Air Pollution Series

Actions on Air Quality in North America

Canadian and U.S. Policies and Programmes to Reduce Air Pollution

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List of abbreviations and acronyms

AQA	Canada–United States Air Quality Agreement
AQBAT	Air Quality Benefits Assessment Tool
AQM	air quality management
AQMS	Canada-wide Air Quality Management System
AZMF	Air Zone Management Framework
BTEX	benzene, toluene, ethylbenzene and xylene
CAA	Clean Air Act (United States of America)
CAAQS	Canadian Ambient Air Quality Standards
CAPMoN	Canadian Air and Precipitation Monitoring Network
CAPP	Community Air Protection Program
CARB	California Air Resources Board
CEC	Commission for Environmental Cooperation
CEPA	Canadian Environmental Protection Act
CH_4	methane
CIPEC	Canadian Industry Partnership for Energy Conservation
CO	carbon monoxide
CO_2	carbon dioxide
CSN	Chemical Speciation Network
CTI	Cleaner Trucks Initiative (United States of America)
DERA	Diesel Emissions Reduction Act
DIMAQ	Data Integration Model for Air Quality
ECA	Emissions Control Area
ECCC	Environment and Climate Change Canada
GAPS	Global Atmosphere Passive Sampling
GBD	Global Burden of Disease project
GDP	gross domestic product
GHG	greenhouse gas
ICAO	International Civil Aviation Organization
IHME	Institute for Health Metrics and Evaluation
IMO	International Maritime Organization
IMPROVE	Interagency Monitoring of Protected Visual Environments
MACT	Maximum Achievable Control Technology
MOAG	Michigan–Ontario Air Working Group
MOOSE	Michigan-Ontario Ozone Source Experiment
MSAPR	Multi-Sector Air Pollutants Regulations
NAAEC	North American Agreement on Environmental Cooperation
NAAQS	National Ambient Air Quality Standards
NAPS	Canada's National Air Pollution Surveillance
NATA	National Air Toxics Assessment
NCore	National Core (network for criteria pollutant monitoring)
NH_3	ammonia
NO_2	nitrogen dioxide
NO_x	nitrogen oxides

O_3	ozone
PAMS	Photochemical Assessment Monitoring Station
PEMA	Pollutant Emission Management Area
PEMS	portable emissions measurement systems
PM_{10}	fine particulate matter with an aerodynamic diameter of less than 10 microns
$PM_{2.5}$	fine particulate matter with an aerodynamic diameter less than 2.5 microns
POPs	persistent organic pollutants
PRTR	North American Pollutant Release and Transfer Register
RCRA	Resource Conservation and Recovery Act
SAFE	Safer Affordable Fuel-Efficient Vehicles
SCR	selective catalytic reduction
SLAMs	State and Local Air Monitoring Stations
SO_2	sulphur dioxide
SO_x	sulphur oxides
sVOC	semi-volatile organic compounds
U.S.	United States of America
U.S. EPA	United States Environmental Protection Agency
UNEA	United Nations Environment Assembly
UNEP	United Nations Environment Programme
USDA	United States Department of Agriculture
VOC	volatile organic compounds
WBCSD	World Business Council for Sustainable Development
WHO	World Health Organization
ZEV	zero emission vehicle

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Executive summary

In North America,[1] air pollution remains a serious health risk despite the large improvements in air quality that have been achieved by regulatory measures implemented under the Canadian Environmental Protection Act (CEPA) and the U.S. Clean Air Act (CAA). In addition, disparities in air pollution exposure by socioeconomic status persist and the burden of disease attributable to air pollution in North America is significant.

This report provides a review of policy actions of Canada and the United States of America per the mandate provided by United Nations Environment Assembly (UNEA) resolution 3/8 on *Preventing and reducing air pollution to improve air quality globally*. This report builds on the United Nations Environment Programme (UNEP) report Actions on Air Quality 2021, which was recently released to provide an update on actions undertaken by countries around the world, focusing on a set of measures that, if adopted, would significantly improve air quality. This North American regional report documents more in-depth actions in key sectors as well as regional trends and priorities.

Both countries in the region have made great progress towards reducing air pollution through air quality management planning. Effective air quality management has occurred following decades of sustained effort due to the extraordinary level of technical and scientific information needed to establish effects-based standards, measure key pollutants, inventory sources and their emissions, develop and estimate costs for alternative control scenarios, and forecast and assess results. Underpinning these efforts are legislative and regulatory frameworks that mandate careful monitoring and establish accountability through airshed management approaches that result in continuous improvement and reduced exposure over time. Although Canada and the United States of America have different approaches to achieve these goals, both systems have resulted in a long-term reduction in exposure for their populations.

