were in compliance with the CAIR NO_x annual programs in 2012, and held enough allowances to cover their NO_x emissions. Additionally, All 900 units subject to ARP NO_x emissions limitations in 2012 were in compliance. Emission data are available to the public within two months of being reported to the EPA, and can be accessed on the Air Markets Program Data website at www.ampd.epa.gov/ampd/.

Acid Deposition Monitoring, Modelling, Maps and Trends

Airborne pollutants are deposited on the Earth's surface by three processes: (1) wet deposition (rain and snow), (2) dry deposition (particles and gases), and (3) deposition by cloud water and fog. Wet deposition is comparatively easy to measure using precipitation monitors, and the concentration of sulphate and nitrate in precipitation is regularly used to assess the changing atmosphere as it responds to decreasing or increasing sulphur and nitrogen emissions. In Canada and the United States, to facilitate this comparison, measurements of wet sulphate deposition are typically corrected to omit the contribution of sea-salt sulphate at near-ocean sites (less than 62 miles, or 100 km, from the coast). The annual sea-salt sulphate contribution to total sulphate wet deposition at coastal sites in Canada ranged from 9 to 41 percent between 2010 and 2012 (with an average of 26 percent).

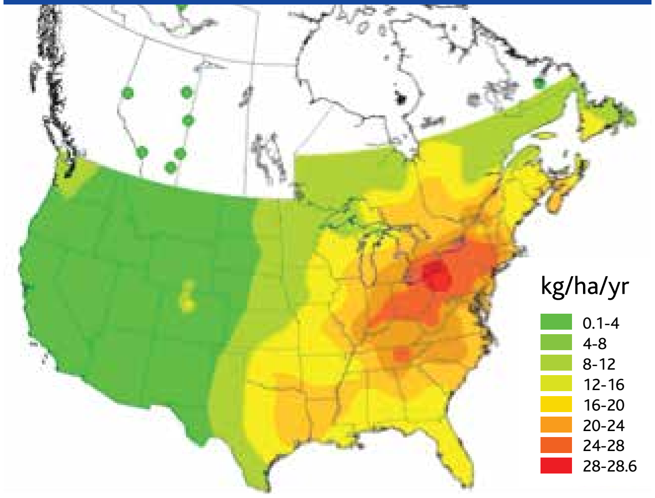
Figures 4, 5 and 6 show the United States–Canada spatial patterns of wet sulphate (sea salt–corrected) deposition for 1990, 2000 and 2012. Figures 7, 8 and 9 show the patterns of wet nitrate deposition for the same three years. Deposition contours are not shown in western and northern Canada, because Canadian experts judged that the locations of the contour lines were unacceptably uncertain due to the paucity of measurement sites in all of the western provinces and northern territories. To compensate for the lack of contours, wet deposition values in western Canada are shown as coloured circles at the locations of the federal/ provincial/ territorial measurement sites.

The three maps indicate that wet sulphate deposition is consistently highest in eastern North America around the lower Great Lakes, with a gradient following a southwest-to-northeast axis running from the confluence of the Mississippi and Ohio rivers through the lower Great Lakes. The patterns for 1990, 2000 and 2012 illustrate that wet sulphate deposition in both the eastern United States and eastern Canada have decreased in response to decreasing SO_2 emissions.

By 2000, the region receiving greater than 24 kg per hectare per year (kg/ha/yr) of wet sulphate deposition had decreased in size, and was limited to a small area located at the eastern end of Lake Erie. By 2012, this deposition region had completely disappeared, leaving only one small area (too small to be visible on Figure 6)—located at the eastern end of Lake Erie in New York—that received wet sulphate deposition greater than 16 kg/ha/yr. From 1990 to 2012, the region that received deposition greater than 8 kg/ha/yr decreased markedly from 5.94 to 4.91 to 1.48 million km^2, respectively. The wet sulphate deposition reductions are considered to be directly related to decreases in SO_2 emissions in both the United States and Canada. The emission reductions are outlined in "Key Commitments and Progress: SO_2 Emission Reductions" in Section 1 of this report.

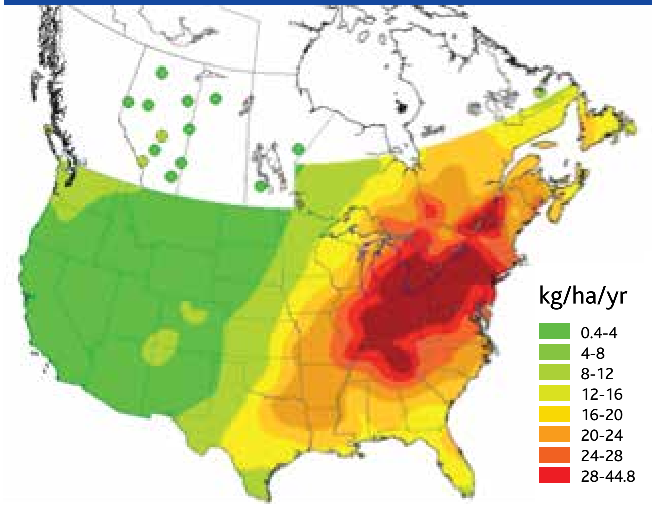
The patterns of wet nitrate deposition (Figures 7, 8 and 9) show a similar southwest-to-northeast axis, but the area of highest nitrate deposition is slightly north of the region with the highest sulphate deposition. Major reductions in wet nitrate deposition occurred in the period between 2000 and

Figure 5. 2000 Annual Wet Sulphate Deposition



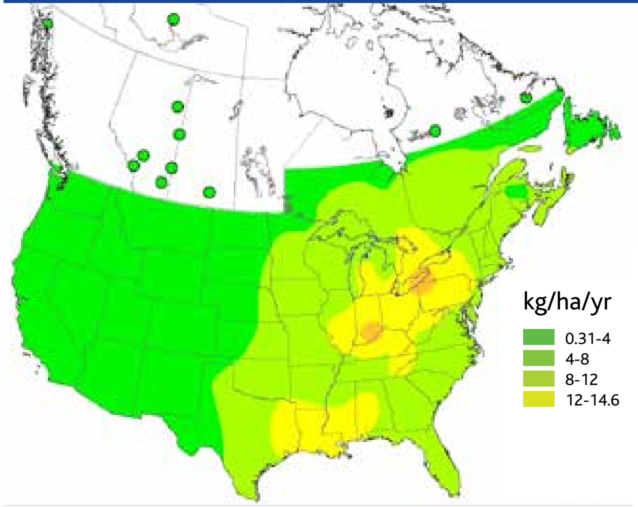
Source: NAtChem Database (www.ec.gc.ca/natchem) and the NADP (nadp.isws.illinois.edu), 2012

Figure 4. 1990 Annual Wet Sulphate Deposition



Source: National Atmospheric Chemistry (NAtChem) Database (www.ec.gc.ca/natchem) and the National Atmospheric Deposition Program (NADP) (nadp.isws.illinois.edu), 2012

Figure 6. 2012 Annual Wet Sulphate Deposition

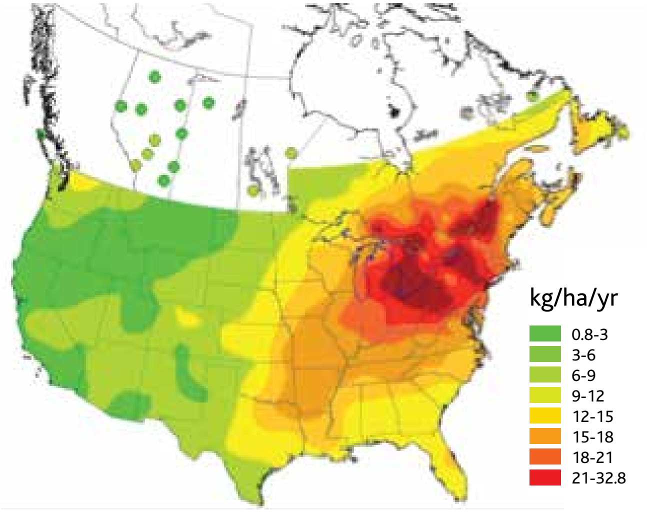


Source: NAtChem Database (www.ec.gc.ca/natchem) and the NADP (nadp.isws.illinois.edu), 2012

2012, when large NO_x emission reductions occurred in the United States and, to a lesser degree, Canada. As a result, by 2012 all regions received less than 15 kg/ha/yr of wet nitrate deposition except one small area (too small to be visible on Figure 9) located at the eastern end of Lake Erie in New York. From 1990 to 2012, the region that received greater than 9 kg/ha/yr decreased from 4.35 to 4.00 to 1.05 million km^2, respectively.

Wet deposition measurements in Canada are made by the federal Canadian Air and Precipitation Monitoring Network (CAPMoN) and networks in a number of provinces/territories, including Alberta, the Northwest Territories, Quebec, New Brunswick and Nova Scotia. Dry deposition estimates are made at a subset of CAPMoN sites using an inferential method whereby air concentration measurements are combined with modelled dry deposition velocities. In the United States, wet deposition measurements are made by two coordinated networks: the National Atmospheric Deposition Program (NADP) / National Trends Network (NTN), which is a collaboration of federal government, state government, and non-governmental organizations (nadp.sws.uiuc.edu); and the NADP/Atmospheric Integrated Research Monitoring Network (AIRMoN), which is a sub-network of the NADP funded by the National Oceanic and Atmospheric Administration (NOAA) (nadp.isws.illinois.edu). Dry deposition estimates in the United States are made using the inferential technique based on modelled dry deposition velocities and ambient air concentration data collected by the Clean Air Status and Trends Network (CASTNET) (www.epa.gov/castnet), which is coordinated by the EPA, National Park Service (NPS), and Bureau of Land Management.

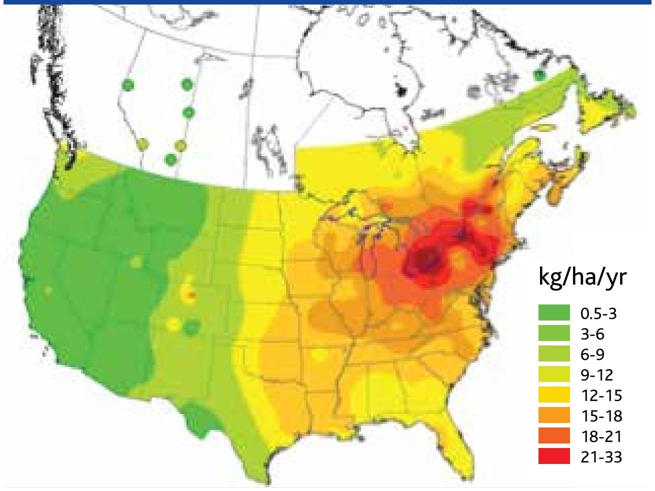
Figure 7. 1990 Annual Wet Nitrate Deposition



Source: NAtChem Database (www.ec.gc.ca/natchem) and the NADP (nadp.isws.illinois.edu), 2012

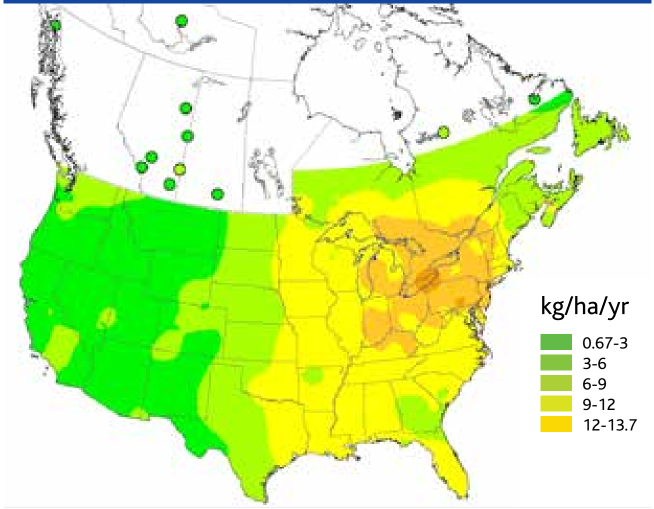
The measurements of wet deposition and air concentrations provided by the Canadian and U.S. networks have been shown to be comparable through collocated studies and inter-laboratory comparisons. In contrast to these measurements, the estimated dry deposition velocities from the Canadian (Big Leaf Model) and U.S. (Multi-Layer Model) models are poorly correlated, due to differences in resistance assumptions. Therefore, deposition fluxes at the collocated site, calculated from the measured concentrations and modelled deposition velocities, are significantly different. Given that dry deposition is an important contributor to total deposition, ongoing efforts are underway to study the

Figure 8. 2000 Annual Wet Nitrate Deposition



Source: NAtChem Database (www.ec.gc.ca/natchem) and the NADP (nadp.isws.illinois.edu), 2012

Figure 9. 2012 Annual Wet Nitrate Deposition



Source: NAtChem Database (www.ec.gc.ca/natchem) and the NADP (nadp.isws.illinois.edu), 2012 sources of these differences. At the Borden research station in Ontario, instruments were collocated for a number of years as part of a bilateral inter-comparison study on modelling dry deposition. Studies are underway to quantify the sensitivity of the Canadian and U.S. dry deposition models to a variety of factors that influence dry deposition velocities, with the goal of refining model parameters for better comparability of future dry deposition estimates, reconciling past dry deposition estimates, and identifying further inter-comparison needs. Measurement data are available from the websites of the individual networks.

Preventing Air Quality Deterioration and Protecting Visibility

CANADA

Canada is addressing the commitment to prevent air quality deterioration and ensure visibility protection by implementing the *Canadian Environmental Protection Act, 1999* (CEPA 1999) and *Canadian Environmental Assessment Act, 2012* (CEAA 2012), and by following the continuous improvement (CI) and keeping clean areas clean (KCAC) principles. These principles are included in Canada's Air Quality Management System (AQMS) and the associated Canadian Ambient Air Quality Standards (CAAQS) that are replacing the Canada-wide Standards (CWS).

British Columbia continues to make progress towards implementing a pilot visibility management program in the Lower Fraser Valley (LFV) through the work of the British Columbia Visibility Coordinating Committee (BCVCC), an inter-agency group comprising representatives from various levels of government involved in air quality management. In 2010, the BCVCC adopted a visibility protection framework that describes the visibility management actions required to achieve "clean air and pristine visibility for the health and enjoyment of present and future generations." In 2011, Metro Vancouver adopted its new Integrated Air Quality and Greenhouse Gas (GHG) Management Plan, which includes the goal to "improve visual air quality." This goal will be accomplished by reducing emissions of visibility-degrading pollutants such as $PM_{2.5}$, and by developing a visual air quality management program. As part of a pilot project to develop this program for the LFV, the BCVCC is working in four main areas: (1) advancement of visibility science, (2) development of a visibility indicator, (3) development of a business case to quantify the benefits of improved visibility, and (4) improvement of communications and outreach.

Environment Canada contributed to the BCVCC through a number of science activities, including upgrading the visibility monitoring network with cameras and nephelometers, attribution of visibility impairment to emission sources, and photochemical modelling to shed light on the effect of different pollutants on visibility impairment. The development of an LFV-specific visibility indicator is nearly complete; in 2013, a public validation study of the indicator

was conducted, and it is expected that the indicator will be made public as a tool to inform residents of visibility conditions throughout the airshed. In addition, it will help develop airshed-specific visibility improvement goals. The BCVCC developed a business case that outlines, in economic terms, the various benefits of improving visibility in the LFV. Elements in the business case include the health benefits of lowering $PM_{2.5}$ in order to improve visibility, a measure of residents' willingness to pay for better visibility, and visibility impacts on tourism, the film industry and real estate valuation. In 2013, modelling work was conducted to quantify the health benefits associated with achieving certain levels of visibility improvement. Communication and outreach efforts have resulted in the development of a visibility website for British Columbia (www.clearairbc.ca) as a means of promoting visibility and educating the public on this issue.

Additional activities have been undertaken in other parts of Canada as part of Environment Canada's National Visibility Monitoring Pilot Study. Visibility monitoring pilot sites, established in 2011 at Barrier Lake, Alberta, and Wolfville, Nova Scotia, continue to operate as does the visibility supersite in Abbotsford, BC. In 2013, a National Air Pollutant Surveillance (NAPS) speciation sampler was installed at the Barrier Lake site to allow comparison with the co-located U.S. Interagency Monitoring of Protected Visual Environments (IMPROVE) sampler, in order to evaluate the suitability of the NAPS samplers to accurately estimate visual extinction. 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 NAPS sites across Canada. Another inter-comparability study is ongoing at Egbert, Ontario, where IMPROVE speciation data are being compared with data obtained from CAPMoN. In addition, an updated assessment of visibility conditions across Canada, using data from the NAPS speciation network from 2003 to 2012, is in progress.

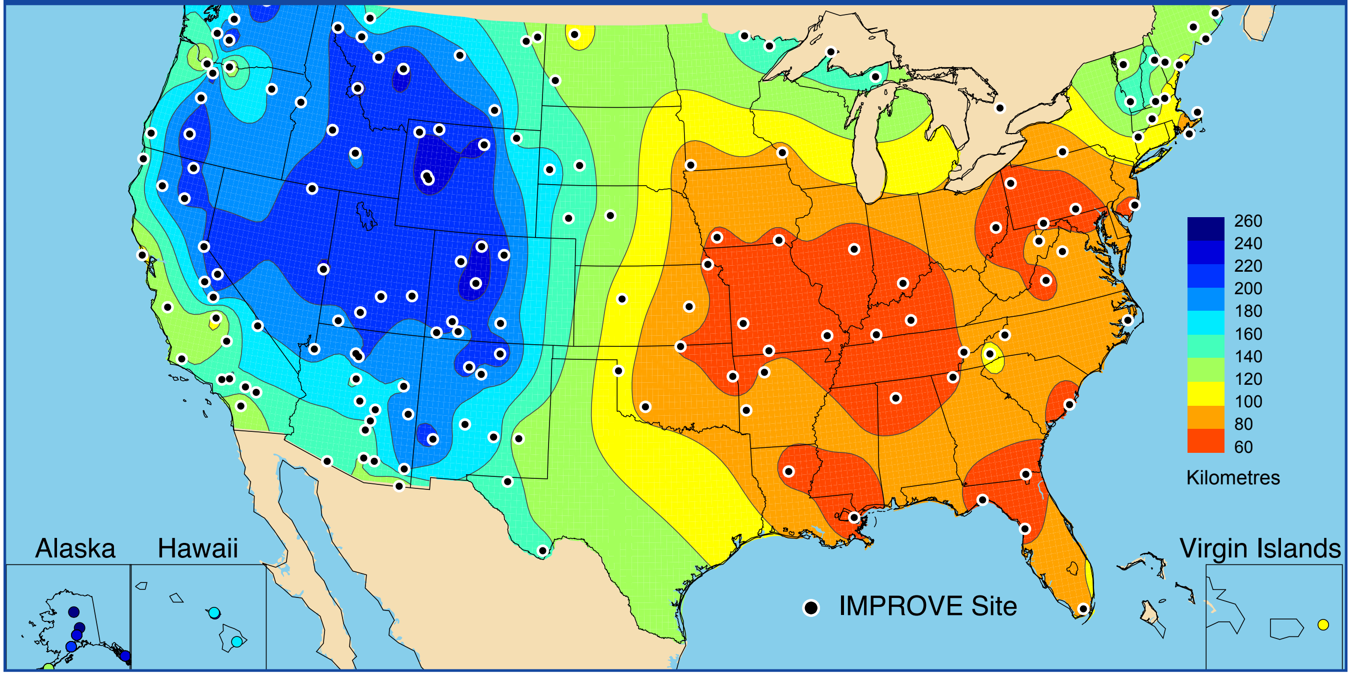
UNITED STATES ★

The United States has various programs to ensure that air quality is not significantly degraded by the addition of air pollutants from new or modified major sources. The CAA requires that pre-construction permits be obtained for major new stationary sources of air pollution and extensive modifications to major existing stationary sources. The permitting process, known as New Source Review (NSR), applies both to areas that meet the National Ambient Air Quality Standards (NAAQS) (attainment areas) and areas that exceed the NAAQS (non-attainment areas). Permits for sources in attainment areas are known as prevention of significant deterioration (PSD) permits, while permits for sources located in non-attainment areas are known as non-attainment area (NAA) permits. PSD permits require air pollution controls that represent the best available control technology (BACT), an emission limitation based on the maximum degree of reduction of each pollutant subject to regulation under the CAA. BACT is determined on a case-by-case basis, and considers energy, environmental and economic impacts. NAA permits require the lowest achievable emission rate (LAER). BACT and LAER must be at least as strict as any existing New Source Performance Standard (NSPS) for sources. One important difference between NSR permits and the NSPS program is that NSR is applied on a source-specific basis, whereas the NSPS program applies to all sources nationwide. 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 federal land management agencies are responsible for protecting air quality–related values (such as visibility) in Class I areas by reviewing and commenting on construction permits.

The CAA established the goal of improving visibility in the nation's 156 Class I areas and returning these areas to natural visibility conditions (i.e. visibility that existed before human-caused air pollution). The 1999 Regional Haze Rule requires that states reach that goal by 2064, and specifies the state implementation plan (SIP) provisions that states must develop toward that goal. In July 2005, the EPA finalized amendments to the Regional Haze Rule, which, for the initial regional haze SIPs, required the installation of emission controls, known as best available retrofit technology (BART). The BART requirements apply to certain older, existing combustion sources within a group of 26 source categories, including certain EGUs that cause or contribute to visibility impairment in Class I areas. Many of these older sources have never been regulated, and applying BART will help improve visibility in Class I areas. 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." Decisions regarding potential emission controls for BART and reasonable progress are informed through an assessment and balancing of factors, including cost effectiveness and the degree of visibility improvement expected.

The first planning period establishes an assessment of expected visibility conditions in 2018. The SIPs must be submitted every 10 years, and states revise their visibility goals accordingly to ensure that reasonable progress is being made to achieve natural visibility conditions by 2064. There is also a reporting check every five years, in which states report their interim progress toward reaching the goals. Additional information on the EPA's Regional Haze Program can be found at www.epa.gov/visibility/index.html.

Figure 10. Annual Average Standard Visual Range in the Contiguous United States, 2008-2012



Source: U.S. NPS, 2014 (data from IMPROVE website: vista.cira.colostate.edu/improve/)

Figure 10 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 2008–2012. 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 pollution in the United States is typically 45–90 miles (75–140 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/.

Consultation and Notification Concerning Significant Transboundary Air Pollution

JOINT EFFORTS

The United States and Canada initiated notification procedures in 1994 to identify potential new sources and modifications to existing sources of transboundary air pollution within 100 km (62 miles) of the border. Additionally, the governments can provide notifications for new or existing sources outside of the 100-km region if they believe there is potential for transboundary air pollution.

Since publication of the last Progress Report in 2012, the United States has notified Canada of five additional sources, for a total of 69 U.S. notifications. Canada has notified the United States of four additional sources, for a total of 62 Canadian notifications.[3]

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[3] Transboundary notification information is available on both countries' federal government websites: www.epa.gov/ttn/gei/uscadata.html for the United States, and www.ec.gc.ca/air/default.asp?lang=En&n=9C1DAE11-1 for Canada.

Ozone Annex

Overview

The Ozone Annex commits the United States and Canada to address transboundary O_3 by reducing emissions of NO_x and VOCs, the precursors to O_3. 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 D.C., and which is where emission reductions are most critical for reducing transboundary O_3. The Annex was added to the Air Quality Agreement in 2000.

Key Commitments and Progress

CANADA

Vehicles, Engines and Fuels

New stringent NO_x and VOC emission standards for vehicles, including cars, vans, light-duty trucks, off road vehicles, small engines and diesel engines, as well as fuels.

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

The *On-Road Vehicle and Engine Emission Regulations* established air pollutant emission standards for on-road vehicles and engines (such as cars, trucks, motorcycles and buses) beginning in the 2004 model year, in alignment with those of the U.S. EPA. Recent amendments to the Regulations introduce new requirements for on-board diagnostic (OBD) systems for on-road heavy-duty engines and vehicles (with a gross vehicle weight rating of more than 6350 kg). The amendments, published in January 2013, are designed to align with U.S. federal requirements, and came into force on January 1, 2014. OBD systems are designed to monitor emission-related components for malfunctions, to identify such malfunctions, and to facilitate repair and maintenance. On September 27, 2014 Environment Canada published proposed Regulations that would incorporate the U.S. EPA 'Tier 3' standards in the *On-Road Vehicle and Engine Emission Regulations*. These standards would 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.

The *Off-Road Small Spark-Ignition Engine Emission Regulations* established air pollutant emission standards, aligned with U.S. federal standards, for 2005 and later model-year small spark-ignition (typically gasoline) engines found in lawn and garden machines, light-duty industrial machines, and light-duty logging machines. In 2008, the EPA published new, more stringent emission standards. With Canada's policy of alignment of emission standards in the transportation sector, Environment Canada intends to amend its regulations to further reduce air pollutant emissions by aligning with the new U.S. Phase 3 exhaust and evaporative emission standards.

The *Off-Road Compression-Ignition Engine Emission Regulations*, in effect as of January 1, 2006, establish air pollutant emission standards aligned with U.S. federal standards (Tiers 2 and 3), for 2006 and later model-year diesel engines, such as those typically found in agricultural, construction and forestry machines. In December 2011, amendments to the *Off-Road Compression-Ignition Engine Emission Regulations* were published, further reducing emissions of air pollutants in Canada by establishing more stringent Canadian off-road diesel emission standards. The amended Regulations align Canadian emission standards with the U.S. Tier 4 standards. The new standards are being phased in beginning on January 16, 2012, and will be fully in force by the end of 2018. Environment Canada intends to amend the Regulations to incorporate emission standards for large spark-ignition engines used in off-road applications such as forklifts and ice resurfacers, in alignment with U.S. federal emission standards and test procedures for these engines.

On February 16, 2011, Environment Canada published the *Marine Spark-Ignition Engine, Vessel and Off-Road Recreational Vehicle Emission Regulations*. These Regulations align air pollutant emission standards with those of the EPA for outboard engines, personal watercraft, sterndrive and inboard engines, vessels powered by these engines, snowmobiles, off-road motorcycles, all-terrain vehicles, and utility vehicles. Most of the standards applied beginning with the 2012 model year, while the emission standards for vessels will apply as of the 2015 model year.

Regulatory initiatives for gasoline include the *Sulphur in Gasoline Regulations and Benzene in Gasoline Regulations*. The *Sulphur in Gasoline Regulations* have limited the level of sulphur in gasoline to an average of 30 milligrams per kilogram (mg/kg) since 2005. In June 2013, the Government of Canada announced its intention to further reduce sulphur levels in gasoline to an average of 10 mg/kg to enable more advanced vehicle emissions-control technologies, in alignment with the EPA's new Tier 3 rules that will further limit emissions of smog-forming air pollutants from new cars and light trucks. The *Benzene in Gasoline Regulations* have reduced benzene emissions from vehicles by limiting the benzene content in gasoline to 1.0 percent by volume since 1999.

The *Sulphur in Diesel Fuel Regulations* set maximum limits for sulphur in diesel fuels. Diesel fuel for use in on-road vehicles, off-road vehicles, rail, and small- and medium-sized vessels has a sulphur limit of 15 mg/kg, phased in for the various diesel fuel types between 2006 and 2012. New limits for diesel fuel used in large marine vessels and large stationary engines came into effect on June 1, 2014, limiting sulphur in these fuels to 1000 mg/kg. This new class of diesel fuel for large marine vessels will enable implementation of the North American Emission Control Area under the International Convention for the Prevention of Pollution from Ships. Large ships will be able to switch from using high-sulphur bunker fuel (with sulphur contents up to 3.5 percent [35 000 mg/kg]) to a lower-sulphur diesel fuel, in order to reduce emissions of sulphur oxide (SO_x) and PM from ships.

The United States and Canada have agreed to work together to:

- harmonize national vehicle, engine and fuels standards for emissions of smog-forming pollutants;
- optimize vehicle and engine emission-testing activities, taking advantage of unique testing capabilities, and sharing emission test data where appropriate to facilitate regulatory administration activities in both countries; and
- share information and discuss strategies and approaches on GHG emission standards for motor vehicles.

Stationary Sources of NO_x

Annual caps by 2007 of 39 000 metric tons of NO_x (as nitrogen dioxide [NO_2]) emissions from fossil fuel power plants in the PEMA in central and southern Ontario, and 5000 metric tons of NO_x in the PEMA in southern Quebec.

In the Canadian portion of the PEMA, the largest source of NO_x emissions from industry is the fossil fuel–fired power sector. Canada has met its commitment to cap NO_x emissions from large fossil fuel–fired power plants in the Ontario and Quebec portions of the PEMA at 39 000 metric tons (42 900 short tons) and 5000 metric tons (5500 short tons), respectively, by 2007. Emissions from power plants in the Ontario portion of the PEMA were approximately 78 000 metric tons (86 000 short tons) in 1990. In 2013, NO_x emissions from Ontario fossil fuel–fired power plants were estimated to be 10 000 metric tons (11 000 short tons), or 74 percent below the 39 000 metric tons (42 900 short tons) Ozone Annex commitment. The only Quebec fossil fuel–fired power plant in the PEMA ceased operations in March 2011; this plant's NO_x emissions for 2011 were below the reporting threshold set at 20 metric tons, and were therefore well below the ceiling.

Ontario's Cessation of Coal Use regulation (O. Reg. 496/07) came into effect in August 2007 to ensure that coal is not used to generate electricity at the Atikokan, Lambton, Nanticoke and Thunder Bay generating stations after December 31, 2014. In 2013, NO_x emissions from coal-fired power plants were 91 percent lower than in 2003. In April 2014, Ontario announced it had eliminated coal-fired electricity generation in advance of the December 31, 2014 deadline. All 19 units at the five coal-fired electricity generating stations in Ontario have now ceased burning coal.

Ontario has been engaged in a number of clean energy initiatives to replace coal-fired electricity generation. For example, the year 2012 marked the first time when more electricity was generated in Ontario using wind power than coal. By the end of the first quarter of 2014, the Ontario Power Authority administered 21 695 renewable energy contracts (including 18 812 contracts for projects 10 kilowatts [kW] or less in size), for a total of 10 690 MW. Of these contracts, 5 873 MW of wind, solar, bioenergy and hydroelectric capacity came online. In addition, 2012 marked the return to service of 1 500 MW at the Bruce nuclear plant.

To ensure that the 5 000 metric ton (5 500 short ton) cap is met for the Quebec portion of the PEMA, Quebec's *Clean Air Regulation*, which came into effect on June 30, 2011, introduced a cap of 2 100 metric tons (2 310 short tons) of NO_x per year for the Sorel Tracy plant. This plant was used mainly during peak periods. After easily meeting the cap in 2010, with only 16 metric tons (18 short tons) of NO_x, this plant permanently ceased activities in March 2011.

Measures to Reduce VOCs and NO_x

Reduce VOC emissions by developing two regulations—one on dry cleaning and another on solvent degreasing—and using VOC emission limits for new stationary sources. In addition, introduce measures to reduce VOC emissions from solvents, paints, and consumer products and measures to reduce NO_x emissions from key industrial sectors.

The final provision of the *Tetrachloroethylene (Use in Dry Cleaning and Reporting Requirements) Regulations* came into effect in August 2005. The Regulations' environmental objective is to reduce the ambient tetrachloroethylene (PERC) concentration in the air to below 0.3 micrograms per cubic metre (µg/m^3). The risk management goal of the regulations is to reduce PERC use in dry cleaning in Canada to less than 1 600 metric tons (1 760 short tons) per year. In 2009, Environment Canada completed a use pattern study indicating that these objectives had been achieved. In 2013, dry cleaners reporting under the Regulations used less than 800 metric tons of PERC.

The *Solvent Degreasing Regulations*, which took effect in July 2003, froze the consumption of trichloroethylene (TCE) and PERC in affected cold and vapor-solvent degreasing facilities for three years (2004–2006) at then-current levels, based on historical use. Beginning in 2007, the annual consumption levels were reduced by 65 percent for affected facilities. Under the Regulations, Environment Canada issues annual allowances (consumption units) for use of PERC or TCE to qualifying facilities. Consumption units issued for 2014 represented a reduction of more than 88 percent and 80 percent for TCE and PERC, respectively, relative to the 2004–2006 baseline.

The federal government has taken actions to reduce VOC emissions from consumer and commercial products that contribute significantly to the formation of smog, such as cleaning products, personal care products, and paints. The *Volatile Organic Compound (VOC) Concentration Limits for Automotive Refinishing Products Regulations* were published in July 2009, while the *Volatile Organic Compound (VOC) Concentration Limits for Architectural Coatings Regulations* were published in September 2009.

Furthermore, the *Proposed Certain Products Regulations* were published in the *Canada Gazette*, Part I, on April 26, 2008, and included concentration limits for VOCs in approximately 100 categories of products, including personal care, cleaning, adhesives, and automotive maintenance products. Since that time, the decision was made to revise the regulatory proposal to include an averaging and trading program and to align the regulations with more recent California regulations. A consultation document outlining a revised regulatory proposal was released in January 2013 for public comment. The revised regulatory proposal covered 130 product categories, including the addition of 30 new product categories as well as updated limits for another 30 categories.

Between 2011 and 2012, Environment Canada contributed to funding of a pilot program to increase awareness of VOCs emitted by portable fuel containers (PFCs) and to facilitate the uptake of new containers that lead to lower VOC emissions. This fuel container exchange program encouraged participants to turn in their old PFCs in exchange for the newly designed containers. In 2012, a total of 700 PFCs were collected. The estimated VOC emissions reductions associated with the PFCs collected was 1 300 kg per year or 6 600 kg over the remaining lifespan of the old PFCs.

A draft *Code of Practice for the Reduction of VOC Emissions from the Use of Cutback and Emulsified Asphalt* (Code) was published in April 2014 for public consultation. The draft Code recommends VOC limits for cutback and emulsified asphalt used in road construction, maintenance and repairs, with more stringent recommendations during the ozone season (May to September). It also includes provisions to guide procurement practices for paving projects and application guidelines for paving companies. The draft Code aims to reduce VOC emissions from the cutback asphalt sector by 55 percent over a five-year period.

Federal, provincial (with the exception of Quebec) and territorial governments are working collaboratively to implement the AQMS agreed to in October 2012, given that these governments all have roles and responsibilities for managing air quality and protecting human health and the environment.[4] Provinces and territories are expected to take air quality management actions in their air zones to reduce air pollutant emissions (NO_x and VOC) such that the established CAAQS are not exceeded.

Actions by the Province of Quebec

Quebec has implemented several regulatory actions to meet its Ozone Annex commitments. The *Clean Air Regulation*, which came into effect on June 30, 2011, and replaced the *Regulation Respecting the Quality of the Atmosphere*, contains stricter standards aimed at reducing NO_x emissions from new and modified industrial and commercial boilers, consistent with Canadian Council of Ministers of the Environment guidelines. In addition, when burners on existing units must be replaced, the replacements must be low-NO_x burners. With respect to VOC emissions, the standards in the *Clean Air Regulation* aim to reduce emissions from the manufacture and application of surface coatings, commercial and industrial printing, dry cleaning, above-ground storage tanks, petroleum refineries, and petrochemical plants.

In Quebec, the *Regulation Respecting Mandatory Reporting of Certain Emissions of Contaminants into the Atmosphere*, entered into force in 2007, requires Quebec enterprises

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[4] Although Quebec supports the general objectives of the AQMS, that province will not implement the system because it includes federal industrial emission requirements that duplicate Quebec's Clean Air Regulation. However, Quebec will collaborate with jurisdictions on developing other elements of the system, notably air zones and airsheds.

to report atmospheric releases of certain contaminants. It determines the reporting thresholds, the information that these enterprises are required to provide, and the parameters applicable to the calculation of the quantities of these contaminants. The Regulation allows for improved information on emission sources of air contaminants across the province, including emissions of VOCs and NO_x. Quebec enterprises whose annual VOC emissions exceed 10 metric tons (11 short tons) and whose annual NO_x emissions exceed 20 metric tons (22 short tons) are required to report their emissions.

Pursuant to its *Regulation Respecting Petroleum Products and Equipment*, Quebec is currently applying provisions aimed at reducing gasoline volatility during the summer months in Montreal and the Gatineau to Montreal section of the Windsor–Quebec City corridor. Quebec is also evaluating the possibility of introducing amendments to this regulation in order to address vapor recovery initiatives, including gasoline storage, transfer depots, and service stations, regardless of whether they are new or existing facilities, in the Quebec portion of the Windsor–Quebec City corridor. The City of Montreal is enforcing regulatory provisions concerning gasoline vapor recovery in its territory.

Actions by the Province of Ontario

Ontario has met its commitments under the Ozone Annex to reduce emissions of NO_x and VOCs in the Ontario portion of the PEMA. Ontario has implemented a number of programs, regulations and guidelines to meet its commitments, including the following:

- The Ontario Drive Clean Program (established under O. Reg. 361/98, as amended by O. Reg. 41/13) is a mandatory vehicle inspection and maintenance program designed to reduce smog-causing emissions. On January 1, 2013, the new Drive Clean test using OBDs was introduced. The OBD test, which is used in all other emissions testing programs in North America, is a faster, more accurate way of protecting the air from vehicle emissions.
- The Province has enacted the *Emissions Trading Regulation* (O. Reg. 397/01), which establishes caps for NO_x and SO_2 emissions from the electricity sector.
- Ontario has implemented the *Industry Emissions—Nitrogen Oxides and Sulphur Dioxide* regulation (O. Reg. 194/05), which caps emissions of NO_x and SO_2 from seven major industrial sectors in Ontario.
- The Province has put in place Guideline A-9: New Commercial/Industrial Boilers and Heaters (2001), which imposes a NO_x emission limit on new or modified large boilers and heaters in industrial installations.
- Most recently, Ontario agreed to begin implementation of the national AQMS in 2013, which has a goal of continuous improvement in air quality.

The Province also amended the *Air Pollution — Local Air Quality* regulation (O. Reg. 419/05) in 2007, 2009 and 2011, in order to introduce new/updated air standards and other tools to demonstrate and improve environmental performance. Since 2005, new/updated air standards for 68 contaminants have been introduced, including several that address VOCs. Air standards are used under the regulation to assess the contributions of contaminants to air from regulated facilities and identify facilities that may require technology-based compliance approaches to address technical or economic challenges.

In addition, to get the best out of the retired capital stock, Ontario Power Generation (OPG) is converting a set of former coal-fired units for future operations based on alternate fuels. For example, former coal-fired units at the Thunder Bay and Atikokan facilities are being converted to biomass technology. OPG is also preserving some of the Lambton and Nanticoke units for potential future conversion to alternate fuels, e.g., natural gas or others. Such actual and potential fuel-switching are deemed to reduce the historical SO_2, NO_x and VOC footprint of Ontario's electricity sector.

UNITED STATES ★

NO_X and VOC Program Updates

- **From 2003 to 2008, implemented the NO_X transport emission reduction program, known as the NO_X SIP Call, in the PEMA states that are subject to the rule.**
- **Began implementing the CAIR NO_X ozone season program in the PEMA states in 2009.**
- **Ongoing implementation of existing U.S. vehicle, non-road engine, and fuel quality rules in the PEMA to achieve both VOC and NO_X reductions.**
- **Ongoing implementation of existing U.S. rules in the PEMA for the control of emissions from stationary sources of hazardous air pollutants (HAPs) and of VOCs from consumer and commercial products, architectural coatings and automobile repair coatings.**
- **Ongoing implementation of 36 existing U.S. NSPS to achieve VOC and NO_X reductions from new sources.**

Current CAIR Implementation in PEMA States

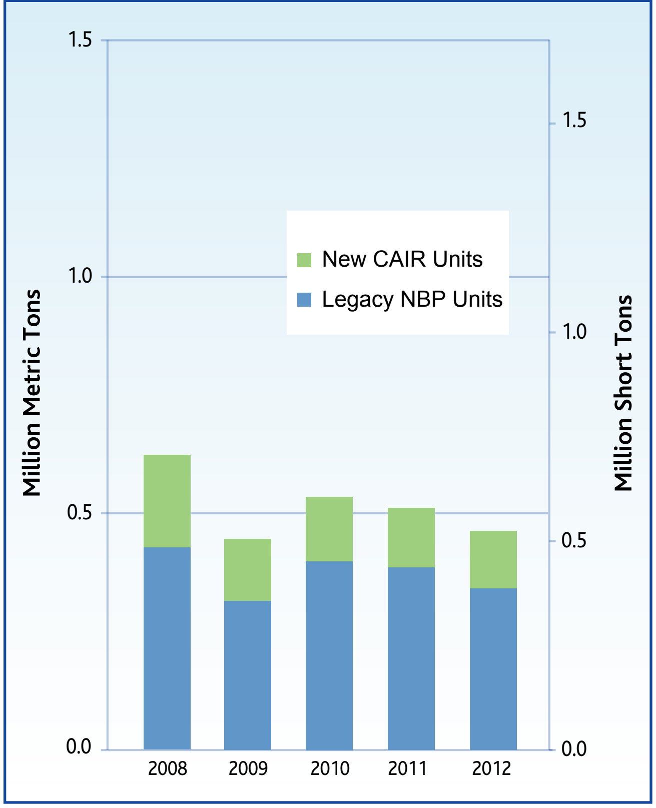
The U.S. EPA stopped administering the NO$_x$ Budget Trading Program (NBP) under the NO$_x$ SIP Call following the 2008 ozone season. Starting in 2009, the NO$_x$ annual and ozone season programs under CAIR took effect.

Ozone Season Reductions

The CAIR NO$_X$ ozone season program includes EGUs as well as, in some states, large industrial units that produce electricity or steam primarily for internal use and that have been carried over from the NBP. Examples of these units are boilers and turbines at heavy manufacturing facilities such as paper mills, petroleum refineries, and iron and steel production facilities. These units also include steam plants at institutional settings, such as large universities or hospitals. In 2012, there were 3 273 EGUs and industrial facility units at 949 facilities in the CAIR NO$_X$ ozone season program; of these, 1 879 were covered units in the Ozone Annex PEMA. In 2012, all CAIR ozone season sources were in compliance.

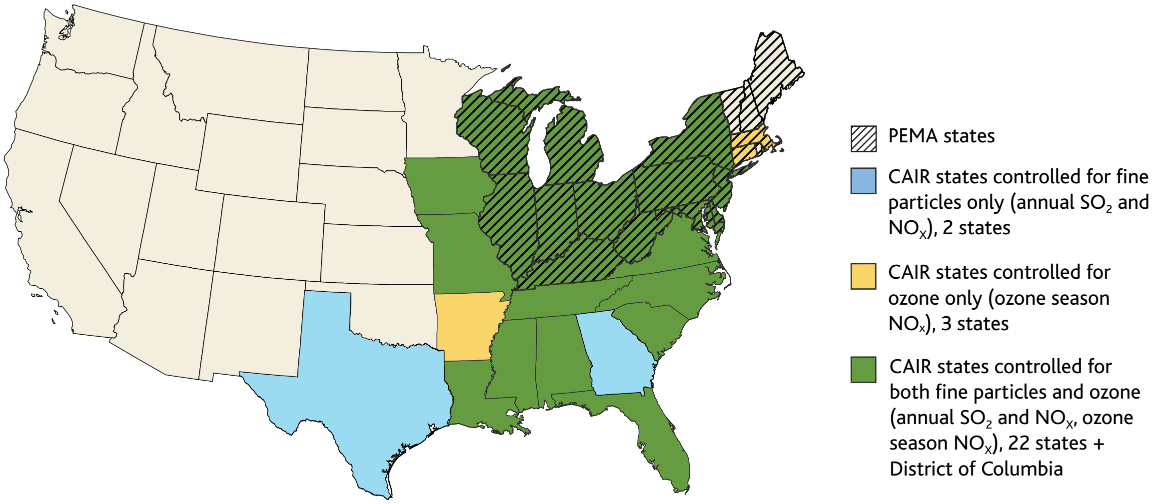
From 2011 to 2012, ozone season NO$_X$ emissions from sources in the CAIR NO$_X$ ozone season program decreased by 52 251 short tons (47 401 metric tons) (nine percent). Units in the NO$_x$ season program have reduced their overall NO$_x$ emissions from approximately 1.5 million short tons (1.4 million metric tons) in 2000 to 513 813 short tons

Figure 12. Ozone Season Emissions from CAIR NO$_X$ Ozone Season Sources



Source: U.S. EPA, 2014

Figure 11. PEMA Region and CAIR



Source: U.S. EPA, 2014

(466 123 metric tons) in 2012 (Figure 12), nine percent below the regional emission budget of 567 744 short tons (515 048 metric tons). In addition to the CAIR NO_X ozone season program and the former NBP, prior programs such as the Ozone Transport Commission's (OTC's) NO_X Budget Program and current regional and state NO_X emission control programs have also contributed significantly to the ozone season NO_X reductions achieved by sources in 2011.

Annual NO_X Reductions

In 2012, the fourth year of the CAIR NO_X annual program, NO_X emissions from all ARP and CAIR units were 1.9 million short tons (1.8 million metric tons) lower (53 percent) than in 2005 and 3.4 million short tons (3.1 million metric tons) lower (67 percent) than in 2000.

Emissions from CAIR NO_X annual program sources alone were 1.17million short tons (1.06 million metric tons) in 2012, 22 percent below the 2012 CAIR NO_X annual program's regional budget of 1.5 million short tons (1.4 million metric tons). Annual NO_X emissions were 1.5 million short tons (1.4 million metric tons) lower (56 percent) than in 2005, and 184 000 short tons (167 000 metric tons) lower (13 percent) than in 2011.

Although the ARP and CAIR NO_X programs were responsible for a large portion of these annual NO_X reductions, other programs, such as the NBP, the OTC NO_X Budget Program, and other regional and state NO_X emission control programs, also contributed significantly to the annual NO_X reductions achieved by sources in 2012.

NSPS: All 36 categories of the NSPS identified in the Ozone Annex for major new NO_X and VOC sources are promulgated and in effect. In addition, the EPA finalized the NSPS for Stationary Compression-Ignition Internal Combustion Engines in July 2006, which is helping these sources achieve significant reductions in NO_X and VOC emissions. Furthermore, in December 2007 the EPA finalized an additional nationally applicable emission standard—an NSPS for NO_X, carbon monoxide (CO) and VOC emissions from new stationary spark-ignited internal combustion engines (for more information on the Stationary Internal Combustion Engines rule, see www.epa.gov/ttn/atw/icengines/).

In February 2006, the EPA promulgated the NSPS for utility and industrial boilers and combustion turbines. The updated standards for NO_X, SO_2 and direct filterable PM are based on the performance of recently constructed boilers and turbines. In February 2012, the EPA promulgated amendments to the NSPS for utility boilers to reflect improvement in the controls for NO_X, SO_2 and direct filterable PM. The EPA amended the 2008 NSPS for petroleum refineries in September 2012 to address issues regarding flares and process heaters.

In September 2010, the EPA promulgated the NSPS for Portland cement kilns. This NSPS for the first time set NO_X limits for all new, reconstructed or modified cement kilns. In August 2012, the EPA published a final rule for oil and gas sources. The rule reflects the first VOC controls for upstream sources. The NSPS for Nitric Acid Production was also revised in August 2012; it includes tighter emission limits for NO_X on new, reconstructed or modified nitric acid production units.

VOC Controls on Smaller Sources: In 1998, the EPA promulgated national rules for automobile repair coatings, consumer products, and architectural coatings. The compliance dates for these rules were January 1999, December 1998 and September 1999, respectively. From a 1990 baseline, the consumer products and architectural coatings rules are each estimated to have achieved a 20-percent reduction in VOC emissions, and the automobile repair coatings rule is estimated to achieve a 33-percent reduction in VOC emissions.

In addition, the EPA had previously scheduled for the regulation of 18 other categories of consumer and commercial products under section 183(e) of the CAA. To date, the EPA has regulated or issued guidance on all 18 categories, including shipbuilding and repair coatings; aerospace coatings; wood furniture coatings; flexible packaging printing materials; lithographic printing materials; letterpress printing materials; industrial cleaning solvents; flatwood panelling coatings; aerosol spray paints; paper, film and foil coatings; metal furniture coatings; large appliance coatings; portable fuel containers; miscellaneous metal products coatings; plastic parts coatings; auto and light-duty truck assembly coatings; miscellaneous industrial adhesives; and fiberglass boat manufacturing materials.

Motor Vehicle Control Program: To address motor vehicle emissions, the United States committed to implementing regulations for reformulated gasoline; reducing air toxics from fuels and vehicles; and implementing controls and prohibitions on gasoline and diesel fuel quality, emissions from motorcycles, light-duty vehicles, light-duty trucks, highway heavy-duty gasoline engines, and highway heavy-duty diesel engines.

On the fuel side, the EPA fully phased-in requirements for reformulated gasoline in non-attainment areas in 1995, and implemented low-sulphur requirements for gasoline in 2005 and on-road diesel fuel in Fall 2006 (30 parts per million [ppm] and 15 ppm sulphur levels, respectively).

The EPA finalized standards that have significantly reduced NO_X, PM and VOCs from on-highway light-duty and heavy-duty vehicles: Tier 2 exhaust and evaporative emissions standards for light-duty cars and trucks were fully phased-in in 2009, and this was followed in 2010 by full implementation of emissions standards for highway heavy-duty engines and motorcycles.

Non-road Engine Control Program: New engine standards in all five non-road engine categories identified in the Ozone Annex, i.e., aircraft, compression-ignition engines, spark-ignition engines, locomotives and marine engines, have also been completed and are in various stages of being fully phased in. Non-road diesel fuel was aligned with on-highway diesel fuel at 15 ppm sulphur in 2010. Locomotive and marine diesel fuel was aligned with on-highway and non-road diesel fuel at 15 ppm in 2012.

The Tier 4 non-road diesel standards, which significantly reduce PM and NO_X emissions, will be fully phased in by 2015. Emission standards that reduce PM and NO_x by 90 percent for newly-built locomotives and marine (C1 and C2) diesel engines began phase-in during 2009 and will be fully implemented in 2017.

Anticipated Additional Control Measures and Indicative Reductions

CANADA

National Reductions

The North American Emission Control Area (ECA), covering the waters of Canada and the United States with the exception of the Arctic, took effect on August 1, 2012, setting environmental standards that will reduce NO_X emissions from new ships by 80 percent, SO_X by 95 percent, and PM by 85 percent, when requirements are fully implemented. The *Regulations Amending the Vessel Pollution and Dangerous Chemicals Regulations* under the *Canada Shipping Act, 2001* were published on May 8, 2013, and implement the ECA in Canada.

On October 13, 2010, the *Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations* were published in the Canada Gazette, Part II. These regulations establish progressively more stringent fleet average GHG emission standards for new vehicles over the 2011-2016 model years, in alignment with U.S. national standards. On October 8, 2014, the Government of Canada published amendments to these regulations in the *Canada Gazette*, Part II, to maintain alignment with even more stringent U.S. regulations for the 2017 and later model years.

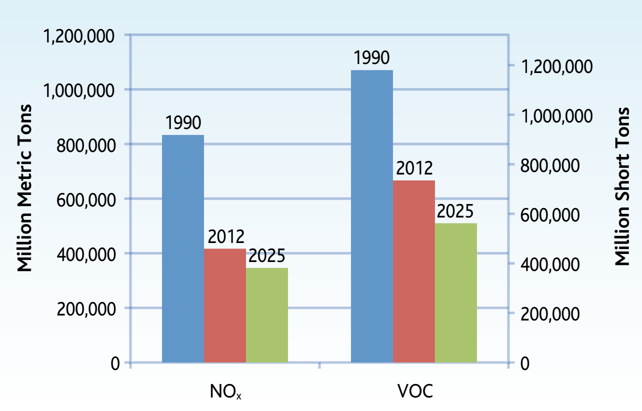
The *Heavy-duty Vehicle and Engine Greenhouse Gas Emission Regulations* were published in the Canada Gazette, Part II, on March 13, 2013. These regulations will reduce GHG emissions from new on-road heavy-duty vehicles and engines, such as full-size pick-ups, semi-trucks, garbage trucks and buses, beginning with the 2014 model year. On October 4, 2014, a Notice of Intent was published in the *Canada Gazette*, Part I indicating Canada's intention to develop proposed regulations to further reduce GHG emissions from on-road heavy-duty vehicles and engines for post-2018 model years.