Despite this progress, more work is needed to reduce the negative health and environmental impacts of air pollution. Emissions of most major air pollutants have declined over decades, but progress is uneven for some pollutants and has been difficult to maintain as levels have been reduced overall. The increased frequency and severity of wildfires associated with climate change is also a major source of intermittent emissions in both countries, posing substantial management challenges. According to the most recently available data, approximately 3 out of 10 Canadians and Americans live in areas where one or more of their respective ambient air quality standards are not met.

This report provides an overview of the legislative and management structures that are in place in the North America region, along with a more detailed assessment of how those structures are implemented in each of five key sectors (industrial emissions, vehicles and transport, waste management, indoor air quality and agriculture), analysing how these programmes have evolved over time. These sectors were selected to align with the UNEP global report, providing insight into how each of these key sectors is being addressed in each region. The report also assesses progress since the last Actions on Air Quality report (2016) in North America by reviewing recent progress in each of the key sectors as well as integrated strategies that are not specific to any one sector.

This report also includes a number of case studies, including one that focuses specifically on the unique role of international collaboration in the region to tackle some of the most problematic but common air quality challenges that span state, provincial, territorial and international borders. Another case study explores the role of subnational action in supporting and sometimes exceeding federal actions to improve air quality and address climate change. A pair of case studies examine the importance of environmental justice from two perspectives. The first analyses recent trends to determine how lower-income, minority and marginalized populations experience higher exposure levels and associated health impacts in both countries, before reviewing state and national efforts to address such disparities, while the second explores how neighbourhood monitoring can improve understandings of disparities. The last case study examines how both countries have supported action in the agriculture sector to simultaneously address air pollution and climate change through support and financing of manure management approaches based on biodigesters.

The information surveyed and assessed for this report have led to several key findings, including on the role of ambient air quality standards with widespread monitoring as a foundational accountability framework for air quality management planning. Clear air quality standards (whether at the national, provincial/territorial or state levels) and widespread and routine air quality monitoring are crucial in understanding where air quality action is required. They can also, in part, address environmental inequalities, since addressing "non-attainment" conditions (when the standards are not met) is a key element of the environmental

1. Throughout this report, the term "North America" is used to refer to the two countries of UNEP's North America region – Canada and the United States of America.

justice action agenda to reduce disproportionately high and adverse human health or environmental effects on minority and low-income populations, wherever they may be. Declaration of non-attainment status triggers further interventions in those areas.

Air pollution does not respect political boundaries, giving rise to the need for regional cooperation. The combined contribution of many dispersed emission sources can be as important as – or sometimes more important than – the contribution of local emission sources for maintaining clean air. Thus, while it is crucial for any jurisdiction to understand and regulate emissions within its boundaries, it is also important to work collaboratively with neighbouring jurisdictions whose emissions may contribute to local non-attainment or whose non-attainment (downwind) may be in part attributable to local emissions.

Iterative review and refinement of air quality management programmes are key to long-term progress and the improvement of air quality in an equitable and effective manner. Air quality monitoring must be continually used in conjunction with air quality modelling to track progress and identify whether programme goals are being achieved. If not, standards can then be strengthened, additional areas of non-attainment can be identified, and additional regulatory programmes can be developed where needed to ensure that the specific source categories or specific geographical areas reduce emissions necessary to achieving standards. In the North America region, this has included many specialized programmes to address specific issues that have been identified over time (such as acid rain, visibility, air toxics and marine emissions).

The structure of air quality management frameworks in the North America region have provided sustained and long-term air pollution reductions despite the routine change in political administrations and governing philosophies. By embedding standards in legal instruments that require action when standards are not met, North American air quality planning has demonstrated significant resilience in the face of changing political parties or popular sentiment regarding environmental regulation.

Stakeholder engagement should focus on shared, reliable data (disaggregated by sex where relevant) and an understanding of tools. Public processes should begin with an agreement on the data and tools to be used for policy assessment. To build trust, ownership and a sense of shared responsibility, it is crucial that citizens, cities, states/provinces and federal agencies establish buy-in to the assessment methods and processes with their industry and public stakeholders. A process utilizing a multi-level governance approach will enable solutions that address air and climate pollution in both a horizontally (cross-sectoral) and vertically (federal, state/provincial and local governments) integrated framework. Active engagement of federal and local officials, as well as across ministries, affected industries and civil society organization representing the public interest, is essential.

Both Canada and the United States of America have framed air quality as one element of larger efforts towards sustainability. The United Nations Sustainable Development Goals (SDGs) include many targets related to air quality, including air quality indicator 11.6.2 on population-weighted annual mean levels of fine particulate matter ($PM_{2.5}$). However, many of the other goals, targets and indicators relate to and depend on integrated planning efforts that can not only deliver improved air quality, but also mitigate climate change, improve public health, enhance resilience and preserve ecosystems. Integrated climate and air quality planning efforts should therefore place a special emphasis on reduction targets for both $PM_{2.5}$ and greenhouse gases (GHGs).