Under the AQMS, Canada is implementing the base-level industrial emission requirements to establish nationally consistent emissions performance standards for industrial facilities across the country. Once fully implemented, industries will be required to reduce their emissions of NO_x and VOCs as well as SO_2, ammonia (NH_3) and PM.

Estimates of Future Emission Reductions

In the Ozone Annex, parties provided 2010 NO_x and VOC emission reduction estimates associated with applying the control measures identified under Part III of the Annex,

Figure 13. Canadian NO_x and VOC PEMA Emissions and Projections



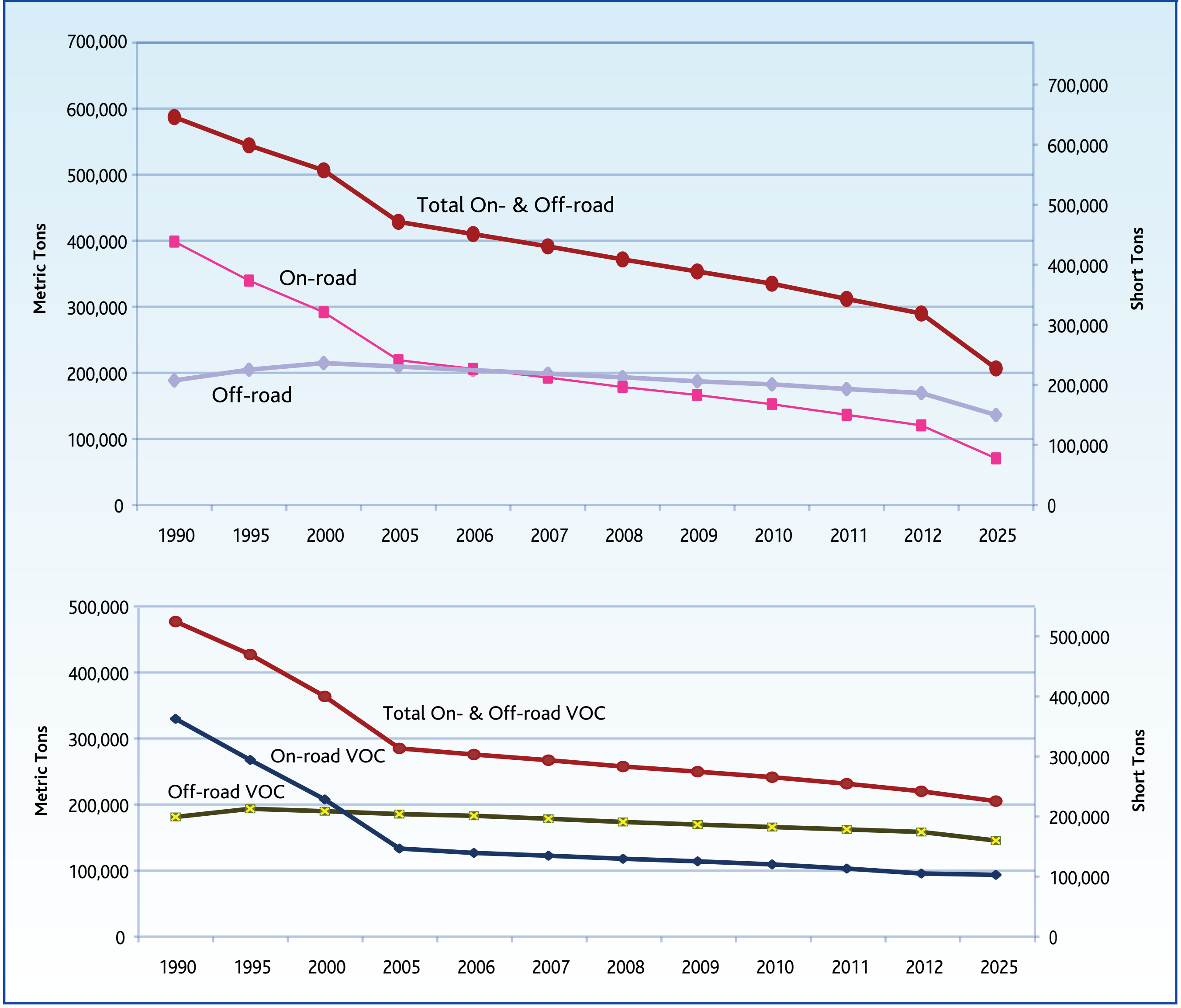
Source: Environment Canada, 2014

and further agreed to update these reduction estimates. In the Canadian PEMA, the largest source of NO_x and VOC emissions is transportation. Figure 14 shows that, by 2025, NO_x and VOC emissions from transportation sources in the PEMA are expected to decrease by 65 and 61 percent, respectively, from 1990 levels. Canada will be switching to the Motor Vehicle Emission Simulator (MOVES) model in the summer of 2014, as well as incorporating new and additional spatial data to improve the transportation emission estimates.

By 2012, the specific NO_x and VOC emission reduction measures outlined in the Ozone Annex reduced annual NO_x and VOC emissions in the PEMA by 50 and 38 percent respectively, from 1990 levels (see Figure 13).

Canada has developed new emission projections for 2025 that are based on the 2010 emissions data, and that are projected into the future using Environment Canada's energy, emission and economy forecast model. The emission projections took into consideration the impact of the recent economic slowdown and the latest economic projections. Based on the projected Canadian emissions shown in Figure 13, it is estimated that annual NO_x emissions in the PEMA will be reduced by 58 percent and annual VOC emissions in the PEMA will be reduced by 44 percent as of 2025, from 1990 levels.

Figure 14. Canadian Transportation NO_x and VOC PEMA Emissions Projections, 1990-2025



Source: Environment Canada, 2014

UNITED STATES ★

Clean Car Program

In 2010, the EPA and U.S. Department of Transportation (DOT) established the first set of coordinated GHG / fuel economy standards for 2012-2016 model year vehicles, and a second set of standards for 2017-2025 model year vehicles in August 2012. Together, these standards will double the fuel economy of light-duty cars and trucks in the United States by 2025. Under the clean car program, new cars and light trucks are expected to reach an average GHG emission performance of 163 grams per mile, equivalent to 54.5 miles per gallon, by 2025, thereby reducing oil consumption by 2.2 million barrels/day in 2025 and reducing GHG emissions by 6 billion metric tons over the lifetime of vehicles sold during this period.

The Tier 3 program for motor vehicles, finalized in early 2014, is part of this comprehensive approach to reducing the impacts of motor vehicles on air quality and public health. The program is designed to be implemented over the same time frame as the second phase of light-duty vehicle GHG standards, starting in model year 2017, and sets new motor vehicle emissions standards for NO_X, PM and other pollutants and lowers the sulphur content of gasoline. The standards reduce both tailpipe and evaporative emissions from passenger cars, light-duty trucks, medium-duty passenger vehicles, and heavy-duty pick-ups and vans.

Together, the Tier 3 and GHG programs provide significant environmental benefits by maximizing reductions in GHGs, criteria pollutants and air toxics from motor vehicles, reducing costs to consumers, and providing automakers with regulatory certainty and streamlined compliance. The standards will be applied in concert with California's clean cars and fuels program to enable automakers to sell the same vehicles in all 50 states.

Heavy-Duty National Program

The Heavy-Duty National Program is reducing fuel use and GHG emissions from heavy-duty vehicles ranging from semi-trucks and buses to heavy-duty pickup trucks and vans. Specifically, the EPA and DOT finalized heavy-duty GHG and fuel consumption standards in a 2011 joint rulemaking that phases in between 2014 and 2018. In addition to reducing GHG emissions, the heavy-duty GHG standards will also reduce criteria pollutants, including NO_X and air toxics

emissions. The first round of standards is projected to reduce GHG emissions by approximately 270 million metric tons and save 530 million barrels of oil, saving vehicle operators an estimated $50 billion in fuel costs over the lifetimes of the vehicles covered.

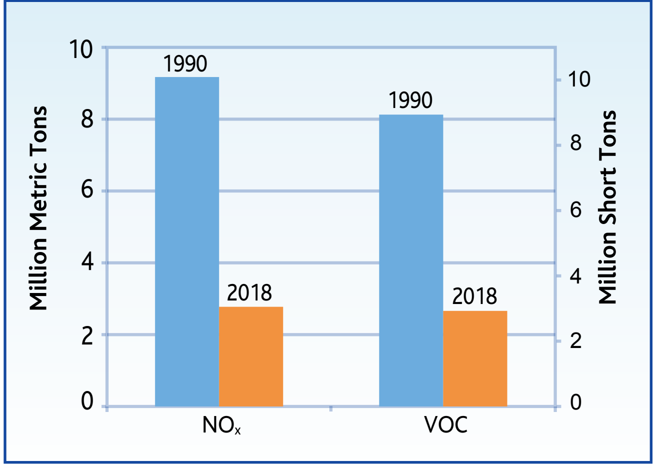
The EPA and DOT, in collaboration with the California Air Resources Board, plan to extend the Heavy-Duty National Program beyond model year 2018, to further reduce GHGs and fuel consumption through the application of cost-effective technologies, and plan to continue efforts toward improving the efficiency of moving goods across the United States. Under the timeline established by President Obama in early 2014, the agencies are directed to develop and issue the next phase of standards by March 2016.

The North American Emission Control Area (ECA)

On March 26, 2010, the International Maritime Organization (IMO), a United Nations agency, officially designated waters off the North American coasts as an area in which stringent international emission standards will apply to ships. The effective date of the first-phase fuel-sulphur standard was 2012, and the second phase begins in 2015. Beginning in 2016, NO_X after-treatment requirements become applicable. NO_X emissions are expected to be reduced by 80 percent, SO_X by 95 percent, and PM by 85 percent, when the requirements are fully implemented.

On April 4, 2014, the Marine Environment Protection Committee of the IMO took action to protect the environmental benefits of the North American and U.S. Caribbean Sea ECAs, by excluding them from an amendment to the International Convention for the Prevention of Pollution from Ships (MARPOL) Annex VI that will otherwise postpone the international Tier III NO_X standards for marine diesel engines. These technology-forcing engine standards will continue to apply to vessels operating in the ECAs beginning with new ships constructed in 2016.

Figure 15. U.S. NO_x and VOC PEMA Emissions and Projections



Source: U.S. EPA, 2014

Area-Specific Reductions

The EPA is implementing NO_X and VOC control measures in specific areas, as required by applicable provisions of the CAA. The measures include NO_X and VOC reasonably available control technology, marine vessel loading, treatment storage and disposal facilities, municipal solid waste landfills, onboard refueling, residential wood combustion, vehicle inspection and maintenance, reformulated gasoline, cement kilns, internal combustion engines, large non-utility boilers and gas turbines, fossil fuel–fired utility boilers, and additional measures needed to attain the NAAQS.

Estimates of Future Emission Reductions

In the Ozone Annex, the United States provided NO_x and VOC emission reduction estimates associated with the application of the control strategies identified under Part III B and Part IV of the Annex. The EPA has updated the estimates using more recent national trends data available in 2012.

Figure 15 shows that the emission reduction obligations are now estimated to reduce annual NO_x emissions in the PEMA by 70 percent and annual VOC emissions in the PEMA by 67 percent as of 2018, from 1990 levels. The 2018 emissions represent the best estimate for the future year that incorporates the impact of current regulations and projected economic changes and fuel usage for EGUs and mobile sectors. The projected EGU emissions include the final Mercury and Air Toxics Standards (MATS) and the CAIR. Note, this projection preceded recent actions in CSAPR litigation that have reinstated CSAPR, replacing CAIR, with CSAPR Phase 1 implementation beginning in 2015 and CSAPR Phase 2 beginning in 2017. For the non-EGU point sector, projection factors and percent reductions reflect comments received during development of the CSAPR along with emission reductions due to national and local rules, control programs, plant closures, consent decrees and settlements. For mobile sources, all national measures for which data were available at the time of estimation were included. The final EPA Tier 3 standards are represented, which, starting in 2017, will reduce air pollution from passenger cars and trucks and lower the sulphur content of gasoline. The 2018 mobile source emissions were estimated using the EPA mobile model MOVES 2010b, and applied 2011 meteorological conditions.

JOINT COMMITMENT

Reporting PEMA Emissions

Provide information on all anthropogenic NO_x and all anthropogenic and biogenic VOC emissions within the PEMA from a year that is not more than two years prior to the year of the biennial progress report, including:

- **annual ozone season (May 1 to September 30) estimates for VOC and NO_x emissions by the sectors outlined in Part V, Section A, of the Ozone Annex; and**
- **NO_x and VOC five-year emission trends for the sectors listed above, as well as total emissions.**

Canada and the United States have complied with emission reporting requirements in the Ozone Annex. In this regard, Canada's NPRI provides a comprehensive emissions inventory for pollutants such as NO_X, VOCs, SO_2, total PM, PM_{10}, $PM_{2.5}$ and CO that contribute to acid rain, O_3 and components of smog. This inventory is based on two components:

- mandatory annual reporting of emissions by about 6500 facilities; and
- emission estimates compiled for various sources, such as motor vehicles, residential heating, forest fires and agricultural activities.

The information reported by facilities is publicly available on Environment Canada's website at www.ec.gc.ca/inrp-npri/default.asp?lang=En&n=B85A1846-1.

The compilation of the comprehensive 2012 air pollutant emission summaries was completed in early 2014, and the emission data have been included in this report. The Canadian emission summaries are available on Environment Canada's website at www.ec.gc.ca/inrp-npri/ default.asp?lang=En&n=F98AFAE7-1.

New emission inventory modelling files for the calendar years 2011 and 2012 are now available, and include updated information on the temporal and the spatial allocation of the emissions for various sources and pollutants.

In the United States, the EPA developed the National Emissions Inventory (NEI) as a comprehensive inventory covering emissions in all U.S. states for point sources, nonpoint sources, on road mobile sources, non-road mobile sources and natural sources (http://www.epa.gov/ttn/chief/net/2011inventory.html). The NEI includes both criteria pollutants and HAPs. The U.S. regulations require that states report criteria pollutant emissions from large point sources every year and for all sources once every three years; the states voluntarily submit HAP emissions. The 2011 NEI is the most recent comprehensive national compilation of emission sources collected from state, local and tribal air agencies. The NEI includes emission information collected from the EPA emission programs, including the Toxics Release Inventory (www.epa.gov/tri/), emission trading programs such as the ARP (www.epa.gov/airmarkt/quarterlytracking.html and www.epa.gov/ampd), and data collected as part of EPA regulatory development for reducing emissions of air toxics. The next comprehensive NEI, for 2014, is expected to be released in mid-2016.

Table 1 shows 2012 U.S. and Canadian emissions in the PEMA. Figures 16 and 17 show U.S. emission trends in these areas for 1990 through 2012. The trend in the PEMA states is similar to the U.S. national trend. For NO_x, most of the emission reductions originate from on-road mobile sources and electric power generation. The sharp decline in EGU NO_x after 2008 illustrates the effect of the CAIR NO_x ozone season program starting in 2009. The sharp increase for on-road transportation in 2002 is due to a different estimation method beginning with that year and continuing for several subsequent years through 2011, wherein the EPA re-computed the on-road and non-road mobile source emissions using the more recent EPA mobile model MOVES 2010b. Non-road transportation is also a significant source of NO_x emissions, but the amount of emissions and the decrease over time is greater for on-road transportation and EGUs.

Similar to the national trends for VOCs, the predominant sectors that contribute VOC emissions for the PEMA are on-road mobile sources, solvent utilization processes, and non-road mobile sources. The reductions in VOC emissions are primarily from on-road mobile sources and solvent utilization. VOC emissions from non-industrial fuel combustion sources increased after 1998 and then returned to a downward trend by 2000, followed by a sharp increase in 2002. The increase in non-industrial fuel combustion VOC emissions for 2002 is due to improved emission characterization methods applied in the 2002 NEI for non-industrial fuel combustion sources, which include commercial and institutional sources such as office buildings, schools and hospitals, as well as residential wood combustion.

The U.S. PEMA 2012 emissions are estimated by applying the same methods used to develop the national trends (http://www.epa.gov/ttn/chief/trends/index.html). The state emissions were held constant from the 2011 NEI for all pollutants and tiers, with the following exceptions: the 2012 NO_x and SO_2 emissions for EGUs are from the EPA's database of continuous emissions monitoring (CEM) data for regulated sources; and the on-road and non-road mobile source emissions are interpolated between the 2011 NEI and projected 2020 inventory. The biogenic and forest wildfire emissions are for the year 2011. Ozone season emissions are approximated as a five-month fraction, e.g., May-September, of the annual emission category totals. Biogenic and forest wildfire emissions for the ozone season are not provided.

Table 1. PEMA Emissions, 2012

		2012 Annual				2012 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	71	65	80	72	30	27	34	31
	Non-industrial Fuel Combustion	43	39	98	89	10	9	16	14
	Electric Power Generation	18	17	0	0	8	7	0	0
	On-road Transportation	133	120	72	66	52	47	31	28
	Non-road Transportation	186	169	146	133	89	81	74	67
	Solvent Utilization	0	0	240	218	0	0	102	93
	Other Anthropogenic Sources	7	6	97	88	4	3	57	52
	Forest Fires	0	0	0	0	0	0	0	0
	Biogenic Emissions*	4	4	1230	1118	2	3	980	891
	TOTALS	**463**	**421**	**1963**	**1785**	**197**	**179**	**1295**	**1177**
	TOTALS without Forest Fires and Biogenics	**459**	**417**	**733**	**667**	**195**	**176**	**315**	**286**
U.S. PEMA States: Annual and Ozone Season Emissions	Industrial Sources	607	550	324	294	253	229	135	123
	Non-industrial Fuel Combustion	317	287	266	241	132	120	111	101
	Electric Power Generation	616	559	14	13	257	233	6	5
	On-road Transportation	1710	1551	786	713	713	647	328	297
	Non-road Transportation	897	814	784	712	374	339	327	297
	Solvent Utilization	0	0	982	891	0	0	409	371
	Other Anthropogenic Sources	54	49	425	386	22	20	177	161
	Forest Fires**	3	2	42	38				
	Biogenic Emissions**	147	133	4,772	4,329				
	TOTALS	**4350**	**3947**	**8395**	**7616**	**1752**	**1589**	**1493**	**1355**
	TOTALS without Forest Fires and Biogenics	**4201**	**3811**	**3581**	**3249**	**1752**	**1589**	**1493**	**1355**

Note:

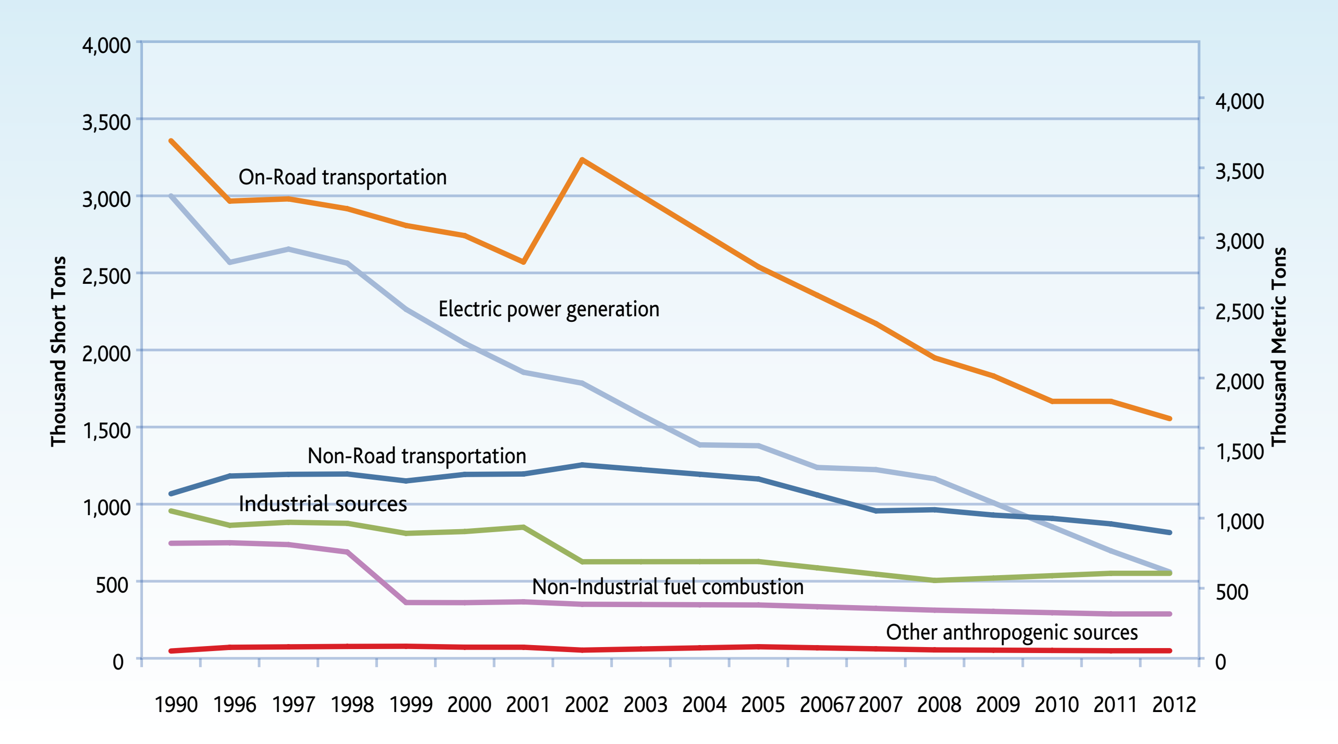
Short tons and metric tons are rounded to the nearest thousand. Totals in rows may not equal the sum of the individual columns due to rounding.

*Canadian biogenic emissions included are for the year 2010.

** Biogenic and forest wildfire emissions are for the year 2011.

Source: Environment Canada and U.S. EPA, 2014

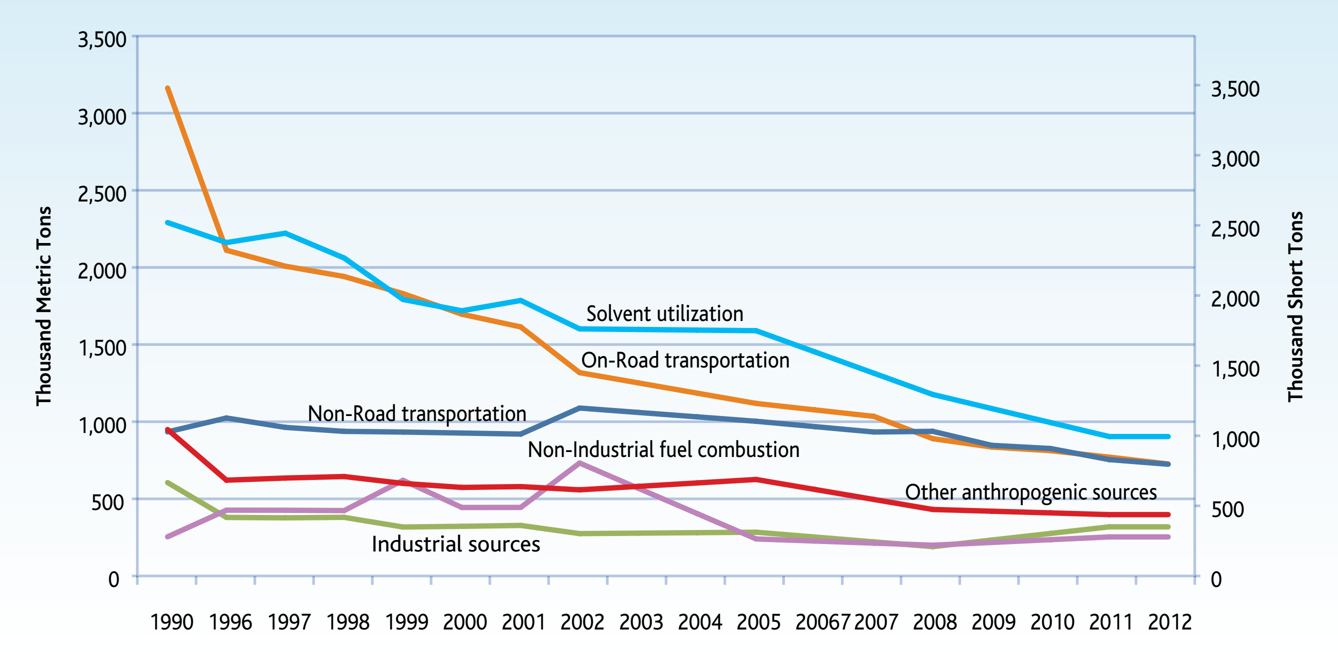
Figure 16. U.S. NO_x Emission Trends in PEMA States, 1990-2012



Note: The scales used to display U.S. and Canadian emissions in Figures 16 through 19 are significantly different.

Source: U.S. EPA, 2014

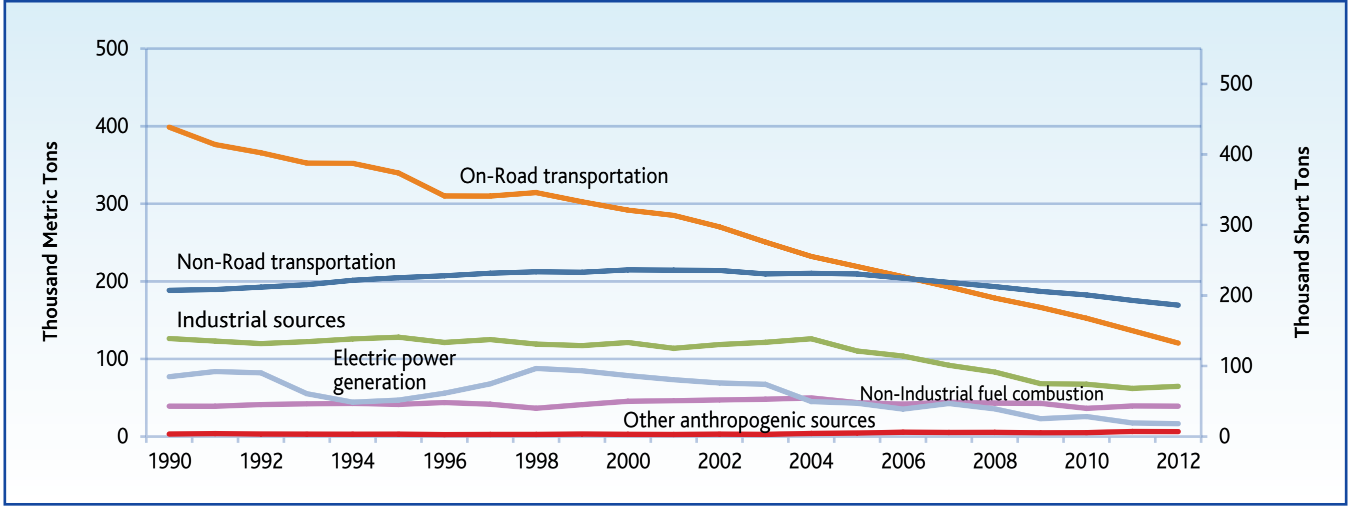
Figure 17. U.S. VOC Emission Trends in PEMA States, 1990-2012



Source: U.S. EPA, 2014

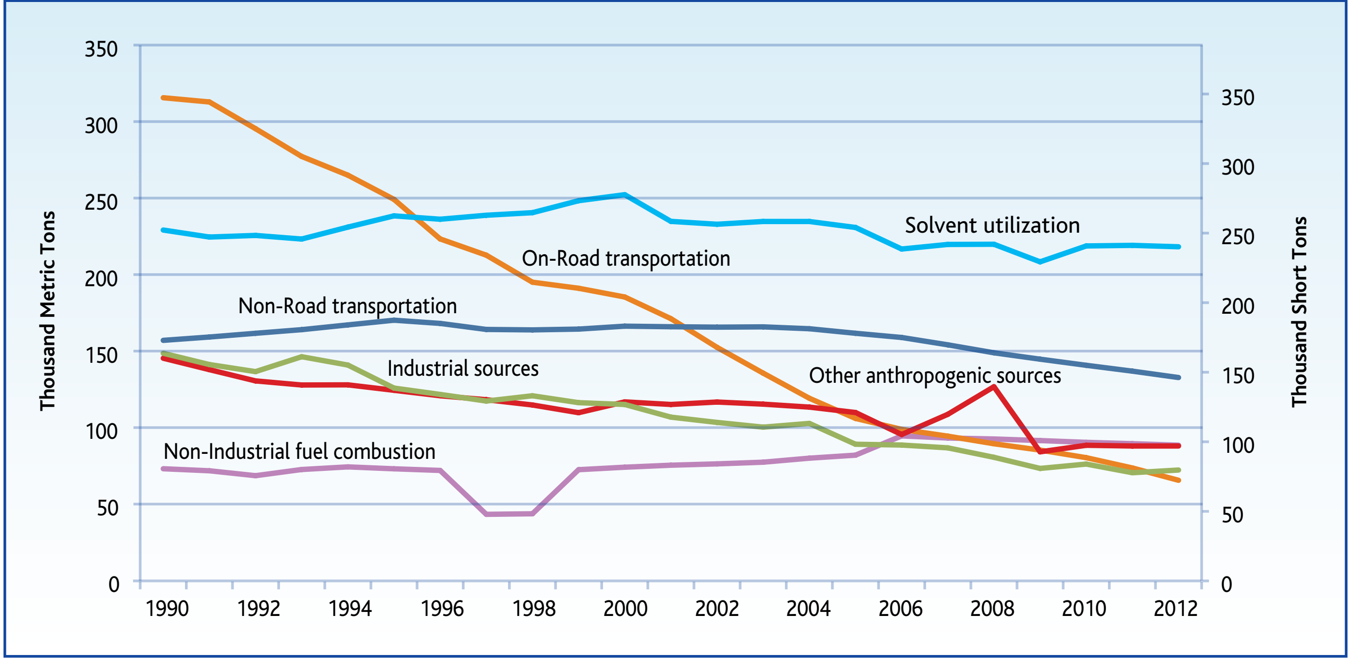
Figures 18 and 19 show Canadian NO_x and VOC PEMA emission trends for 1990 through 2012. For NO_x, most of the reductions originate from on-road mobile sources and electric power generation, with increases in non-industrial fuel combustion and other anthropogenic sources. Similar reductions and increases were observed for VOC emissions. VOC emission reductions were primarily from on-road mobile sources, electric power generation, industrial sources, and solvent utilization, with a slight increase in non-industrial fuel combustion.

Figure 18. Canada NO_x Emission Trends in the PEMA Region, 1990-2012

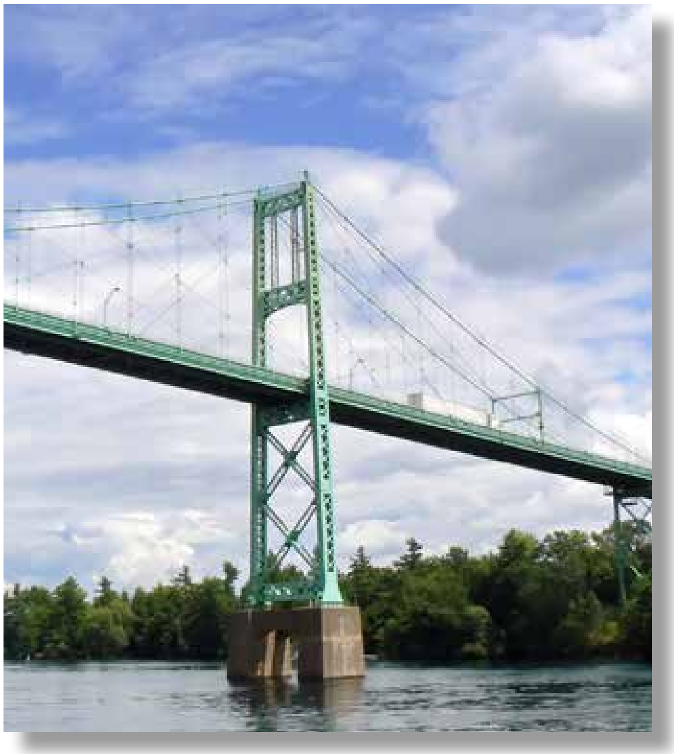


Source: Environment Canada, 2014

Figure 19. Canada VOC Emission Trends in the PEMA Region, 1990-2012



Source: Environment Canada, 2014



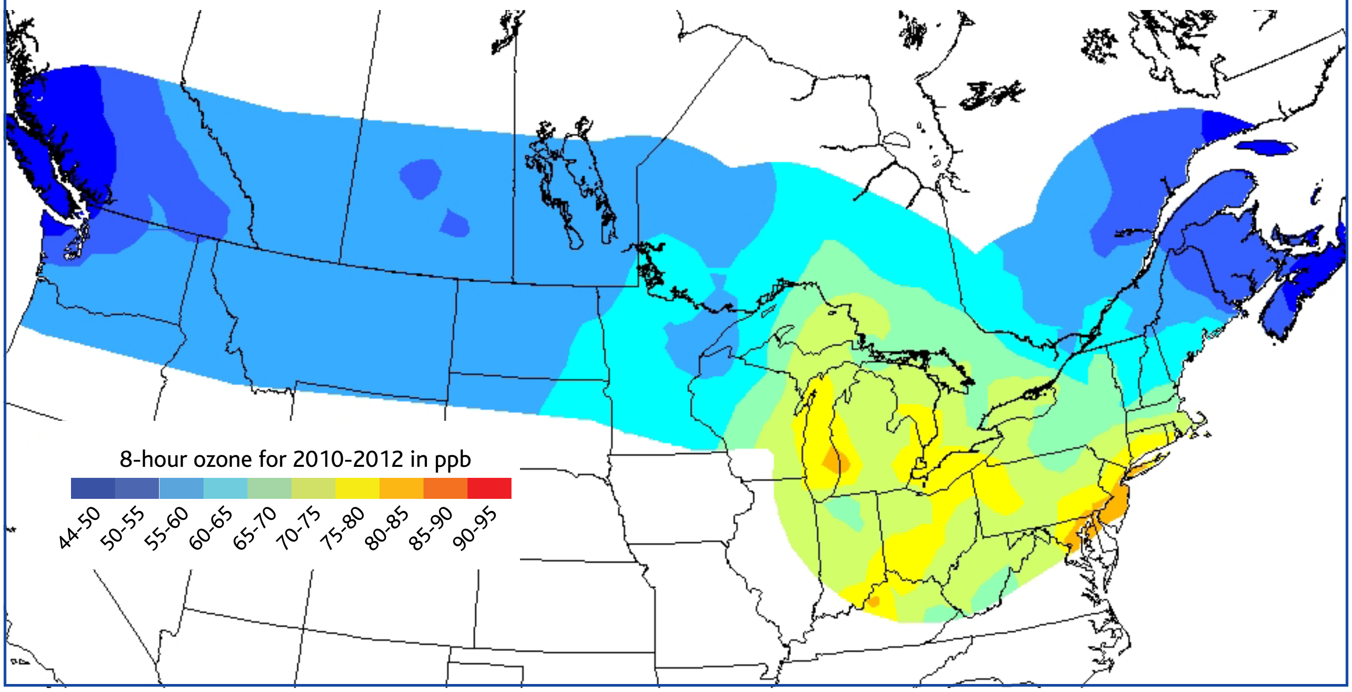
Reporting Air Quality for All Relevant Monitors within 500 km of the Border between Canada and the United States

The United States and Canada operate extensive networks to monitor O_3 and its precursors. Both federal governments prepare routine reports summarizing measurement levels and trends, with the latest quality-assured complete data set from both countries being from 2012.

Ambient Levels of Ozone in the Border Region

Figure 20 illustrates O_3 conditions in the border region in the metrics of national standards; the reference period is 2010 through 2012. Only data from sites within 500 km (310 miles) of the United States–Canada border that met data completeness requirements were used to develop this map. The figure shows that higher O_3 levels occur in the Great Lakes and Ohio Valley regions and along the U.S. east coast, and that the lowest values are generally found in the west and Atlantic Canada. Levels are generally higher

Figure 20. Ozone Concentrations along the United States–Canada Border (Three-Year Average of the Fourth-highest Daily Maximum 8-hour Average), 2010–2012



Note: Data are the 2010–2012 averages of annual fourth-highest daily values, where the daily value is the highest running 8-hour average for the day. Sites used had at least 75 percent of possible daily values for the period.

Sources: Environment Canada NAPS Network Canada-wide Database, 2012 (www.ec.gc.ca/rnspa-naps/default.asp?lang=En&n=8BA86647-1); U.S. EPA Air Quality System (AQS) Data Mart (www.epa.gov/airdata).

downwind of urban areas, as can be seen in the western portions of lower Michigan, though the full detail of urban variation is not shown. For O_3, the data completeness requirement was that a site's annual fourth-highest daily maximum 8-hour concentration, in parts per billion (ppb) by volume, be based on 75 percent or more of all possible daily values during the EPA-designated O_3 monitoring seasons.

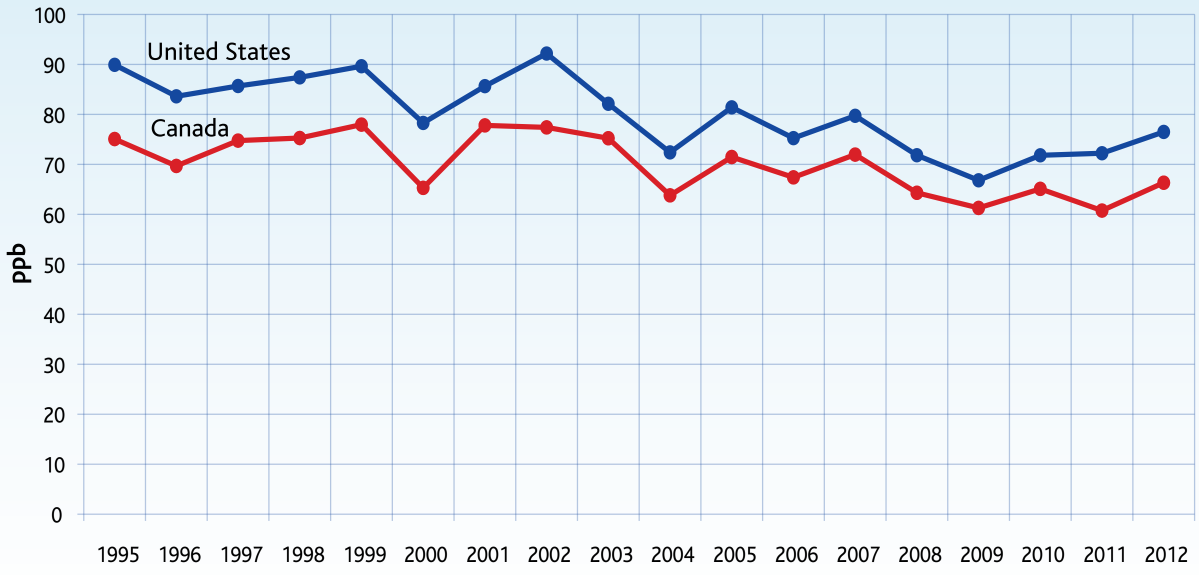
Ambient Concentrations of O_3, NO_x and VOCs

Annual O_3 levels over the 1995–2012 time period are presented in Figure 21, based on information from longer-term eastern monitoring sites within 500 km (310 miles) of the United States–Canada border. Ozone levels have decreased over this period, with a notable decline in O_3 levels since 2002. The lower O_3 levels shown for 2004 and 2009 were due, in part, to the cool, rainy summers in eastern North America. There is also a complex regional pattern in O_3 level concentrations, which is not evident from the graph shown in Figure 21. Figures 22 and 23 depict the average ozone season levels of O_3 precursors (NO_x and VOCs) in the eastern United States and Canada. These measurements represent information from a more limited network of monitoring sites than is available for O_3. Figure 24 shows the network of monitoring sites actually used to create the trend graphs in Figures 21 through 23. The data in Figures 22 and 23 represent measurements for the ozone season (i.e. May through September). NO_x and VOC concentrations have fluctuated over recent years, most likely due to varying meteorological conditions. Overall, the data indicate a downward trend in the ambient levels of NO_x and VOCs. The limited correspondence between composite ozone trends and NO_x and VOC trends could reflect the complex regional patterns in ozone concentrations as well as the limited number of NO_x and VOC monitoring sites. The NO_x and VOC concentration trends shown in Figures 22 and 23 are based on a limited number of U.S. and Canadian monitoring sites with sufficient long-term data availability. Therefore, the number of monitoring sites used to depict the trends in Figures 22 and 23 will vary from previous versions of the Progress Report and will likely show slightly different concentration values in the trends graphics.

Recently in the United States, there has been much investigation into the relationship between NO_x emission reductions and observed concentrations of ambient O_3 in the PEMA states. Generally, a strong association has been found between areas with the greatest NO_x emission reductions and downwind monitoring sites measuring the greatest improvements in O_3.

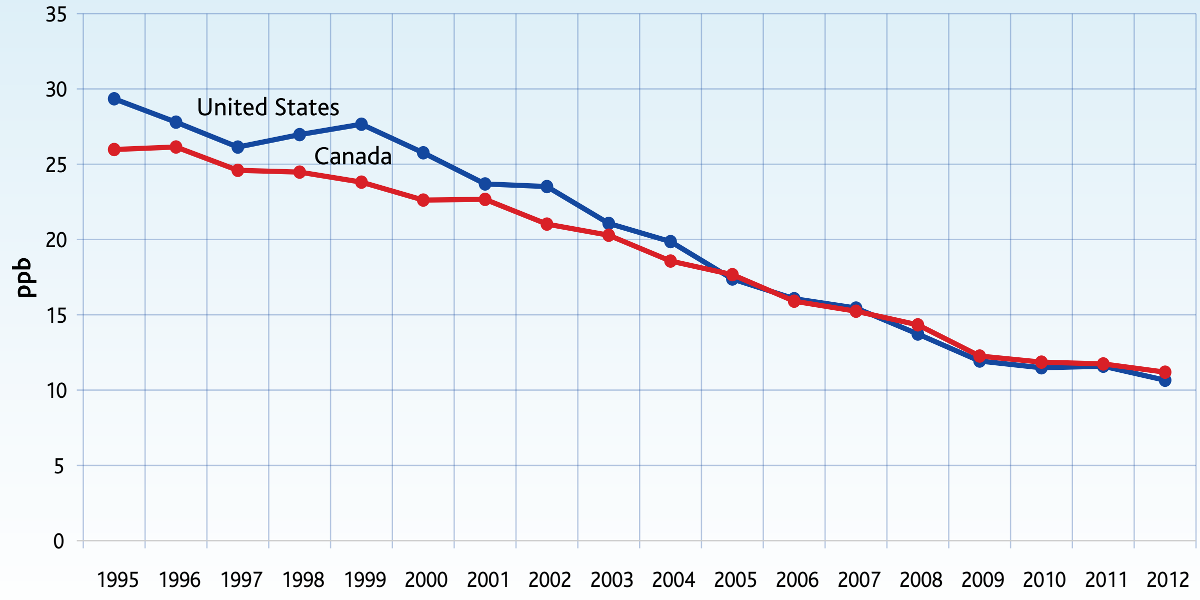
From 2010 to 2012, reductions in NO_x emissions during the O_3 season from power plants under the NO_x SIP Call, ARP and CAIR have continued contributing to significant regional improvements in ambient total nitrate (nitrate (NO_3) plus nitric acid (HNO_3)) concentrations. For instance, annual mean ambient total NO_3 concentrations for 2010–2012 in the mid-Atlantic region were 48 percent less than the annual mean concentration from 1989–1991. These improvements can be partly attributed to added NO_x controls installed for compliance with the NO_x SIP Call and CAIR. For further information on the changes in O_3 concentrations before and after implementation of the NBP and CAIR, and for a comparison of regional and geographic trends in O_3 levels to changes in meteorological conditions (such as temperature) and NO_x emissions from CAIR sources, consult www.epa.gov/airmarkets/progress/ARPCAIR10_02.html.

Figure 21. Annual Average Fourth-Highest Daily Maximum 8-hour Ozone Concentration for Sites within 500 km of the United States–Canada Border, 1995–2012



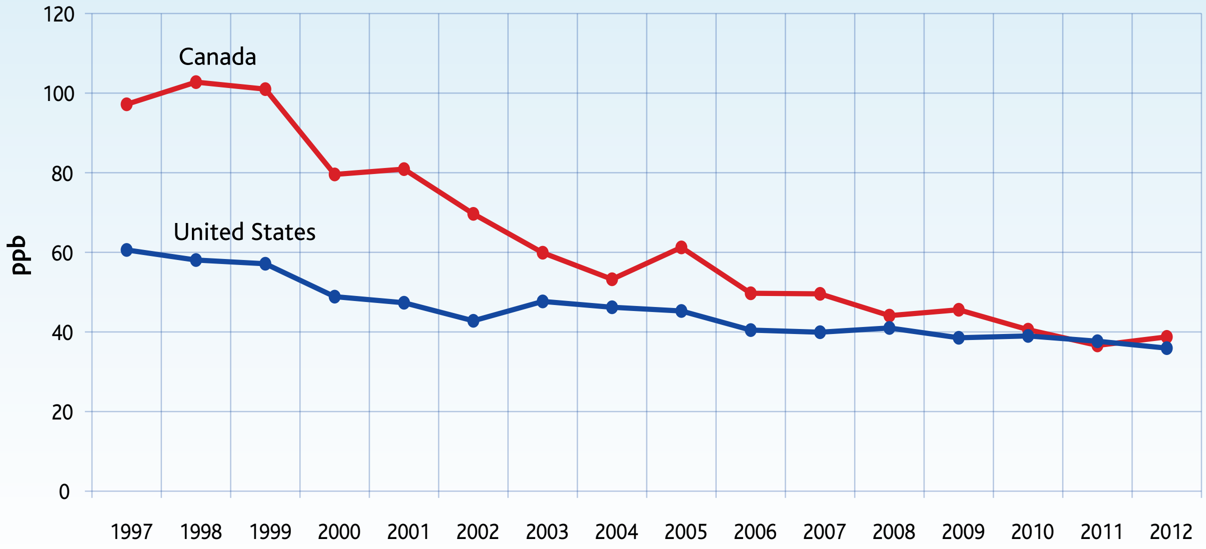
Source: U.S. EPA and Environment Canada, 2014

Figure 22. Average Ozone Season (May–September) 1-hour NO_x Concentrations for Sites within 500 km of the United States–Canada Border, 1995–2012



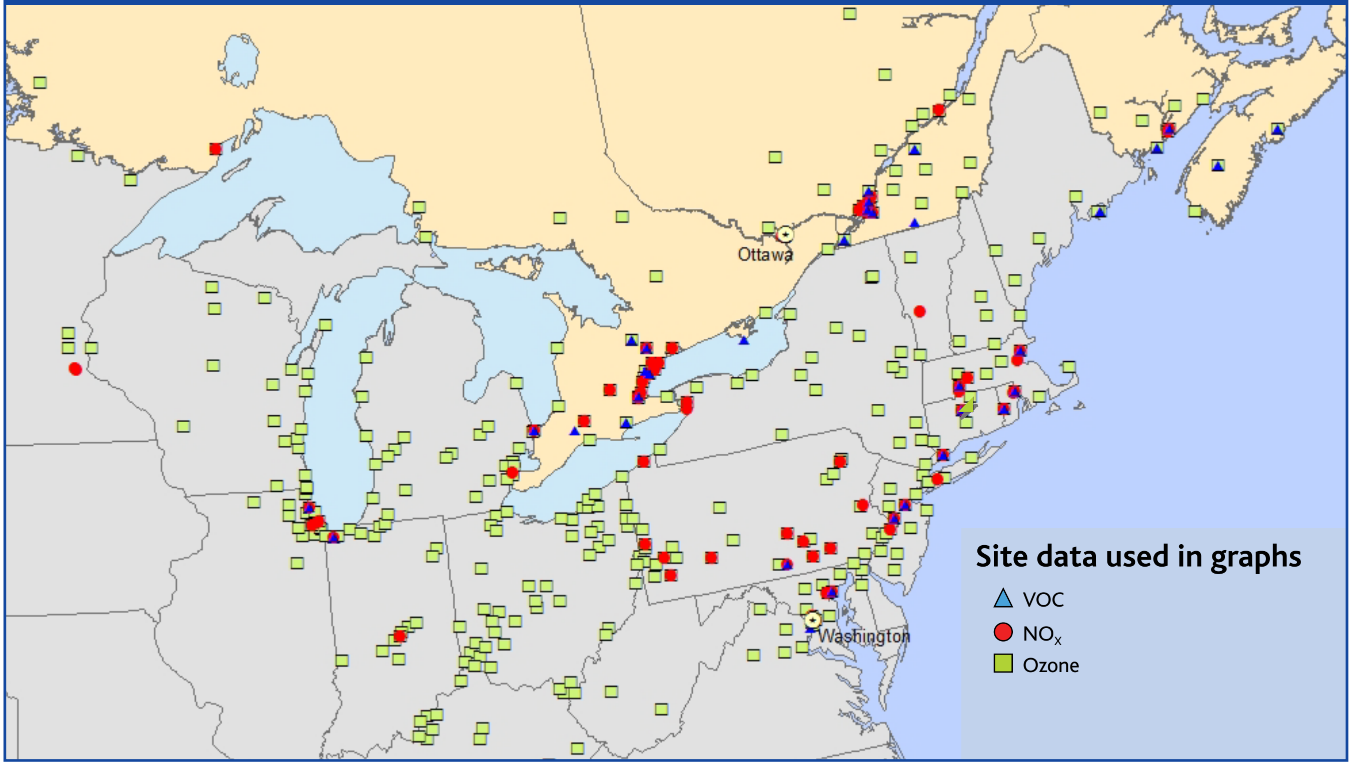
Source: U.S. EPA and Environment Canada, 2014

Figure 23. Average Ozone Season (May–September) 24-hour VOC Concentrations for Sites within 500 km of the United States–Canada Border, 1997–2012



Source: U.S. EPA and Environment Canada, 2014

Figure 24. Network of Monitoring Sites Used to Create Graphs for Ambient Ozone, NO_x, and VOC Levels



Source: U.S. EPA and Environment Canada, 2012

SECTION 2:

SCIENTIFIC AND TECHNICAL COOPERATION AND RESEARCH

Joint Efforts

Emission Inventories and Trends

The United States and Canada have updated and improved their emission inventories and projections on pollutants, including PM_{10}, $PM_{2.5}$, VOCs, NO_x and SO_2, to reflect the latest information available. In Canada, the most recent complete emission inventory data are for the year 2012. In the United States, the most recent complete emission inventory data are for the year 2011 (2011 NEI). The 2012 emission data in this section are based on the estimation methods used to develop the national emissions trends (http://www.epa.gov/ttn/chief/trends/index.html).

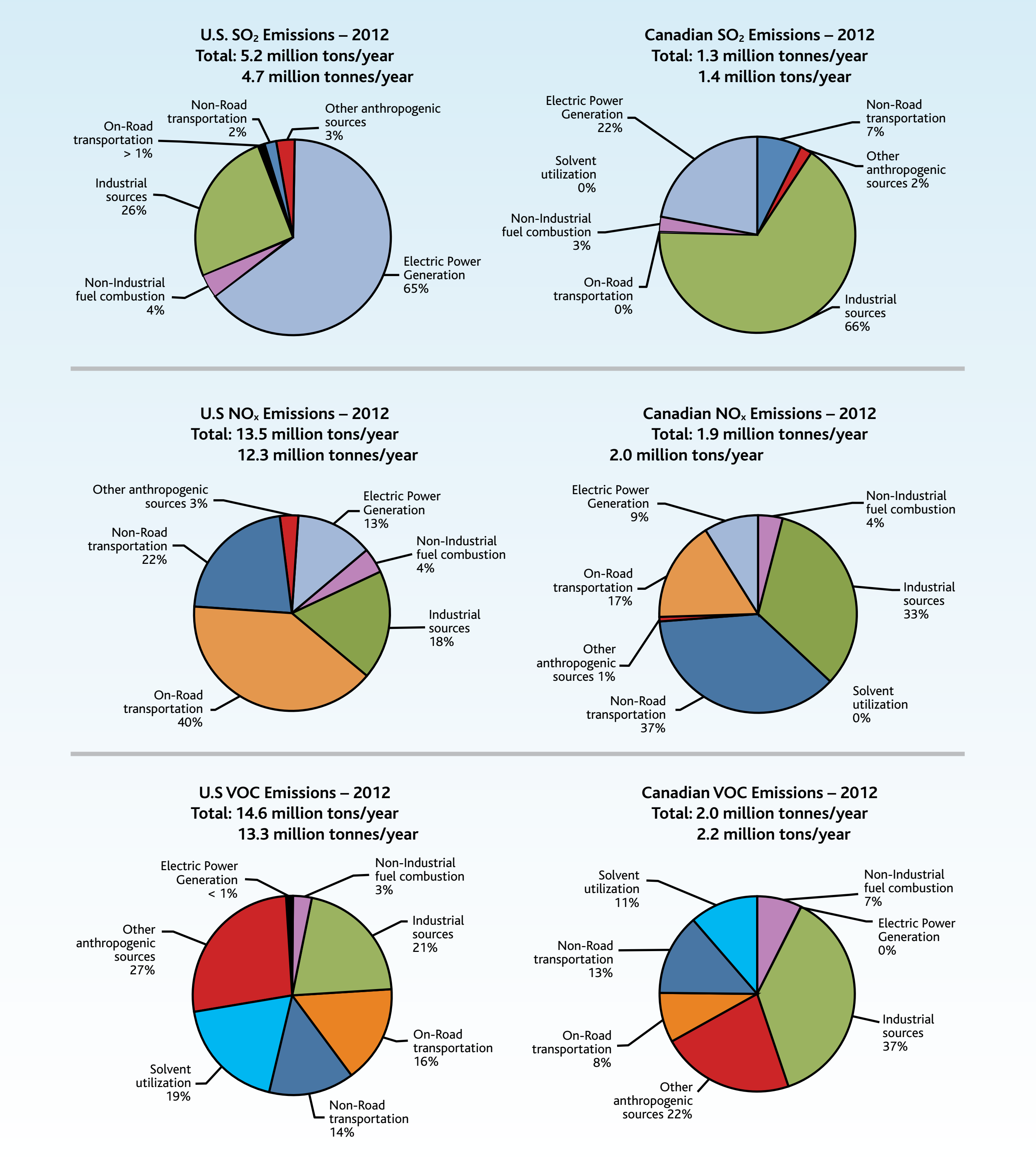
Emissions for 2012 are held constant from the 2011 NEI for all pollutants and emission categories, with the following exceptions: the 2012 NO_x and SO_2 emissions for EGUs are from the EPA's database of CEM data for regulated EGU sources; and the on-road and non-road mobile source emissions are interpolated between the 2011 NEI and projected 2020 inventory. The 2020 projected inventory was used to support EPA rulemaking on the ambient air health standard for PM, and is a product of the 2008-based modelling platform described at http://www.epa.gov/ttn/chief/emch/index.html#2008. For Canada, the 2012 emission inventory was developed using the latest emission estimation methods and statistics, and includes the pollutant emission information reported by approximately 6500 facilities to the NPRI for 2012. The Canadian inventories are available at www.ec.gc.ca/inrp-npri/default.asp?lang=en&n=0EC58C98-1.

Figure 25 shows the distribution of emissions by source category grouping for SO_2, NO_x and VOCs. The following observations can be made from 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, and differences in population and demand.
- 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.
- Similarly, in the U.S., non-road and on-road vehicles account for the greatest portion of NO_x emissions, followed by industrial sources, of which half of the portion indicated is contributed by industrial boilers.

VOC emissions are the most diverse of the emission profiles in each country. The most significant difference is that most VOCs (37 percent) in Canada originate from the industrial sector because of the proportionately higher contribution of oil and gas production in Canada. In the United States, solvent utilization and other anthropogenic sources (e.g. gas stations and bulk gas terminals, petroleum storage and transport, and prescribed fires) contribute the highest percentage of VOCs, representing 19 percent and 27 percent, respectively. In the U.S., the on-road and non-road mobile sources together contribute 30 percent of VOC emissions.

Figure 25. U.S. and Canadian National Emissions by Sector for Selected Pollutants, 2012



U.S. SO_2 Emissions – 2012
Total: 5.2 million tons/year
4.7 million tonnes/year

Canadian SO_2 Emissions – 2012
Total: 1.3 million tonnes/year
1.4 million tons/year

U.S NO_x Emissions – 2012
Total: 13.5 million tons/year
12.3 million tonnes/year

Canadian NO_x Emissions – 2012
Total: 1.9 million tonnes/year
2.0 million tons/year

U.S VOC Emissions – 2012
Total: 14.6 million tons/year
13.3 million tonnes/year

Canadian VOC Emissions – 2012
Total: 2.0 million tonnes/year
2.2 million tons/year

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

Source: U.S. EPA and Environment Canada, 2014

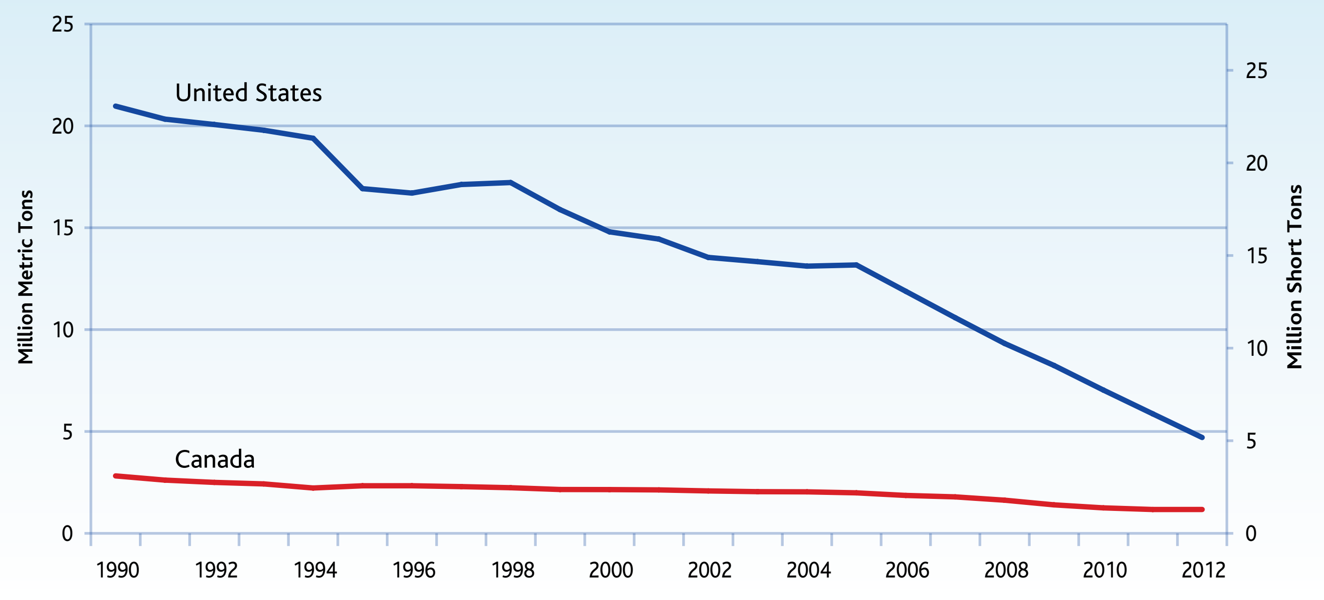
Figure 26, Figure 27 and Figure 28 for SO_2, NO_x and VOCs, respectively, show emissions from 1990 through 2012. Both countries have seen major reductions in SO_2 emissions.

In the United States, there is an overall trend of emission reduction for all three pollutants, with the largest percentage decrease occurring in SO_2 emissions (78 percent), followed by NO_x (46 percent) and VOCs (37 percent). The major reductions in SO_2 emissions came from electric power generation sources as well as industrial boilers. For NO_x, the largest reductions since 1990 came from on-road and non-road mobile sources, and electric power generation sources. As noted earlier, the increase in NO_x emissions in 2002 is due to a different estimation method beginning in 2002.

For VOC emissions, the largest reductions were mainly from on-road and non-road mobile sources, and for solvent utilization processes. Similar to NO_x, the increase in VOC emissions in 2002 reflects the EPA's more recent mobile estimation model, but is also due to improved characterization methods for residential fuel combustion, and more complete characterization and exclusion of wildfires to account for anthropogenic sources only. Around 2005, there was an increase in emissions reporting and improved characterization of emissions from oil and gas production activities as well as prescribed fires. VOC emissions were also slightly higher in 2007 than 2008, which is attributed to more on-road mobile source emissions during 2007 than 2006 or 2008, and the effect of excluding wildfire emissions (which were much higher in 2008 than the previous estimate in 2005).

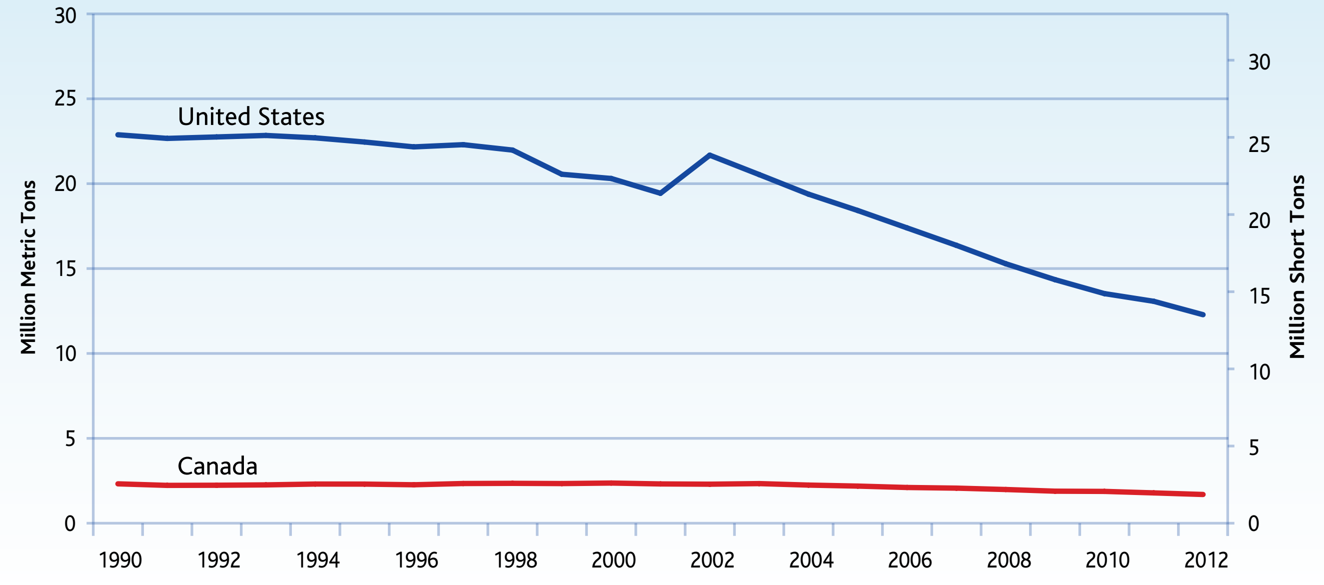
In Canada, the reductions in SO_2 emissions came from the non-ferrous smelting and refining industry and the electric power generation utilities. For NO_x, the reductions were from on-road mobile sources, electric power generation utilities, and the mining and rock quarrying industry. The VOC reductions came from on-road mobile sources and the downstream petroleum industry, with additional reductions from various industrial sectors such as chemical, pulp and paper, wood products, and iron and steel industries.

Figure 26. National SO_2 Emissions in the United States and Canada from All Sources, 1990-2012



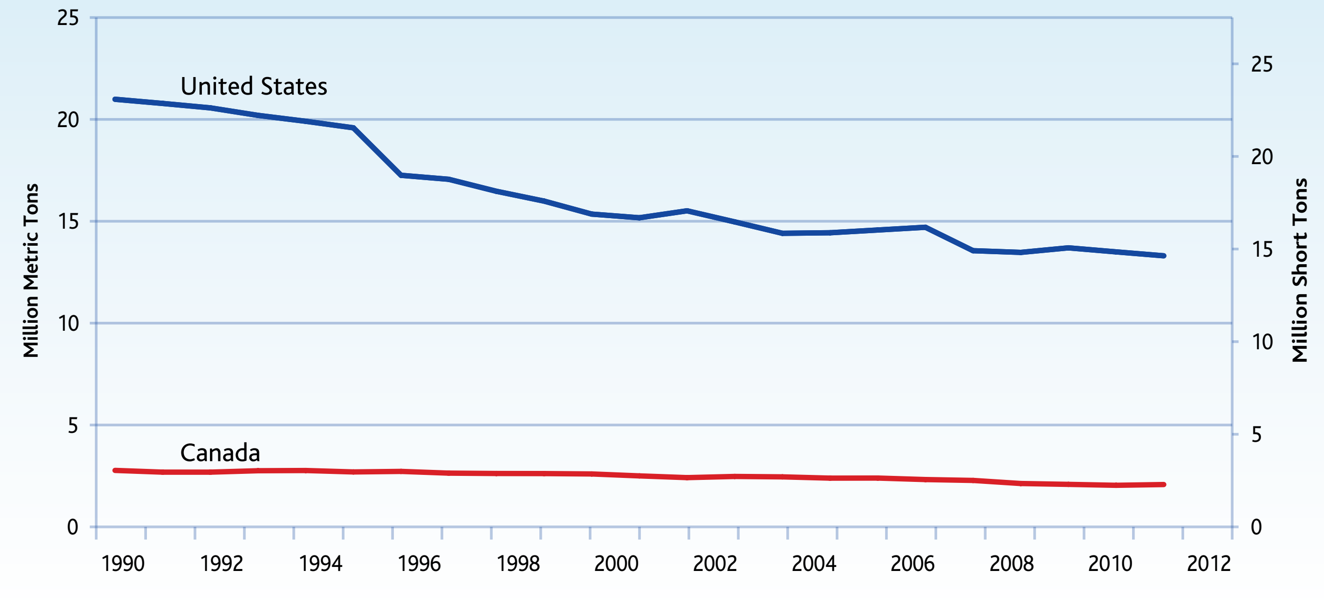
Source: U.S. EPA and Environment Canada, 2014

Figure 27. National NO_x Emission s in the United States and Canada from All Sources, 1990-2012



Source: U.S. EPA and Environment Canada, 2014

Figure 28. National VOC Emissions in the United States and Canada from All Sources, 1990-2012



Source: U.S. EPA and Environment Canada, 2014

Air Quality Reporting and Mapping

CANADA

The National Air Pollution Surveillance (NAPS) program and the Canadian Air and Precipitation Monitoring Network (CAPMoN) are the two major ambient air monitoring networks in Canada. The NAPS program, a joint initiative of the federal, provincial and territorial governments, coordinates the collection of air quality data from existing provincial, territorial and regional air quality monitoring networks, and provides accurate and long-term air quality data of a uniform standard in a unified Canada-wide air quality database. For more information on NAPS and CAPMoN, visit www.ec.gc.ca/rnspa-naps/Default.asp?lang=En&n=5C0D33CF-1 and www.ec.gc.ca/rs-mn/default.asp?lang=En&n=752CE271-1.

The associated federal and provincial/territorial/regional monitoring networks reporting data to the Canada-wide database comprise 290 air monitoring stations located in 150 communities. In total, over 800 instruments, including continuous analyzers for SO_2, CO, NO_2, O_3 and fine PM, are used to provide continuous air quality measurements. Time-integrated samples are also analyzed for polycyclic aromatic hydrocarbons (PAHs), VOCs and the chemical components of PM_{10} and $PM_{2.5}$, for 24-hour events at scheduled intervals of one every three days or one every six days.

CAPMoN consists of 30 stations located in rural or remote areas, including one station in the United States. The objectives of CAPMoN differ from those of NAPS in that CAPMoN measurements provide data for research into: (1) regional-scale spatial and temporal variations of air pollutants and deposition, (2) long-range transport of air pollutants (including transboundary transport), (3) atmospheric processes, and (4) chemical transport model evaluation.

Figure 29 shows the location of $PM_{2.5}$ and O_3 sites reporting to the Canada-wide air quality database in 2012. These sites are located in over 100 communities, including all communities with a population greater than 100 000. In total, these communities account for approximately 75 percent of the Canadian population. Updates to these air monitoring networks include the following:

Table 2. Air Parameters Reported to the NAPS Canada-wide Air Quality Database (2012)

Measurement Parameter	Number of Sites (2012)	Frequency	Initiated
Ozone (O_3)	207	Hourly	1980
Continuous $PM_{2.5}$	195	Hourly	1997
Nitrogen oxides (NO_X)	161	Hourly	1980
Sulphur dioxide (SO_X)	128	Hourly	1970
Carbon monoxide (CO)	63	Hourly	1970
PM_{10} (manual)	23	24 hours; 1 in 3 or 6 days	1984
$PM_{2.5}$ (manual reference method)	37	24 hours; 1 in 3 or 6 days	1984
$PM_{2.5}$ speciation	12	24 hours; 1 in 3 or 6 days	2003
Volatile organic Compounds (VOCs)	49	Urban: 24 hours; 1 in 6 days Rural: 4 hours; 1 in 3 days	1990
Polycyclic aromatic hydrocarbons (PAHs)	5	24 hours; 1 in 6 days	1990

Source: Environment Canada, 2012

- As of the beginning of 2013, all continuous $PM_{2.5}$ monitors reporting to the NAPS program are U.S. Class III Federal Equivalent Method instruments.

- The launch of a new NAPS Data Products public website, which now includes integrated sampling data for the chemical components of PM_{10} and $PM_{2.5}$, VOCs and PAHs.

- Resumption of the carbonyl measurement program at several VOC sites.

- Development of an analytical method for routine chromium(VI) measurements.

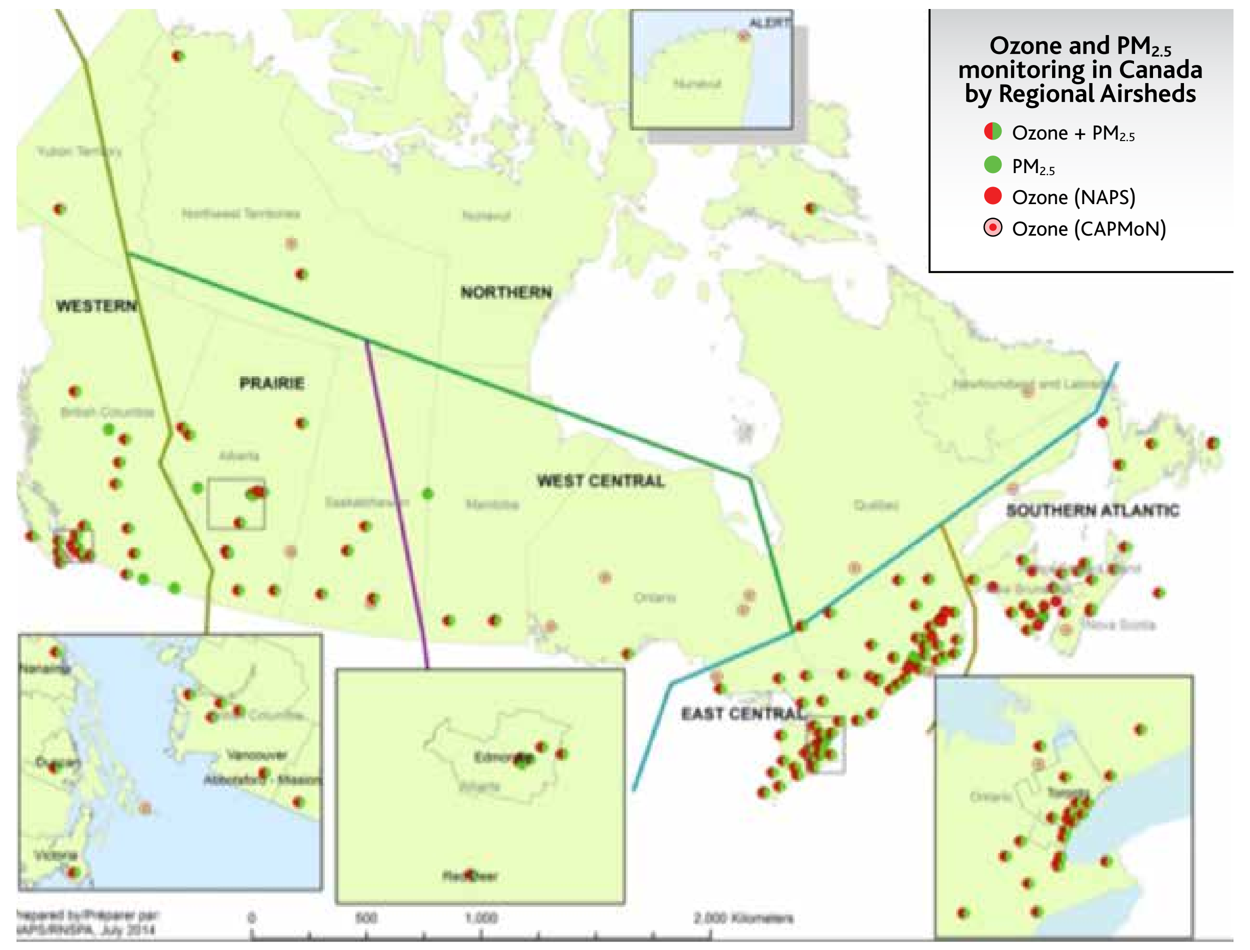
- Expansion of the laboratories and analytical equipment used to carry out detailed chemical analysis such as VOC and $PM_{2.5}$ speciation.

- CAPMoN has begun to deploy continuous $PM_{2.5}$ instruments at its ozone monitoring stations.

- CAPMoN is also expanding its air filter pack, continuous $PM_{2.5}$ and O_3 monitoring, and precipitation chemistry measurements in western Canada with the installation of new sites.

Environment Canada provides daily air quality forecasts for Canadian cities using the Canadian Air Quality Health Index (AQHI) (www.airhealth.ca). This index presents the combined short-term health risk associated with the smog mixture (as indicated by concentrations of $PM_{2.5}$, O_3 and NO_2) on a 1-10 open-ended scale. The index includes health protection advice for the at-risk population and the general public across all ranges.

Figure 29. O_3 and Continuous $PM_{2.5}$ Monitoring Sites Reporting to the NAPS Canada-wide Air Quality Database, 2012



Source: Environment Canada, 2014

UNITED STATES ★

The majority of air quality monitoring in the United States is carried out by state, local and tribal agencies in four major networks of monitoring stations: State and Local Monitoring Stations (SLAMS), Photochemical Assessment Monitoring Stations (PAMS), the $PM_{2.5}$ Chemical Speciation Network (CSN), and air toxics monitoring stations including the National Air Toxics Trends Stations (NATTS). In addition, ambient air monitoring is performed by the federal government (EPA, NPS, NOAA, U.S. Geological Survey and U.S. Department of Agriculture), tribes and industry. Air quality monitoring in the United States supports several air quality management objectives:

- NAAQS attainment/non-attainment determination
- Human exposure assessment for health research studies
- Public air quality reporting and forecasting (AQI/AirNow)
- Accountability of control studies (ARP, NO_x SIP Call, NBP and CAIR)
- Model evaluation
- Determination of source receptor relationships
- Characterization of regional air masses and transport
- Ecological exposure assessments (acidity; nutrients; ozone; mercury; and other persistent, bioaccumulative, and toxic chemicals)
- Assessments for toxic air pollutants; trends, hotspots, human health exposure, research

A summary of monitoring networks is provided in Table 3.

The EPA introduced a new multi-pollutant monitoring network, referred to as NCore, that became operational in 2011. Monitors at NCore sites measure particles (e.g. $PM_{2.5}$, speciated $PM_{2.5}$, $PM_{10-2.5}$), O_3, SO_2, CO, nitrogen monoxide (NO), total reactive nitrogen (NO_y), lead (Pb), and basic meteorological parameters. Sites are placed in broadly representative urban locations (about 60 sites) and rural locations (about 20 sites) throughout the United States. During 2014, additional NCore sites are being added in St. Marks, Florida (rural) and San Juan, Puerto Rico (urban). The EPA collaborates on site selection with individual state and local agencies and multi-state organizations. Where possible, states have located urban NCore sites next to existing monitoring operations, including PAMS or NATTS, in order to leverage existing resources. Similarly, the EPA coordinates with states and other monitoring network programs (i.e. IMPROVE and CASTNET) to establish rural-based NCore sites. The objective of the NCore network is to gather additional information needed to support emissions and air quality model development, air quality program accountability, and future health studies. General information on the NCore network is available at www.epa.gov/ttn/amtic/ncore/index.html. More specific information on each candidate NCore site can be viewed at or downloaded from http://ncore.sonomatechdata.com/.

The EPA has completed transitioning of the carbon measurement at CSN-speciated $PM_{2.5}$ stations to the IMPROVE protocol, in order to support better comparability between the CSN and IMPROVE networks. This effort was initiated in 2007. The EPA finalized revisions to monitoring requirements for Pb in 2008 in order to support the tightening of the Pb NAAQS from 1.5 micrograms per cubic metre ($\mu g/m^3$) (quarterly average) to 0.15 $\mu g/m^3$ (rolling three-month average). New monitoring requirements included the establishment of source-oriented Pb monitoring sites around Pb sources emitting 1.0 or greater tons of Pb per year by January 1, 2010. Additional Pb monitoring requirements were finalized at the end of 2010, including: 1) the establishment of source-oriented Pb monitoring sites around Pb sources emitting between 0.5 and 1.0 tons (0.5 and 1.0 metric tons) of Pb per year; 2) the addition of trends monitoring at urban NCore sites; and 3) the establishment of a short-term monitoring study at 15 general aviation airports across the United States. Information on changes to the Pb NAAQS and associated monitoring requirements can be found at http://www.epa.gov/air/lead/actions.html.

New ambient monitoring requirements have been established for the recently (2013) revised $PM_{2.5}$ NAAQS (http://www.epa.gov/airquality/particlepollution/2012/decfsimp.pdf). These requirements include the addition of $PM_{2.5}$ to the near-road monitoring requirements that have been established previously for NO_2 and CO. The NO_2 portion of the near-road network is being implemented in phases, with sites being established in the biggest metropolitan areas by January 1, 2015. The CO and $PM_{2.5}$ monitors will be phased into this network by January 1, 2017. Information on the near-roadway effort is available at http://www.epa.gov/ttnamti1/nearroad.html. The NADP, with support from the EPA and other partners, operates an international network that measures atmospheric mercury concentrations to estimate dry and total deposition of mercury. The Atmospheric Mercury Network (AMNet) measures concentrations of the three forms of atmospheric mercury: gaseous oxidized (GOM), elemental (GEM), and particle-bound (PBM). Established in 2009, the network now consists of 20 sites throughout the United States, Canada and Taiwan. Mercury fractions are measured continuously

Table 3. U.S. Air Quality Monitoring Networks

MAJOR ROUTINE OPERATING AIR MONITORING NETWORKS: State / Local / Tribal / Federal Networks

	Network[1]	Sites	Initiated	Measurement Parameters	Source of Information and/or Data
Urban/Human-Health Monitoring	National Core Monitoring Network (NCore)	~80	2011	O_3, NO/NO_y, SO_2, CO, $PM_{2.5}$/$PM_{10-2.5}$, $PM_{2.5}$ speciation, surface meteorology	www.epa.gov/ttn/amtic/ncore/index.html
	SLAMS	~4500	1978	O_3, NO_X/NO_2, SO_2, $PM_{2.5}$/PM_{10}, CO, Pb	www.epa.gov/airdata
	CSN	189 currently active	1999	$PM_{2.5}$ mass, $PM_{2.5}$ speciation, major ions, metals	www.epa.gov/airdata
	PAMS	75	1994	O_3, NO_X/NO_Y, CO, speciated VOCs, carbonyls, surface meteorology, upper air	www.epa.gov/ttn/amtic/pamsmain.html
	Near-Road Network	74	2014	NO_2, CO, $PM_{2.5}$	Optional measurements include British Columbia, ultrafine particles, air toxics, meteorology, traffic counts http://www.epa.gov/ttn/amtic/nearroad.html
Rural/Regional Monitoring	IMPROVE	110 plus 67 protocol sites	1988	$PM_{2.5}$/PM_{10}, major ions, metals, light extinction, scattering coefficient	http://vista.cira.colostate.edu/IMPROVE/
	CASTNET	80+	1987	O_3, weekly concentrations of SO_2, HNO_3, SO_4^{2-}, NO_3^-, Cl^-, NH_4^+, Ca^{2+}, Mg^{2+}, Na^+, K^+ for Dry and Total Deposition	www.epa.gov/castnet
	Gaseous Pollutant Monitoring Program (GPMP)	33	1987	O_3, NO_X/NO/NO_2, SO_2, CO, surface meteorology, enhanced monitoring of CO, NO, NO_X, NO_Y and SO_2, canister samples for VOC at three sites	http://www.nature.nps.gov/air/Monitoring/network.cfm
	NADP/NTN	250+	1978	Precipitation chemistry and wet deposition for major ions (SO_4^{2-},NO_3^-, NH_4^+, Ca^{2+}, Mg^{2+}, Na^+, K^+, H^+ as pH)	http://nadp.sws.uiuc.edu/
	NADP/AMNet	20	2009	Atmospheric mercury concentrations of gaseous oxidized, particulate-bound, and elemental mercury forms	http://nadp.sws.uiuc.edu/
	NADP/MDN	100+	1996	Mercury measured in precipitation and Wet Deposition	http://nadp.sws.uiuc.edu/mdn/
	NADP/AMoN	66	2007	Bi-weekly concentrations of gaseous NH_3	http://nadp.isws.illinois.edu/amon
	IADN	20	1990	PAHs, PCBs, and organochlorine compounds are measured in air and precipitation	http://www.epa.gov/greatlakes/monitoring/air2/iadn/
Air Toxics Monitoring	National Air Toxics Trends Stations (NATTS)	27	2005	VOCs, Carbonyls, PM_{10} metals[2], Hg	http://www.epa.gov/ttn/amtic/natts.html
	State/Local Air Toxics Monitoring	250+	1987	VOCs, Carbonyls, PM_{10} metals[2], Hg	
	NDAMN	34	1998–2005	CDDs, CDFs, dioxin-like PCBs	http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=54812

Notes:

[1] Some networks listed separately may also serve as sub-components of other larger, listed networks; as a result, some double counting of the number of individual monitors is likely. This list of networks is not meant to be totally inclusive of all routine monitoring in the United States.

[2] PM_{10} metals may include arsenic, beryllium, cadmium, chromium, lead, manganese, nickel, and others.

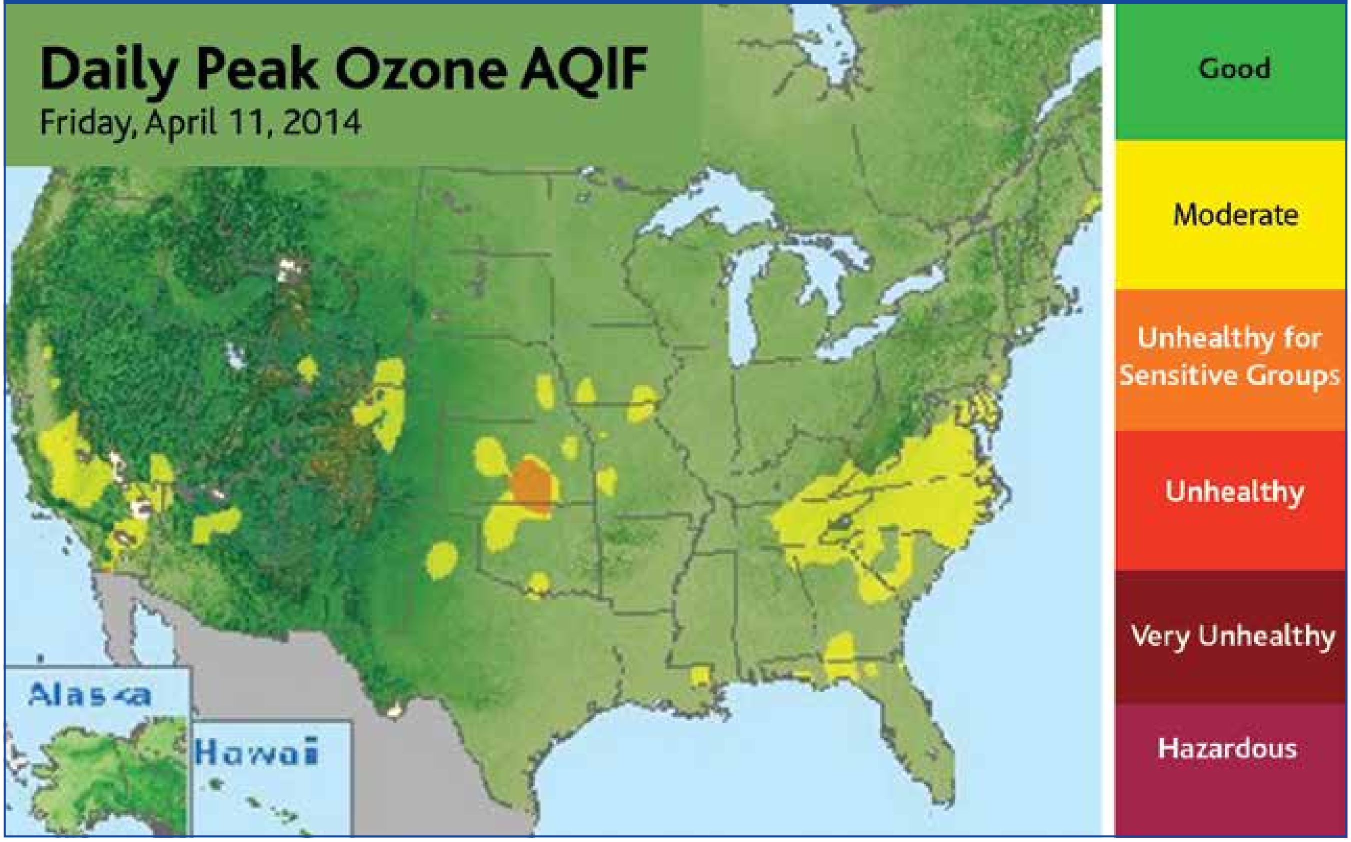
Source: U.S. EPA, 2014

using an automated system. GEM is measured at a 5-minute interval, whereas GOM and PBM are measured at a 60- or 120-minute interval. The data from this network will indicate the status and trends of atmospheric mercury concentrations at select locations, and information for model development and validation as well as source apportionment.

The EPA is also providing support to the NADP's Ammonia Monitoring Network (AMoN), which uses passive devices to measure gaseous NH_3 concentrations. Currently there are 66 sites collecting bi-weekly samples of ambient NH_3 concentrations, providing measurements that are needed to enhance atmospheric and deposition models, validate emission inventories, and understand the chemistry driving $PM_{2.5}$ formation. Both efforts aim to utilize the NADP committee structure as a platform for initiation and continued growth. For data, maps and other program information, consult the NADP website at http://nadp.isws.illinois.edu.

In 2011, all CASTNET ozone monitors and quality assurance methods were upgraded to meet the regulatory requirements applicable to SLAMS. CASTNET O_3 data are submitted to the EPA's Air Quality System (AQS), and were included in the 2011-2013 O_3 design value calculations. The EPA is continuing to support and evaluate methods for measuring highly time-resolved concentrations of both gaseous (SO_2, HNO_3, NH_3) and aerosol (sulphate [SO_4^{2-}], ammonium [NH_4^+], NO_3-, chlorine [Cl-] and other base cations) pollutants. Five small-footprint, filter-pack-only CASTNET sites have been installed since 2012 to assess sulphur and nitrogen impacts on sensitive ecosystems and tribal lands. Additionally, the EPA and NPS have installed AMoN samplers at 41 CASTNET sites, and the EPA recently added 5 NO_y trace gas analyzers at CASTNET sites to provide a more complete nitrogen budget. The website for CASTNET includes program information, data and maps, annual network reports, and quality assurance information (www.epa.gov/castnet).

Figure 30. AirNow Map Illustrating the AQI for 8-hour Ozone



Note: This map is an illustration of the highest O_3 concentrations reached throughout the region on a given day. It does not represent a snapshot at a particular time of the day, but is more like the daily high temperature portion of a weather forecast. The AQI shown in the legend is based on 8-hour average O_3.

Source: U.S. EPA, 2014

AirNow

The AirNow program (www.airnow.gov) was initiated by the EPA more than a decade ago, to provide current and forecasted air quality information for monitoring sites throughout the United States and Canada; it presents PM and O_3 pollutant concentrations in terms of the U.S. Air Quality Index (AQI). Each country is responsible for ensuring instrument calibration and comparability of ambient measurements of O_3 and $PM_{2.5}$. In 2004, the AirNow program was expanded to provide information on $PM_{2.5}$ and O_3 measurements on a continental scale year-round. Figure 30 is an example of the type of maps available on the AirNow website; they display pollutant concentration data expressed in terms of the color-coded U.S. AQI. AirNow also distributes air quality data via web services and text files through the AirNow Application Programming Interface (API), at http://www.airnowapi.org.

Note: The AQI for O_3 reflects 8-hour average O_3 concentrations. Areas shaded in orange indicate values that are "unhealthy for sensitive groups." More information on the AQI is available at www.airnow.gov.

Air Quality Standards

Canadian Ambient Air Quality Standards

New ambient air quality standards for $PM_{2.5}$ and ground level O_3 were implemented under CEPA 1999, as approved by federal, provincial and territorial Ministers of the Environment. The new standards are more stringent and replace the existing CWS for these two pollutants. In addition, the federal, provincial and territorial governments have initiated development of the CAAQS for other air pollutants of concern (SO_2 and NO_2) and are expecting to complete the work in 2015.

Air Zone Management/Regional Airsheds

Canada's AQMS includes a framework for managing air quality through local air zones (geographic areas within each province or territory) with unique air quality issues and challenges. The framework contains four air quality management levels with threshold values based on CAAQS that encourage progressively more rigorous actions by jurisdictions as air quality approaches or exceeds the CAAQS. Provinces and territories will lead air quality management in their jurisdiction guided by this framework and select air quality management actions tailored to each air zone. The AQMS also promotes proactive measures to protect air quality ensuring that the CAAQS are not exceeded and do not become "pollute up to" levels.

In addition to the air zones, six regional airsheds have been established to coordinate air quality management actions across the country and to better understand the transboundary flow of pollutants. The airsheds are larger areas, cutting across jurisdictional boundaries where air quality characteristics and air movement patterns are similar. They provide a framework for interjurisdictional collaboration and coordination of overall system reporting.

Review of U.S. O_3, PM, SO_2 and NO_2 Air Quality Standards

Under the Clean Air Act (CAA), the EPA is required to set NAAQS for widespread pollutants from numerous and diverse sources considered harmful to public health and the environment. The CAA established two types of NAAQS:

- Primary standards set limits with an adequate margin of safety to protect public health, including the health of at-risk populations such as children, older adults, and persons with pre-existing cardiovascular or respiratory disease such as asthma.

- Secondary standards set limits to protect public welfare from any known or anticipated adverse effects, including protection against decreased visibility and damage to animals, crops, vegetation and buildings.

The EPA has established NAAQS for six common pollutants, which are often referred to as "criteria" pollutants: PM, O_3, SO_2, NO_2, CO and Pb. The CAA requires the EPA to review each standard every five years and determine whether there is sufficient new scientific information to warrant a revision of the standard. Reviewing a NAAQS is a lengthy undertaking that follows a well-established process: each involves a comprehensive review, synthesis and evaluation of the scientific information, or "criteria," available to inform a decision (Integrated Science Assessment [ISA]); the design and conduct of complex air quality and risk and exposure analyses (Risk and Exposure Assessment [REA]); the development of a comprehensive Policy Assessment providing a transparent staff analysis of the scientific basis for the broadest range of alternative policy options supported by the scientific and technical information; and the issuance of a proposed rule in the Federal Register, opportunity for public comment, and publication of the final rule in the Federal Register. These assessments, which provide the foundation for the EPA Administrator's decision, undergo extensive internal and external scientific peer review.

Ozone NAAQS

Exposure to O_3 is associated with a wide variety of adverse health effects, ranging from decreased lung function and increased respiratory symptoms to serious indicators of respiratory morbidity, including emergency department visits and hospital admissions for respiratory causes, new-onset asthma and premature mortality. Children and individuals with lung disease are considered at-risk populations. Ozone exposure also leads to detrimental environmental effects: repeated exposure to O_3 during the growing season damages sensitive vegetation; and cumulative O_3 exposure can lead to reduced tree growth, visibly injured leaves, and increased susceptibility to disease, damage from insects, and harsh weather.

On March 12, 2008, the EPA strengthened the primary and secondary 8-hour standards for O_3 by lowering the levels of the standards from 0.08 to 0.075 ppm, in order to improve protection of public health and of sensitive trees and plants. Final area designations for these standards were completed in May 2012, with 46 areas being designated as non-attainment.

The EPA is in the midst of its next review of the ozone standards to ensure that the NAAQS provide appropriate public health and environmental protection. As part of this ongoing review, EPA has issued a number of documents for external scientific and public review. Under the terms of a consent decree, EPA is expected to issue a proposed notice by December 1, 2014, and a final action by October 1, 2015. Additional information on the current and previous O_3 NAAQS reviews can be found at www.epa.gov/ttn/naaqs/standards/ozone/s_o3_index.html.

Particulate Matter NAAQS

An extensive body of scientific evidence demonstrates that exposure to PM can lead to premature death, and is linked to a variety of significant health problems, such as increased hospital admissions and emergency department visits for cardiovascular and respiratory effects, including non-fatal heart attacks. Exposure to PM is also linked to the development of chronic respiratory disease. Several groups within the general population are at greater risk for experiencing PM-related effects, including individuals with pre-existing heart and lung disease, older adults, children, and people of lower socio-economic standing. Research indicates that pregnant women, newborns and people with certain health conditions, such as obesity or diabetes, may also be at increased risk of PM-related health effects.

It has been further recognized for many years that PM in the atmosphere (particularly fine PM) causes visibility impairment. Hazy conditions due to air pollution can be experienced in all types of areas, from urban areas to national parks. Visibility is affected by particles that scatter and absorb light, and the composition and size of these particles, as well as relative humidity, are important factors in understanding the impacts of particle pollution on visibility impairment. Particles are also associated with a wide range of non-visibility welfare effects, including ecological effects, effects on materials, and climate impacts.

In December 2012, the EPA finalized revisions to the PM NAAQS, which strengthened the primary annual average $PM_{2.5}$ standard to a level of 12 $\mu g/m^3$. This revised standard provides increased protection against health effects associated with long- and short-term $PM_{2.5}$ exposures. The primary 24-hour $PM_{2.5}$ standard of 35 $\mu g/m^3$, originally established in 2006, was retained. The existing secondary standards for $PM_{2.5}$ (an annual standard of 15.0 $\mu g/m^3$ and a 24-hour standard of 35 $\mu g/m^3$) were also retained to address PM-related welfare effects such as visibility impairment, ecological effects, damage to materials and climate impacts.

The EPA is working with state governments to designate non-attainment areas for the 2012 standards. Additional information on the revised PM NAAQS, including supporting documents, can be found at http://www.epa.gov/air/particlepollution/.

SO_2 NAAQS (Primary Standard)

Asthmatics are especially susceptible to the effects of SO_2. Short-term exposure of asthmatic individuals to elevated levels of SO_2 while exercising at a moderate level may result in breathing difficulties, accompanied by symptoms such as wheezing, chest tightness or shortness of breath. Studies also provide consistent evidence of an association between short-term exposure to SO_2 and increased respiratory symptoms in children, especially those with asthma or chronic respiratory symptoms. In addition, short-term exposure to SO_2 has been associated with respiratory-related emergency department visits and hospital admissions, particularly for children and older adults.

On June 2, 2010, based on the results of SO_2 health effects evidence assessed in the ISA, and on estimates of SO_2-associated exposure and health risks presented in the REA, the EPA strengthened the primary NAAQS for SO_2, revising the primary SO_2 standard by establishing a new 1-hour standard at a level of 75 ppb. The revised standard will improve public health protection, especially for children, older adults, and people with asthma. The EPA's evaluation of the scientific information and the risks posed by inhaling SO_2 indicate that this new 1-hour standard will protect public health by reducing people's exposure to high, short-term concentrations (5 minutes to 24 hours) of SO_2. The EPA revoked the two existing primary standards of 140 ppb evaluated over 24 hours and 30 ppb evaluated over a year, because they will not add additional public health protection given a 1-hour standard at 75 ppb.

The EPA recently started its next periodic review of the primary SO_2 standards; the draft integrated review plan was published in March 2014 and a final version is scheduled for release later in 2014. Additional information on the SO_2 NAAQS, including supporting documents, can be found at www.epa.gov/air/sulfurdioxide.

NO_2 NAAQS (Primary Standard)

Exposure to NO_2 has been associated with a variety of health effects, including respiratory symptoms, especially among asthmatic children; and to respiratory-related emergency department visits and hospital admissions, particularly for children and older adults. On January 22, 2010, based on the results of NO_2 health effects evidence as assessed in the ISA and estimates of NO_2-associated exposures and health risks presented in the REA, the EPA revised the primary NO_2 NAAQS, and established new requirements for the NO_2 monitoring network.

Specifically, the EPA promulgated a new 1-hour primary NO_2 standard with a level of 100 ppb, retained the existing annual standard with a level of 53 ppb, and established a requirement for more than 50 NO_2 monitors to be sited within 50 metres of major roads and in other locations where maximum NO_2 concentrations are expected to occur. The states are deploying new monitors in three phases: by the beginning of 2014, 2015 and 2017.

The EPA recently started its next periodic review of the primary NO_2 standards; the final integrated review plan was issued in June 2014. Additional information on the NO_2 NAAQS can be found at http://www.epa.gov/air/nitrogenoxides.

Oxides of Sulphur and Nitrogen NAAQS (Secondary Standards)

NO_x and SO_x in the air can damage the leaves of plants, decrease their ability to produce food (photosynthesis), and decrease their growth. In addition to directly affecting plants, NO_x and SO_x can, when deposited on land and in estuaries, lakes and streams, acidify and over-fertilize sensitive ecosystems, resulting in a range of harmful deposition-related effects on plants, soils, water quality, and fish and wildlife (e.g. changes in biodiversity and loss of habitat, reduced tree growth, loss of fish species, and harmful algal blooms).

On March 20, 2012, the U.S. EPA completed its review of the secondary NO_x and SO_x standards, representing the first time that the Agency reviewed the environmental impacts separately from the health impacts of these pollutants. It is also the first time that the EPA examined the effects of multiple pollutants in one NAAQS review. Based on its review of the currently available scientific information, the EPA retained the current annual NO_2 secondary standard set at a level of 0.53 ppm and 2-hour SO_2 secondary standard set at a level of 0.5 ppm, in order to address the direct effects on vegetation (e.g. decreased growth and foliar injury). With regard to the deposition-related effects, the final rule recognized that the existing secondary standards do not provide adequate public welfare protection. Although there is strong scientific support for developing a multi-pollutant standard to address these deposition-related effects, the EPA concluded that it does not yet have sufficient information to set such a standard that would adequately protect the diverse ecosystems across the country.

The EPA recently started its next periodic review of the NO_x and SO_x secondary standards; the draft integrated review plan is scheduled for release in Fall 2014. Additional information on the past and current reviews of these secondary standards, and supporting documentation, can be found at http://www.epa.gov/ttn/naaqs/standards/no2so2sec/index.html.

Ecological Effects

Research and Monitoring of Acid Deposition Effects on Aquatic Ecosystems

Recovery of Acidified Lakes and Streams in the United States

Acid rain, resulting from SO_2 and NO_x emissions, is one of many large-scale anthropogenic effects that negatively affect the health of water bodies (lakes and streams) in the United States and Canada. Surface water chemistry provides direct indicators of the potential effects of acidic deposition on the overall health of aquatic ecosystems, and, in this regard and in collaboration with federal and state agencies as well as universities, the EPA administers two monitoring programs that provide information on the impacts of acidic deposition on otherwise protected aquatic systems: Temporally Integrated Monitoring of Ecosystems (TIME) and Long-term Monitoring (LTM) programs. These programs are designed to track changes in surface water chemistry in the four acid-sensitive regions shown in Figure 31: New England, the Adirondack Mountains, the Northern Appalachian Plateau, and the central Appalachians (the Valley and Ridge geologic province and Blue Ridge geologic province).

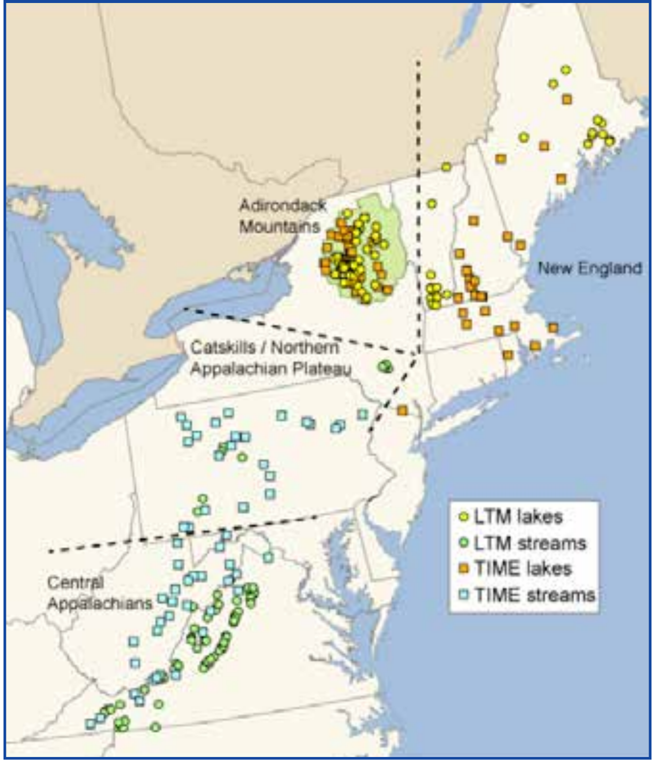
Five chemical indicators of aquatic ecosystem response to emission changes are presented: trends in sulphate and nitrate anions, sum of base cations, acid neutralizing capacity (ANC), and dissolved organic carbon (DOC). These indicators provide information regarding the surface water sensitivity to acidification and the degree of impact on the aquatic ecosystem. Trends in these measured chemical indicators in drainage waters allow for the determination of whether the water bodies are improving and heading towards recovery or still acidifying. The following is a description of each indicator:

Sulphate is the primary anion in most acid-sensitive waters and has the potential to acidify drainage waters and leach base cations and toxic forms of aluminum from the soils.

Nitrate has the same potential as sulphate to acidify drainage waters. However, nitrogen is an important nutrient for plant and algae growth, and a large portion of nitrogen inputs from deposition are quickly taken up by plants, leaving less leaching of nitrate into surface waters.

Base cations are the positively charged ions in soils and surface waters that buffer both sulphate and nitrate anions, thereby preventing surface water acidification. Base cation availability is largely a function of underlying geology and soil age, such that young soils of cation-rich bedrock will tend to have a greater buffering capacity.

Figure 31. Long-Term Monitoring Program Sites



Source: EPA, 2013

Acid Neutralizing Capacity (ANC) is a measure of overall buffering capacity against acidification, and indicates the ability to neutralize strong acids that enter aquatic systems. When ANC is low, and especially when it is negative, stream water pH is also low (less than pH 6, commonly less than pH 5), and may be harmful to fish and other aquatic organisms essential for a healthy aquatic ecosystem. Figure 32 shows how waterbody acidification is categorized by ANC concentration. Recovery of an aquatic ecosystem is indicated by increasing trends in ANC and base cations, and decreasing trends in sulphate and nitrate concentrations.

Dissolved organic carbon (DOC) is essentially dissolved organic material that is an important part of the acid-base chemistry of most freshwater systems (particular low-ANC waterbodies) because it can assist in neutralizing strong acids. A host of factors control DOC concentrations in surface waters, and increases can indicate reduced acidification and/or increased decomposition of organic matter in the watershed.

Table 4 shows regional trends in indicators of acidified surface waters from 1990 (before implementation of the ARP) to 2012 in lakes and streams, through the LTM program. Over this time frame, significant improving trends in sulphate concentrations are found at nearly all LTM monitoring

Table 4. Regional Trends in Sulphate, Nitrate, ANC, Base Cations, and DOC at Long-term Monitoring Sites, 1990–2012

Region	Water Bodies Covered	Percentage of Sites with Improving Sulphate Trend	Percentage of Sites with Improving Nitrate Trend	Percentage of Sites with Improving ANC Trend	Percentage of Sites with Improving Base Cations Trend	Percentage of Sites with Improving DOC Trend
Adirondack Mountains	50 lakes in New York	100%	54%	76%	88%	62% (29 sites)
New England	26 lakes in Maine and Vermont	100%	18%	43%	74%	39% (13 sites)
Catskills / N. Appalachian Plateau*	9 streams in NY and PA	80%	40%	58%	90%	0% (9 sites)
Central Appalachians	66 streams in Virginia	15%	58%	15%	14%	N/A

* Data for streams in N. Appalachian Plateau are only through 2011.

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.
- DOC was only examined in low-ANC waterbodies (ANC less than 25 micro-equivalents per litre [μeq/L]).
- DOC is not currently measured in Central Appalachian streams.

Source: U.S. EPA, 2013

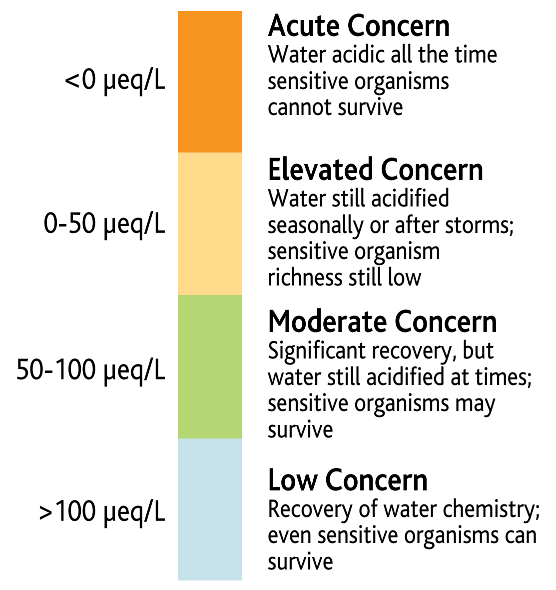
sites in New England, the Adirondacks and the Catskill Mountains/ Northern Appalachian Plateau. However, in the Central Appalachians, only 15 percent of monitored streams have a decreasing sulphate trend, while 20 percent of monitored streams had increasing sulphate concentrations. This is due to the highly weathered soils of the Central Appalachians, which are able to store deposited sulphate such that the decrease in acidic deposition has not yet resulted in lower sulphate concentrations in most streams. However, as long-term sulphate deposition exhausts the soil's ability to store more sulphate, a decreasing proportion of the deposited sulphate is retained in the soil and an increasing proportion is exported to surface waters. Thus, sulphate concentrations in some streams in this region are not changing or are still increasing despite reduced sulphate deposition.

Nitrate concentration trends are variable across the LTM site network, with improving trends measured at approximately half of all monitored sites. This improvement in nitrate trend may only be partially explained by decreasing deposition. Ecosystem factors, such as vegetation disturbances, increased uptake by vegetation, and soil retention, are also known to affect surface water nitrate concentrations.

Improving ANC trends are likely the result of reductions in sulphate deposition. Recovery in ANC, however, often lags behind declining surface water sulphate and nitrate concentrations. Dynamics in surface water chemistry are complicated and highly dependent on local factors, such as watershed size, geology and hydrology, which can influence the availability of base cations and DOC and thereby inhibit ANC recovery. From 1990 to 2012, ANC concentration increased markedly at LTM monitoring sites in the Adirondacks (76 percent), in the Catskills / northern Appalachian Plateau (58 percent), and New England (43 percent). In contrast, only 15 percent of LTM streams in the Central Appalachians had improving ANC trends, likely due to decreasing base cation levels and the still-increasing sulphate concentrations at some sites.

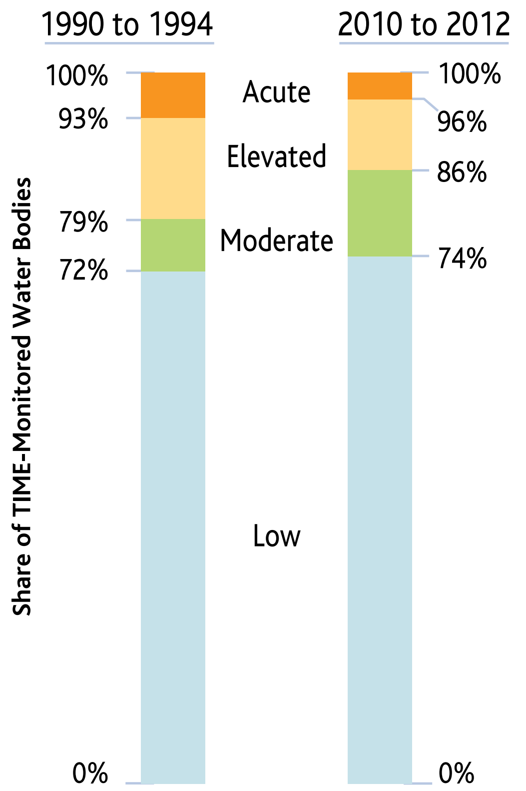
Figure 33 presents a comparison of the average ANC value of the 580 lakes in the northeast monitored and modelled under the TIME program for the 1991–1994 and 2010–2012 time periods. Seven percent of lakes in the 1991–1994 time period had mean ANC levels below 0 µeq/L, and were categorized as acute concern, but less than 4 percent of lakes were categorized as acute concern in the 2010–2012 time frame, and the percentage of lakes in the elevated concern category dropped from 14 to 10 percent over the same time frame. Meanwhile, the net percentage of lakes in the moderate concern category increased from 7 to 12 percent. These results point to a decrease in acidity, particularly for the subset of TIME lakes in the acute and elevated concern categories.

Figure 32. Acid Neutralizing Capacity and Aquatic Ecosystem Concern Levels



Source: EPA, 2013

Figure 33. TIME Lakes by ANC Category, 1991–1994 vs. 2010–2012



Source: EPA, 2013

Critical Loads and Exceedances

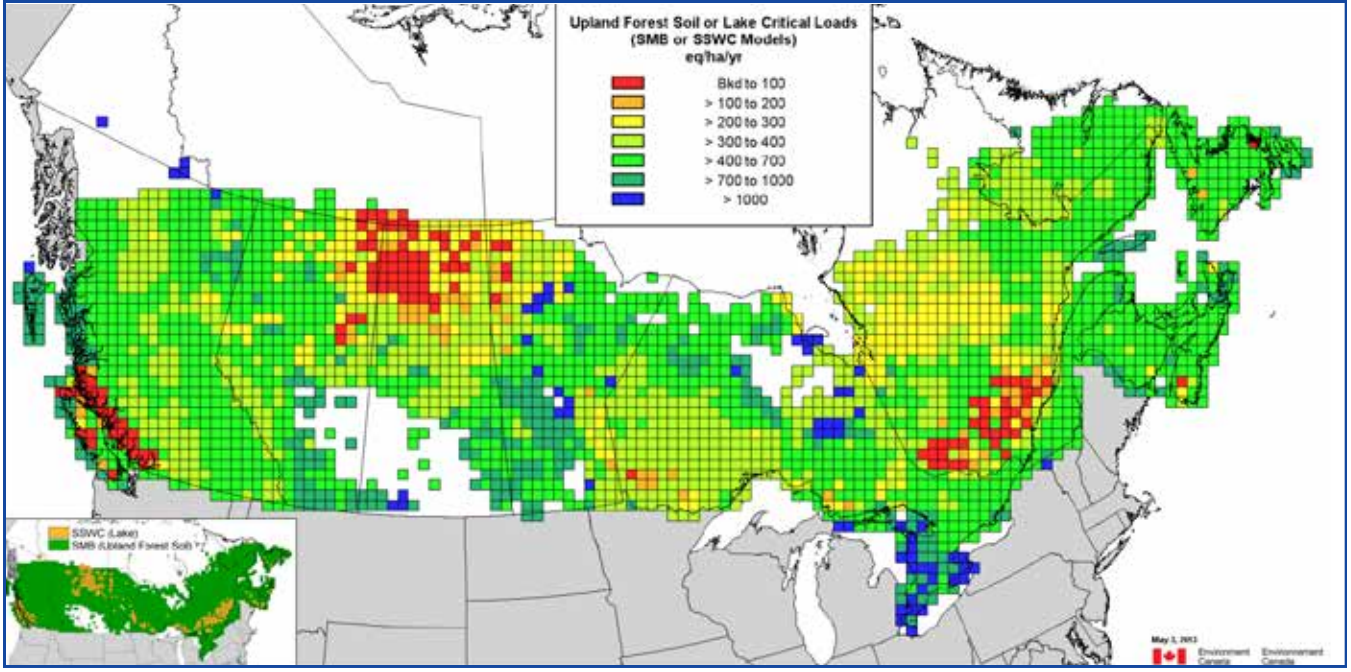
Updating Canadian Critical Loads of Acidity for Lakes and Upland Forest Soils

Canada has created a new national critical load map for acidity that combines current information for lakes and soils.

Critical load values were estimated using the steady-state water chemistry (SSWC) model (Henriksen and Posch 2001) for lakes, and the steady-state simple mass balance (SMB) model (Sverdrup and De Vries 1994) for forest soils. Both models depend on a chemical threshold that defines the onset of harmful ecosystem effects. For lakes, the threshold is an acid neutralizing capacity (ANC_{limit}), and, for soil water, the threshold is the ratio of base cations (Bc) to aluminum (Al) (ratio denoted by Bc:Al). For this report, ANC_{limit} was set at a value related to the DOC concentration in the lake water (Lyderson et al. 2004), or, in the absence of a DOC value, set at the typical value of 40 micromoles of charge per litre (μmolc L^{-1}); the Bc:Al threshold was set at 10. The SSWC calculates an aquatic critical load for each sampled lake, and the SMB calculates critical loads for every upland forest soil type (or "polygon") across the modelled areas of Canada. In total, critical loads were estimated for 4702 lakes and 7867 soil polygons across Canada. These critical loads were superimposed on the 45x45 km grid generated by the atmospheric deposition model AURAMS (A Unified Regional Air-Quality Modelling System). When a grid square contained multiple lake and/or soil critical load values, the 5th percentile for each type was calculated (area-weighted in the case of soil polygons). The lower 5th percentile critical load value was then selected to represent the critical load for that square. If a square did not have any sampled lakes, the critical load value for the square was the 5th percentile value for forest soils. In this manner, a single critical load value was assigned to each of 2874 grid squares across Canada (Figure 34). Using the 5th percentile critical load value is a way of ensuring that some of the most sensitive elements of an ecosystem are protected. If actual acid deposition does not exceed the 5th percentile critical load value, at least 95% of all lakes and soil ecosystems within the grid are protected from the adverse effects of acid deposition.

Some squares in Figure 34 were not assigned a critical load because they contained neither sampled lakes nor forest soils that could be modelled. In other cases, the square consisted entirely or mostly of cultivated soils, and critical load values are not established for cultivated soils because the physical,

Figure 34. Critical Loads of Acidity for Lakes or Upland Forest Soils across Canada



Note: Lake or upland forest soil critical loads for acidity (wet + dry deposition in eq/ha/yr) is calculated using either the SSWC or SMB models. The index map (lower left) indicates the model selected for each grid square: yellow = SSWC, green = SMB. The CL value for a given square is either the 5th percentile lake value or the 5th percentile soil polygon value. Areas that cannot be classified by either the lake or forest soil models are white.

Source: Environment Canada, 2014

chemical and biological composition of these soils is altered and managed by human activities.

In Figure 34, critical loads are shown in ranges consisting of seven classes. The four lowest classes range from background (Bkd) deposition to 400 equivalents per hectare per year (eq/ha/yr), and grid squares within these classes are the most sensitive to the adverse effects of acid deposition and of greatest concern. Critical load values for upland forest soils cover the greater portion of the map. Of the 2874 grid squares (representing an area of approximately 5.8 million km^2), 89 percent have a critical load defined by forest soils. This is due to the nature of the data available for modelling. Spatial coverage by the geology, soil and land cover characteristic databases used to obtain input data for the SMB model is much greater than the coverage provided by the lake chemistry database (sampled lakes occurred in 633 grid squares, or 18 percent of the total).

All grid squares with critical loads in the classes from Bkd to 100 eq/ha/yr and from >100 to 200 eq/ha/yr were defined by the aquatic critical load. Within the remaining five classes, lakes defined the critical load from 18% of the squares for the >200-300 eq/ha/yr class to <1 percent of the squares for the >300-400 eq/ha/yr class. This was expected in eastern Canada, because many lakes sampled for the purpose of acid rain assessment occur in areas that are acid sensitive or have known aquatic effects. Nevertheless, lakes recently sampled on acid-sensitive terrain in western Canada (but without any pre-knowledge of acidification or effects) show the same pattern.

There are obvious "hot spots" of sensitive ecosystems, represented by very low critical loads (red and orange squares in Figure 34). These are located in southern Quebec, northwestern Saskatchewan and extreme northeastern Alberta, and the coastal mountain range of southwestern British Columbia (including some parts of Vancouver Island). There are also isolated occurrences of very low critical loads in southern Nova Scotia, Newfoundland, northern Ontario, northwestern Manitoba, and east central Alberta. The commonality among all these areas with low critical load values is the occurrence of lakes with very low base cation and ANC concentrations.

Overall, approximately 0.4 million km^2 or 6.6 percent of the Canadian terrain covered by the analysis shown in Figure 34 is extremely sensitive to acidic deposition, i.e., falling within the two lowest critical load classes. An additional 2.1 million km^2 or 35 percent of the total falls within the next two critical load classes.

Use of Critical Loads in the United States

In the United States, the critical loads approach is not an officially accepted approach to ecosystem protection. Language specifically requiring a critical loads approach

Table 5. Critical Load Exceedances by Region

Region	Number of Waterbodies Modelled	Waterbodies in Exceedance of Critical Load				Percent Reduction
		2000–2002		2010–2012		
		Number of Sites	Percentage of Sites	Number of Sites	Percentage of Sites	
New England (ME, NH, VT, RI, CT)	1298	273	21%	147	11%	46%
Adirondack Mountains (NY)	341	160	47%	70	21%	56%
Northern mid-Atlantic (PA, NY, NJ)	784	263	34%	155	20%	41%
Southern mid-Atlantic (VA, WV, MD)	1690	1070	63%	745	44%	30%
Southern Appalachian Mountains (NC, TN, SC, GA, AL)	773	308	40%	192	25%	38%
Total	**4886**	**2074**	**42%**	**1309**	**27%**	**37%**

Source: U.S. EPA, 2013

does not exist in the CAA. Nevertheless, the critical loads approach provides a useful lens through which to help understand the potential aquatic ecological benefits that have resulted from emission reduction programs such as the ARP and CAIR.

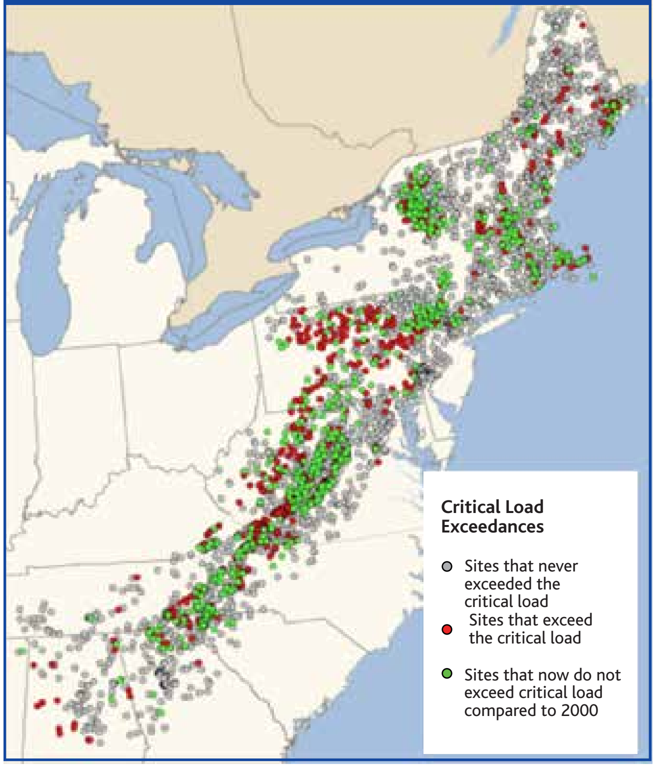
Estimations of critical load exceedances serve as a measurement for determining if present acid deposition levels will provide sufficient reductions to allow the systems to recover over time, or if they will never recover under present loading scenarios. If acidic deposition is less than the calculated 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.[5] Lake and stream waters having an ANC value greater than 50 μeq/L are classified as having a moderately healthy aquatic community; therefore, this ANC value is often used as a goal for ecological protection of drainage waters affected by acid deposition.

Figure 35 shows a comparison of the estimated critical load exceedances for waterbodies for the periods 2000–2002 and 2010–2012. For this analysis, the critical load represents the annual deposition load of sulphur and nitrogen to which a lake or stream could be subjected and still support a moderately healthy ecosystem (i.e. having an ANC greater than 50 μeq/L). Surface water samples from 4886 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 for those waterbodies were calculated using the SSWC model.[6,7]

For the period 2010–2012, 27 percent of all the represented waterbodies were shown to still receive levels of combined total sulphur and nitrogen deposition in excess of their critical load, a 37-percent improvement over the 2000–2002 period when 42 percent were in exceedance. Regional differences in critical load exceedances were examined for New England, the Adirondack Mountains, the northern mid-Atlantic, the southern mid-Atlantic, and the southern Appalachian Mountains, as summarized in Table 5.

This analysis suggests that 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. This result is consistent with the water quality monitoring findings (see Table 4), except that the anticipated improvements (e.g. reduction of exceedances) based on the critical load analysis are much larger. This is expected, as water quality improvements often lag behind the reduction in acidic deposition while critical loads represent the equilibrium conditions between deposition and water quality. Based on this critical load analysis, current acidic deposition loadings still fall short for recovery of many modelled waterbodies, which indicates additional emission reductions would be necessary for acid-sensitive aquatic ecosystems along the Appalachian Mountains to recover and be protected from acid deposition.

Figure 35. Lake and Stream Exceedances of Estimated Critical Loads for Total Nitrogen and Sulphur Deposition for the Periods 2000–2002 and 2010–2012



Note:

- Surface water samples from the represented waterbodies were collected through the National Surface Water Survey (NSWS), Environmental Monitoring and Assessment Program, Wadeable Stream Assessment (WSA), National Lake Assessment (NLA), TIME, LTM, and other water quality programs.
- Steady-state exceedances were calculated in units of micro-equivalents per square metre per year (meq/m2/yr).

Source: EPA, 2013

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[5] Dupont J. et al. 2005. Estimation of critical loads of acidity for lakes in the northeastern United States and eastern Canada. Environmental Monitoring and Assessment 109:275–291.

[6] Sullivan T.J. et al. 2007. Streamwater acid-base chemistry and critical loads of atmospheric sulfur deposition in Shenandoah National Park, Virginia. Environmental Monitoring and Assessment 137:85–99.

[7] Nilsson J. and Grennfelt P. (editors). 1988. Critical loads for sulphur and nitrogen. UNECE/Nordic Council workshop report, Skokloster (SW). March 1988. Nordic Council of Ministers: Copenhagen (DK).

Canada–United States Scientific Cooperation

Transboundary PM Science Assessment

Scientists from Canada and the United States have prepared a Transboundary PM Science Assessment that updates findings from the 2004 Canada–United States Transboundary Particulate Matter Science Assessment. This updated assessment was developed to provide the scientific and technical basis for discussions regarding the possibility of adding a PM annex to the Canada–United States AQA, to assess the potential impacts of a PM annex, and to help determine whether such an annex is currently warranted.

This assessment focuses on the fine particle fraction of PM, i.e., $PM_{2.5}$, because a fraction of this size can remain suspended in the air for several days to weeks and can be transported by winds over large distances, and therefore is subject to atmospheric transboundary transport in North America.

This document is organized around five key science questions:

(1) What are the impacts of $PM_{2.5}$ on human/ecosystem health and public welfare, and what are the current air quality standards to protect human and ecosystem health in the United States and Canada?

(2) What are the recent levels of $PM_{2.5}$ in the United States and Canada?

(3) What are the emissions and emission trends of the pollutants that contribute to ambient $PM_{2.5}$ concentrations in the United States and Canada?

(4) What is the evidence that transboundary flow of $PM_{2.5}$ occurs across the U.S.–Canada border, and what changes are projected, given future emission rates in both countries?

(5) Are there emerging science issues that could affect the understanding of $PM_{2.5}$ formation and levels, and its impacts on human and ecosystem health?

The key findings from the updated assessment are bulleted below.

- $PM_{2.5}$ and its precursors have significant effects on the health of humans and ecosystems.

The extensive body of studies providing evidence on the effects of fine particles on health has grown further and significantly since the 2004 assessment. These studies provide evidence of consistent increases in premature mortality and morbidity related to ambient $PM_{2.5}$ concentrations, with the strongest evidence being reported for cardiovascular-related effects. Furthermore, the ubiquity of $PM_{2.5}$ implies that exposure to ambient $PM_{2.5}$ concentrations can have a substantial public health impact, even with recent reductions.

In addition, although deposition (wet and dry) of acidifying sulphur and nitrogen compounds related to $PM_{2.5}$ in Canada and the United States has been reduced since 2004, recent deposition in both countries continues to exceed thresholds (critical loads) in some geographic areas, thus posing a risk of harmful effects to terrestrial and aquatic ecosystems. In addition, although significantly reduced in most border areas, $PM_{2.5}$ continues contributing to visibility impairment in the United States and Canada, particularly in highly populated regions of southern Ontario and Quebec in Canada and the midwest and Montana in the United States. In response, both countries recently lowered ambient air quality standards to protect human and ecosystem health from the harmful impacts of $PM_{2.5}$.

- Recent levels of ambient $PM_{2.5}$ have been declining in the United States and Canada.

In both countries, ambient concentrations of $PM_{2.5}$ have diminished significantly from the levels reported in the 2004 assessment. More specifically, between 2000 and 2012 the national U.S. average annual and 24-hour concentrations of $PM_{2.5}$ decreased by 33% and 37%, respectively. Data from Canadian $PM_{2.5}$ speciation sites indicate that, between 2003 and 2010, average annual concentrations of $PM_{2.5}$ declined by approximately 4 $\mu g/m^3$ in eastern Canada, while average levels across western Canada remained fairly constant. In 2012, ambient concentrations reported at most monitoring sites in the United States along the Canadian border met the annual and 24-hour NAAQS for $PM_{2.5}$ set in 2012. In eastern and western Canada, data from the filter-based monitoring network indicate that average annual concentrations (2008–2010) met the CAAQS set for 2015.

- The decline of most $PM_{2.5}$ precursors is expected to continue, while direct emissions of $PM_{2.5}$ and ammonia (NH3) have remained and are expected to remain relatively stable.

National emission inventories in the United States and Canada show that emissions of the $PM_{2.5}$ precursors SO_2, NO_x and VOCs declined between 2002 and 2010. However, total direct emissions of anthropogenic $PM_{2.5}$ have remained fairly stable in both countries during this period, as have emissions of NH_3.

Projections based upon known policies established in Canada and the United States for governing future emissions indicate that emissions of $PM_{2.5}$ and its precursors will follow recent trends. In Canada, primary emissions of $PM_{2.5}$ are expected to remain stable through 2020, while emissions of SO_x and NO_x are projected to decline by 33% and 13%, respectively, between 2006 and 2020. By contrast, Canadian VOC and NH3 emissions are not projected to change significantly during this period. In the United States, emissions of SO_2, NO_x and VOCs are forecast to decrease by 65%, 42% and 21%, respectively, from 2008 to 2020, while emissions of $PM_{2.5}$ are projected to decrease modestly (8%). NH_3 emissions in the United States are expected to be 2% higher in 2020 than 2008.

- It is projected that the influence of transboundary transport between Canada and the United States will be reduced, and that current and planned $PM_{2.5}$ ambient air standards will likely not be exceeded.

Modelling analyses of the impact of future emission projections show notable anticipated reductions in ambient $PM_{2.5}$ concentrations between 2006 and 2020 in the United States and Canada. Significant declines in ambient $PM_{2.5}$ concentrations are expected to occur in most border region cities, with percentage reductions ranging up to 35% in major U.S. cities near the border and up to 25% in their Canadian counterparts.

There is ongoing evidence that $PM_{2.5}$ is transported across the U.S.–Canada border. However, for most cities in both countries, the dominant sources of $PM_{2.5}$ in 2020 will continue to be domestic emissions; overall, transboundary influence is projected to be less in 2020 than 2006. The influence of U.S. emissions on $PM_{2.5}$ concentrations in Canadian cities near the border is projected to decrease by approximately 2–10%, with the largest reductions occurring in eastern Ontario and southwestern Quebec. The exception is Abbotsford, B.C., where there is a small projected increase in U.S. influence. The influence of Canadian emissions on select U.S. cities near the border is also projected to decrease—but by less, in the range of 1–3%, with the exceptions of Seattle, WA, Buffalo, NY, and Rochester, NY, where the Canadian influence is projected to increase slightly.

In the United States, no areas in the border region are predicted to exceed the current annual or 24-hour $PM_{2.5}$ NAAQS (12 $\mu g/m^3$) in 2020, including areas with projected increases in Canadian influence. In Canada, the predicted 2006–2020 decreases in $PM_{2.5}$ are expected to result in rural/regional background $PM_{2.5}$ concentrations in the region near the southern Ontario and southern Quebec borders, expected to be below the 2015 and 2020 annual and 24-hour CAAQS. However, these levels are close enough to the CAAQS that some populated areas with relatively large local emissions may experience $PM_{2.5}$ above the CAAQS. In the border regions of western and Atlantic Canada, 2015 and 2020 CAAQS levels are not projected to be exceeded.

- Emerging air quality issues could influence future concentrations of $PM_{2.5}$ in both countries, and therefore there is a continued need to improve the scientific understanding of health and ecological effects, the impacts of air quality management activities, and the magnitude of transboundary transport.

The following emerging science issues are expected to affect future ambient $PM_{2.5}$ concentrations and/or how air quality management activities are developed to address $PM_{2.5}$:

- The need for improved understanding of the health effects of $PM_{2.5}$ and its components in the context of exposure to other pollutants, and how these combined effects could affect air quality standards and management strategies
- The need for increased understanding of the impacts of climate change on $PM_{2.5}$ concentrations and of the effects of $PM_{2.5}$ and its components on climate change
- The effects of changes in the mix of energy generation and end-use technologies on the concentrations of $PM_{2.5}$, and the impacts of growing domestic fossil fuel extraction activities, such as the oil sands, and unconventional oil and gas development, such as the use of hydraulic fracturing (fracking)
- Changes in the relative importance of natural sources and intercontinental transport that could affect the management of ambient $PM_{2.5}$ concentrations in Canada and the United States

As the science continues to evolve on these issues, air quality management activities in the United States and Canada may require adjustment in order to continue effectively protecting public health and the environment.

Global Assessment of Precipitation Chemistry and Deposition

Canadian and U.S. scientists co-led and co-authored a global assessment of precipitation chemistry and deposition of sulphur, nitrogen, sea salt, base cations, organic acids, acidity and pH, and phosphorus, which was published in a special issue of the journal *Atmospheric Environment*.[8] The global assessment was written by 21 authors from 14 countries under the auspices of the World Meteorological Organization's Global Atmosphere Watch Scientific Advisory Group for Precipitation Chemistry. The objective was to understand spatial patterns and temporal changes of precipitation chemistry and wet, dry and total deposition,

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[8] Vet R et al. 2014. A global assessment of precipitation chemistry and deposition of sulfur, nitrogen, sea salt, base cations, organic acids, acidity and pH, and phosphorus. Atmospheric Environment 93.

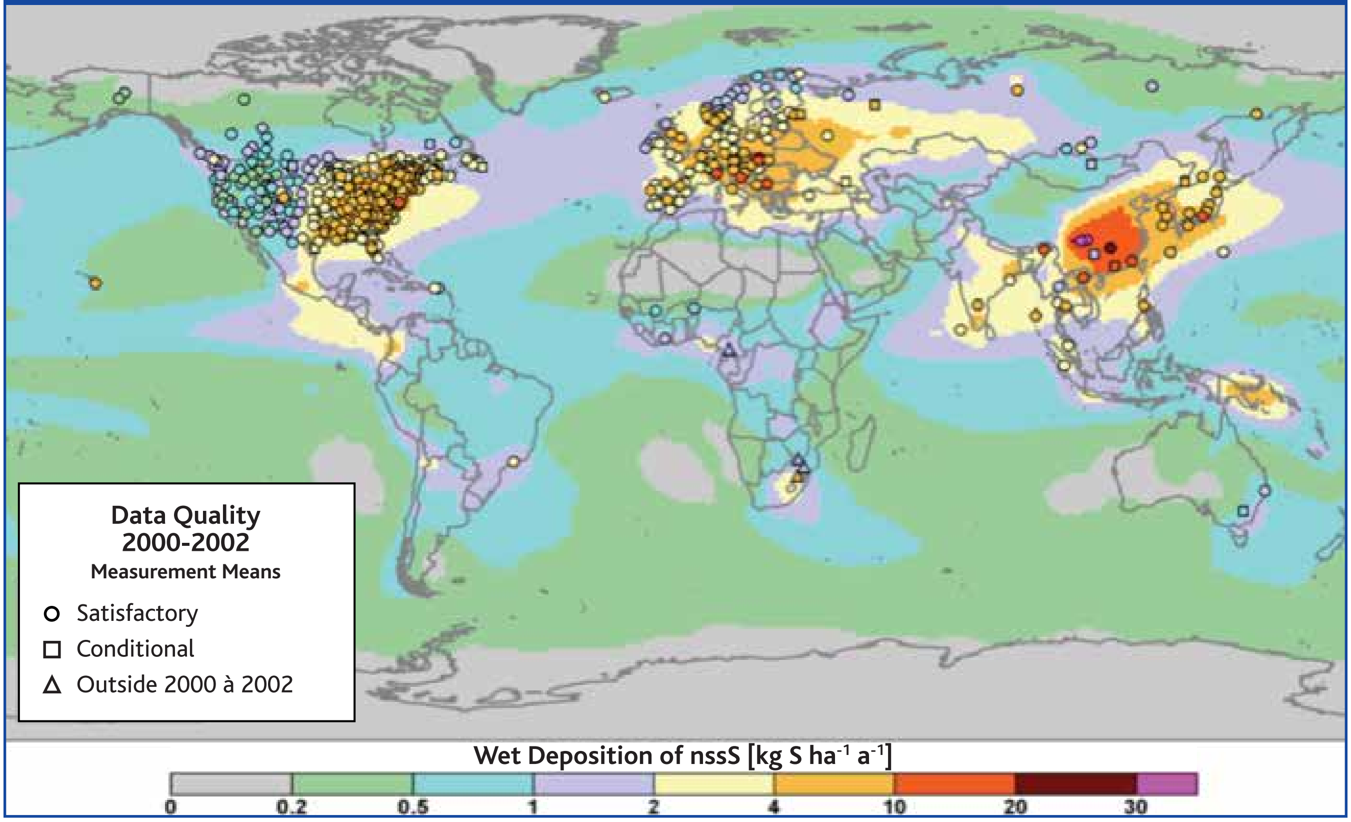
as well as to identify the major uncertainties and gaps in measurement programs and current scientific understanding.

This global assessment was based on worldwide measurement data and chemical transport modelling results provided by Phase 1 of the Coordinated Model Studies Activities of the United Nations Economic Commission for Europe's Task Force on Hemispheric Transport of Air Pollution (UNECE TF HTAP). The measurement data included wet and dry deposition results from the U.S. National Atmospheric Deposition Program, the U.S. Clean Air Status and Trends Network, the Canadian Air and Precipitation Monitoring Network, and a number of provincial networks in Canada. The broad geographical and chemical coverage of the assessment greatly expanded scientific understanding of U.S. and Canadian deposition relative to the rest of the world. Focusing on sulphur and nitrogen results, the assessment indicated that deposition in eastern North America has declined significantly due to SO_2 and NO_x emission regulations in Canada and the U.S. However, eastern North America continues to receive very high deposition of sulphur and nitrogen relative to the rest of the world, while western North America receives relatively low deposition. Gaps in deposition monitoring identified for North America include insufficient measurements in western and northern Canada, and incomplete nitrogen deposition measurements in both countries. Figure 36 shows a map from the assessment that illustrates the global pattern of non-sea-salt sulphate as sulphur wet deposition, based on combined measurement and modelling results.

Air Quality Model Evaluation International Initiative

The Air Quality Model Evaluation International Initiative (AQMEII) seeks to advance regional air quality modelling science through the development of a common model evaluation framework and joint evaluation and analysis of European and North American regional air quality models. AQMEII is coordinated by two chairs, one for North America and the other for Europe. It is supported by the European Commission's Joint Research Centre/Institute for Environment and Sustainability, Environment Canada and Environmental Protection Agency.

Figure 36. Measurement-model Wet Deposition of Non-sea-salt sulphate as sulphur (nssS) in kg S ha-^{1} a-^{1}



Note: Measurement values represent 3-year averages (2000-2002) of nssS; model results represent 2001 nssS values.

Source: (Vet et al. 2014).

Phase 1 of AQMEII, which concluded in 2011, included annual regional air quality simulations over North America and Europe for 2006 that allowed regional air quality models from those two areas to be compared for common long-term case studies. The key findings from AQMEII Phase 1 are summarized in a series of manuscripts published in *Atmospheric Environment* 53, 2012, and EM, the Air and Waste Management Association's magazine for environmental managers, July 2012.

Phase 2 of AQMEII began in 2012 to compare the "next generation" of air-quality models (which include feedback effects between weather and air pollution) to one other and to observations. Seventeen modelling groups from various governments and universities contributed to the effort. Emissions data for the North America simulations were contributed by the EPA and Environment Canada; the EPA is co-chair for AQMEII Phase 2 and is leading the development of a special issue of *Atmospheric Environment* to be published in 2015; Environment Canada is leading a paper comparing the performance of the models for both "feedback" and "non-feedback" simulations. This initiative is contributing to our understanding of the significance of air quality's effect on weather and to identifying strengths and weaknesses in the various air quality models developed by various agencies.

Tropospheric Ozone Monitoring of Pollution

Tropospheric Emissions: Monitoring of Pollution (TEMPO) is a satellite instrument funded by the U.S. National Aeronautics and Space Administration (NASA), scheduled for launch in 2019. TEMPO will provide observations several times per day of air pollutants over North America, from the Atlantic to the Pacific and from Mexico City to the Alberta oil sands region. TEMPO, the first air quality instrument to be placed in a geostationary orbit over North America, will provide unprecedented coverage and precision in observing important pollutants such as O_3, aerosols, NO_2, SO_2, formaldehyde and others. As such, TEMPO will be ideal for capturing rapidly varying emissions and chemistry, and will significantly enhance air quality monitoring and prediction capabilities.

Canada and the United States are members of the TEMPO science team. In the fall of 2013, the Government of Canada formed a Canadian TEMPO science team comprising leading Canadian scientists from government and academia, to contribute to and complement the objectives of the U.S. TEMPO science team, which comprises scientists from the EPA collaborating with NASA scientists as part of the DISCOVER-AQ research program to evaluate and enhance the capabilities of remote-sensing instruments that will be deployed in TEMPO.

SECTION 3:

NEW ACTIONS ON ACID RAIN, OZONE AND PARTICULATE MATTER

CANADA

Canada's AQMS is expected to reduce the emissions from all sources of air pollution in order to improve air quality. The three key elements of the AQMS include CAAQS, air zone management / regional airsheds (see Air Quality Standards described in Section 2), and Base-Level Industrial Emissions Requirements.

Base-Level Industrial Emissions Requirements

Emission standards were developed to address emissions from 13 industrial sectors, three types of industrial equipment, and cross-cutting requirements to address VOC emissions from hydrocarbon sources. On June 7, 2014, Canada published, for public comment, proposed Multi-Sector Air Pollutant Regulations (MSAPR) to limit emissions from stationary engines, industrial boilers and heaters, and cement manufacturing facilities, immediately followed by publication of Codes of Practice to limit emissions from the aluminum and iron and steel sectors. Canada is implementing additional emission requirements for the following industrial sectors (iron and steel, aluminum, pulp and paper, upstream oil and gas, chemicals and fertilizers, natural gas combustion turbines, potash, iron ore pellets, cement, oil sands, petroleum refineries and electricity) using regulatory and non-regulatory instruments in phases over the next few years. When implemented, they will ensure that all significant industrial sources in Canada, regardless of the air quality where facilities are located, meet a base level of environmental performance.

Multi-Sector Air Pollutants Regulations

The proposed MSAPR would reduce emissions of NO_X from new and existing industrial boilers and heaters and stationary spark-ignition engines, and NO_X and SO_2 emissions from the cement manufacturing sector. Implementation of the requirements would take place between 2015 and 2036. Across Canada, the MSAPR would lead to an estimated reduction of approximately two million tonnes of NO_X and 100 000 tonnes of SO_2 over the 20 year period. The proposed regulations would be amended in the future to include emission requirements for additional industrial sectors. Once fully implemented, industries will be required to reduce their emissions of particulate matter and/or NO_X, SO_2, VOCs, and ammonia which are precursor pollutants that contribute to PM and ozone.

Monitoring Downwind of Canada's Oil Sands

The oil sands deposits in western Canada are a major natural resource whose development necessitates a more comprehensive understanding of their potential cumulative environmental impact. In response to concerns on the impacts of oil sands activities and to ensure the resource is being developed in an environmentally responsible manner, the Government of Canada and Government of Alberta developed a joint plan to implement a world-class monitoring program in the oil sands region, known as the Joint Implementation Plan. It focuses on: air quality; water quantity and quality; aquatic ecosystem health; terrestrial biodiversity and habitat disturbance; and wildlife contaminants and toxicology.

The Plan provides additional ambient-air monitoring of SO_2 and NO_x, provides further information on SO_2 and NO_x deposition in western Canada, and contributes to the refining of aquatic and terrestrial critical loads downwind of the major oil sands activities. Modelling under the plan will document instances of transboundary transport of PM and O_3, including any long-range transport to the United States. The program is integrated across all components, and the data collected from the program add to Canada's monitoring commitments under the AQA.

In the first year of the three-year Implementation Plan (fiscal year 2012-13), existing air quality monitoring activities in the oil sands region were enhanced by the following activities:

- Refining estimates of emissions from development activities
- Distinguishing between oil sands–specific sources of emissions and other sources such as natural and long-range transported emissions
- Quantifying transport over a large spatial range from upwind sites to sites outside of Alberta
- Establishing approaches that quantify atmospheric transformation mechanisms
- Adding precision to mapping deposition patterns
- Integrating data into a predictive model that provides air quality and deposition data to water quality, acid-sensitive lakes, aquatic biota and wildlife components

Monitoring data are available on the Canada-Alberta Oil Sands Environmental Monitoring Information Portal at http://jointoilsandsmonitoring.ca/default.asp?n=5F73C7C9-1&lang=en. In addition, a summary of the key findings from the first year of implementation, the *Joint Canada-Alberta Implementation Plan for Oil Sands Monitoring First Annual Report: 2012-13*, is available at the Portal. Key findings from the annual report include the following:

- Atmospheric concentrations of NO_2 and SO_2 increase near the oil sands development areas, and are comparable to or less than concentrations typically found near coal-fired power plants, mining smelters, or metropolitan areas (e.g. Edmonton).
- Satellite observations from the period 2005–2010 show an enhancement of NO_2 over an area of intensive surface mining. Further analysis will be carried out to assess potential impact and relevance.

New Tier 3 Standards for On-Road Vehicles and Fuel

On June 8, 2013, Environment Canada published a notice in the *Canada Gazette*, Part I, to inform interested parties that the Government of Canada intends to further limit emissions of smog-forming air pollutants from new cars and light-duty trucks and to reduce the sulphur content of gasoline, in alignment with U.S. EPA's Tier 3 standards. Following preliminary consultations with interested parties, on September 27, 2014 Environment Canada published proposed amendments to the *On-Road Vehicle and Engine Emissions Regulations* (ORVEER) and to the *Sulphur in Gasoline Regulations* (SiGR) for a formal 75-day public comment period. The proposed amendments to the ORVEER would introduce more stringent air pollutant emission standards for new passenger cars, light-duty trucks, and certain heavy-duty vehicles such as delivery trucks, beginning with the 2017 model year. The proposed amendments to the SiGR would introduce lower limits for the sulphur content of gasoline beginning in 2017, to ensure the effective operation of advanced emission control technologies on 2017 and later model year vehicles. Lower levels of sulphur in gasoline would also reduce air pollutant emissions from the fleet of in-use vehicles. The proposed amendments to the two regulations align with the U.S. EPA's Tier 3 standards and would work in concert to reduce air pollutant emissions that result from the operation of vehicles.

UNITED STATES ★

Proposed Carbon Pollution Standards

Power plants are the largest individual sources of carbon pollution in the United States, and currently there are no uniform national limits on the amount of carbon pollution that future power plants will be allowed to emit. Consistent with the U.S. Supreme Court's decision, in 2009 the EPA determined that GHG emissions lead to long-lasting changes in the climate that can have a range of negative effects on human health and the environment. Reducing power-sector CO_2 would result in reductions of SO_2 and NO_x emissions, which in turn would lower overall ambient concentrations of $PM_{2.5}$ and O_3.

Standards for New Power Plants

On September 20, 2013, the EPA issued a new proposal for carbon pollution from new power plants. After considering more than 2.5 million comments from the public about the original 2012 proposal and considering recent trends in the power sector, the EPA changed certain aspects of its approach, and now has proposed to set separate standards for certain natural gas–fired stationary combustion turbines and for fossil fuel–fired utility boilers and integrated gasification combined cycle units.

Standards for Existing Power Plants

On June 2, 2014, the EPA proposed the Clean Power Plan to cut carbon pollution from existing power plants. The Plan will be implemented through a state-federal partnership, under which states identify a path forward using pollution control policies for existing power plants in order to meet the Plan's goals. The proposal provides guidelines for states to develop plans to meet state-specific goals to reduce carbon pollution, and provides them with the flexibility to design a program that makes the most sense for their unique situation. States can choose the right mix of generation using diverse fuels, energy efficiency and demand-side management in order to meet the Plan's goals and their own needs. It allows them to work alone to develop individual plans or work together with other states to develop multi-state plans. The Clean Power Plan puts the United States on track to cut carbon pollution from the power sector by 30 percent as of 2030.

CONCLUSION

Canada and the United States continue to successfully meet their commitments set forth in the 1991 Air Quality Agreement. While the initial focus of the AQA was on reducing emissions of SO_2 and NO_x, the major contributors to acid rain, the two countries expanded their efforts to cooperatively address transboundary issues such as ground-level O_3 and PM. The Ozone Annex, added to the Agreement in 2000, committed both countries to reducing emissions of NO_x and VOCs, the precursors to ground-level ozone—a key component of smog. Considerable progress has been made to address transboundary O_3 pollution in the eastern border regions of each country.

In recent years, both countries undertook joint scientific and technical analyses to assess the transboundary transport of PM and precursor emissions to inform the consideration of whether to add an annex to the AQA in order to address PM. The results of these joint analyses are reported in the 2013 Transboundary Particulate Matter Science Assessment, the findings of which do not support adding a PM annex to the Agreement at this time. However, $PM_{2.5}$ remains a significant concern for both countries due to the potential risks to public health and ecosystems. The two countries will continue to monitor and evaluate $PM_{2.5}$, particularly in border areas, and will continue to develop and implement emission reduction programs to reduce $PM_{2.5}$ concentrations.

Both countries recognize that continued cooperative effort is necessary to address the ongoing health and environmental effects associated with acid rain and smog. The AQA provides a formal and flexible method for addressing transboundary air pollution and continues to provide a framework under which the two countries can cooperate on ongoing and future air quality issues.

APPENDIX A

CANADA–UNITED STATES AIR QUALITY COMMITTEE

Canadian Members

Canada Co-Chair:

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Assistant Deputy Minister
Environmental Stewardship Branch
Environment Canada

Members:

Yayne-abeba Aklilu
Air Policy Section
Alberta Environment and Sustainable Resource Development

Ellen Burack
Environmental Policy
Transport Canada

Karen Clark
Air, Policy and Climate Change Branch
Ontario Ministry of the Environment and Climate Change

John Cooper
Water, Air and Climate Change Bureau
Safe Environments Directorate
Health Canada

France Delisle
Direction des politiques de la qualité de l'atmosphère
Ministère du Développement durable, Environnement et Lutte contre les changements climatiques

David Henry
Energy and Environment Policy Division
Energy Policy Branch
Natural Resources Canada

Louise Métivier
Industrial Sectors Directorate
Environmental Stewardship Branch
Environment Canada

Glen Okrainetz
Environmental Standards Branch
British Columbia Ministry of Environment

Catherine Stewart
Americas Directorate
International Affairs Branch
Environment Canada

Sing-En Tam
Foreign Affairs
Trade and Development Canada

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Director General
Industrial Sectors Directorate
Environmental Stewardship Branch
Environment Canada

Subcommittee on Scientific Cooperation Co-Chair:

Cathy Banic
Executive Director
Air Quality Research Division
Science and Technology Branch
Environment Canada

United States Members

United States Co-Chair:

Daniel Reifsnyder
Deputy Assistant Secretary for Environment
U.S. Department of State

Members:

Ann Acheson
U.S. Forest Service
Department of Agriculture

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Air Resources Laboratory
National Oceanic and Atmospheric Administration

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Department of Energy

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Office of Atmospheric Programs
U.S. Environmental Protection Agency

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David Shaw
Division of Air Resources
New York State Department of Environmental
Conservation

George Sibley
Office of Environmental Quality and
Transboundary Issues
U.S. Department of State

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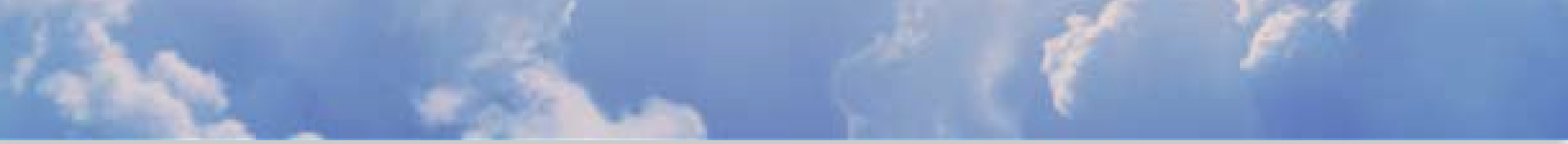
Sarah Dunham
Director, Office of Atmospheric Programs
U.S. Environmental Protection Agency

Subcommittee on Scientific Cooperation Co-Chair:

Timothy H. Watkins
Deputy Director
Human Exposure and Atmospheric Sciences Division
Office of Research and Development, U.S.
Environmental Protection Agency



APPENDIX B

LIST OF ACRONYMS

AIRMoN	Atmospheric Integrated Research Monitoring Network
AMoN	Ammonia Monitoring Network
ANC	acid-neutralizing capacity
ARP	Acid Rain Program
AQA	Air Quality Agreement
AQI	Air Quality Index
AQMEII	Air Quality Model Evaluation International Initiative
AQMS	Air Quality Management System
AQS	(EPA) Air Quality System
BACT	best available control technology
BART	best available retrofit technology
BCVCC	British Columbia Visibility Coordinating Committee
Bc:Al	base cation to aluminum ratio
Bkd	background
Ca^{2+}	calcium ions
CAA	Clean Air Act
CAAQS	Canadian Ambient Air Quality Standards
CAIR	Clean Air Interstate Rule
CAPMoN	Canadian Air and Precipitation Monitoring Network
CASTNET	Clean Air Status and Trends Network
CDDs	chlorinated dibenzo-p-dioxins
CDFs	furans
CEM	continuous emissions monitoring
CEMS	continuous emissions monitoring system
CEPA 1999	*Canadian Environmental Protection Act, 1999*
CI	continuous improvement
Cl-	chlorine
CO	carbon monoxide
CO_2	carbon dioxide
CSAPR	Cross-State Air Pollution Rule
CSN	$PM_{2.5}$ Chemical Speciation Network
CWS	Canada-wide Standards
D.C.	District of Columbia
DOC	dissolved organic carbon
DOT	Department of Transportation
ECA	Emission Control Area
EGU	electric generating unit
EPA	Environmental Protection Agency
Eq/ha/yr	equivalents per hectare per year
FIPs	Federal Implementation Plans
GHG	greenhouse gas
H^+	hydrogen ion
HAPs	hazardous air pollutants
Hg	mercury
HNO_3	nitric acid
IJC	International Joint Commission
IMPROVE	Interagency Monitoring of Protected Visual Environments
ISA	Integrated Science Assessment
K^+	potassium ion
KCAC	Keeping Clean Areas Clean
kg/ha/yr	kilograms per hectare per year
kW	kilowatts
LAER	lowest achievable emission rate
LFV	Lower Fraser Valley
LTM	Long-Term Monitoring

APPENDIX B: LIST OF ACRONYMS

Mg^{2+}	magnesium ion
mg/kg	milligrams per kilogram
MW	megawatt
Na+	sodium ion
NAA	Non-attainment area
NAAQ	National Ambient Air Quality Standards
NADP	National Atmospheric Deposition Program
NAPS	National Air Pollution Surveillance
NAtChem	National Atmospheric Chemistry Database
NATTS	National Air Toxics Trends Stations
NBP	Budget Trading Program
NCore	National Core Monitoring Network
NEI	National Emissions Inventory
NH_3	ammonia
NH^{4+}	ammonium
NHTSA	National Highway Traffic Safety Administration
NO	nitrogen monoxide
NO_2	nitrogen dioxide
NO_3	nitrate
NO_x	nitrogen oxides
NO_y	total reactive nitrogen
NOAA	National Oceanic and Atmospheric Administration
NPRI	National Pollutant Release Inventory
NPS	National Park Service
NSPS	New Source Performance Standards
NSR	New Source Review
NTN	National Trends Network
OBD	on-board diagnostic
OPG	Ontario Power Generation
O_3	ground-level ozone
OTC	Ozone Transport Commission
PAH	polycyclic aromatic hydrocarbon
PAMS	Photochemical Assessment Monitoring Stations

Pb	lead
PCB	polychlorinated biphenyl
PEMA	Pollutant Emission Management Area
PERC	tetrachloroethylene
PFC	portable fuel container
pH	measure of the activity of the solvated hydrogen ion
PM	particulate matter
$PM_{2.5}$	particulate matter less than or equal to 2.5 microns
PM_{10}	particulate matter less than or equal to 10 microns
ppb	parts per billion
ppm	parts per million
PSD	Prevention of Significant Deterioration
REA	Risk and Exposure Assessment
SIP	State Implementation Plan
SLAMS	State and Local Air Monitoring Stations
SMB	simple mass balance
SO_x	sulphur oxide
SO_2	sulphur dioxide
SO_4^{2-}	sulphate
SSWC	steady-state water chemistry
TCE	trichloroethylene
TEMPO	Tropospheric Emissions: Monitoring of Pollution
TIME	Temporally Integrated Monitoring of Ecosystems
µeq/L	micro-equivalents per litre
$\mu g/m_3$	micrograms per cubic metre
UNECE	United Nations Economic Commission for Europe
VOCs	volatile organic compounds

To obtain additional information, please contact:

In Canada
Air Emissions Priorities
Environment Canada
351 St. Joseph Blvd.
19th Floor, Place Vincent Massey
Gatineau, Quebec K1A 0H3

In United States:
Clean Air Markets Division
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, NW (6204J)
Washington, DC 20460

Environment Canada's website:
www.ec.gc.ca/Air/default.asp?lang=En&n=83930AC3-1

U.S. Environmental Protection Agency's website:
www.epa.gov/airmarkets/progsregs/usca/index.htm