Prioritizing short-lived climate pollutants, i.e. the black carbon component of $PM_{2.5}$ and ground-level ozone (O_3) (to ensure that policies targeting health benefits skew towards those with additional climate benefits) along with the methane (CH_4)/short-lived hydrofluorocarbon (HFC) component of GHG emissions reductions (to ensure that climate policies skew towards those with additional health benefits through ground-level O_3 formation and near-term climate stabilization, while remaining focused on long-term carbon dioxide (CO_2) targets) can protect public health and deliver multiple benefits simultaneously.

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In North America, **air pollution remains a serious health risk** **despite the large improvements** in air quality that have been achieved by regulatory measures.

Air quality and health risks in North America

Air pollution[1] is the single greatest environmental risk to human health and one of the main avoidable causes of death and disease globally. More than 90 per cent of the world's population lives in areas that exceed the World Health Organization (WHO) guideline for healthy air. Global estimates of the burden of disease associated with air pollution are based on WHO's Data Integration Model for Air Quality (DIMAQ) (WHO 2018a) and the Global Burden of Disease (GBD) process, led by the Institute for Health Metrics and Evaluation (IHME). Ambient air pollution was estimated to cause 4.2 million premature deaths worldwide in 2016 (Ibid.), with the GBD even higher in a more recent estimate in 2019, at 6.67 million premature deaths (Health Effects Institute 2020). This places air pollution as the fourth highest risk for death overall after high blood pressure, tobacco and dietary risks (Ibid.).

In North America,[2] air pollution remains a serious health risk despite the large improvements in air quality that have been achieved by regulatory measures implemented under the Canadian Environmental Protection Act (CEPA) and the U.S. Clean Air Act (CAA), as well as measures put in place by subnational jurisdictions within the region. As a result of this legislation and the significant investment of time and resources in policies to address the serious consequences of air pollution, it is only the third highest environmental/occupational risk in Canada and the United States of America, which is lower than the comparable global statistic. The rate of deaths in Canada and the United States of America are 5.35 and 8.49 deaths per 100,000, respectively, compared with 52.7 deaths per 100,000 globally (Ibid.). This difference explains why only 9 per cent of the global deaths attributable to air pollution occurred in high-income countries, such as Canada or the United States of America (WHO 2018d). However, disparities in air pollution exposure by socioeconomic status persist (Colmer *et al.* 2020) and the burden of disease attributable to air pollution in North America is significant.

Air pollution also has gender-differentiated health impacts Research from the Organisation for Economic Co-operation and Development (OECD) (2020) revealed that more men than women were likely to die from ambient and occupational air pollution in developed countries, while globally women are more likely to die from indoor pollution from air and unsafe water. These deaths are strongly linked to gender roles, and the welfare costs associated with these deaths are considerable (OECD 2020).

Global data indicate that ambient (outdoor) air pollution – including fine particulate matter ($PM_{2.5}$) and ground-level ozone (O_3) – leads to an estimated 96,000 (WHO 2018d) or 64,600 (Health Effects Institute 2020) premature deaths each year in North America[3] Of these deaths, approximately 95,000 (WHO 2018b) or 52,000 (Health Effects Institute 2020) are associated with $PM_{2.5}$.

These global statistics are likely to underrepresent the true burden associated with premature mortality, as they do not include additional pollutants and health outcomes that scientific evidence indicates could be causally associated with such mortality (for example, nitrogen dioxide (NO_2) air pollution and paediatric asthma incidence; Achakulwisut *et al.* 2019). For example, a more detailed analysis by Health Canada that includes NO_2, $PM_{2.5}$ and O_3, and uses Canadian-specific concentration response functions, estimated 14,600 deaths per year in Canada (Health Canada 2019a), which is almost double the GBD estimate. Differences are driven by different data inputs and methods, including the choice of a low concentration cut-off, below which health impacts are not calculated. Studies estimating $PM_{2.5}$ mortality burdens for the United States of America indicate a range of approximately 100,000–200,000 premature deaths attributable to $PM_{2.5}$ per year, depending largely on the year, whether all $PM_{2.5}$ or only anthropogenic $PM_{2.5}$ were included, and the risk functions used (Bowe *et al.* 2019; Fann *et al.* 2018; Thakrar *et al.* 2020; Vodonos and Schwartz 2021). Bowe *et al.* (2019) also found that underlying socioeconomic and racial disparities are significant factors in rates of $PM_{2.5}$-related disease.

Similarly, global statistics are likely to undercount the 2,000 (WHO 2018c) or 160 (Health Effects Institute 2020) estimated premature deaths in North America that are attributable to household air pollution (i.e. emissions in or near the home due to residential biomass burning).[4] These estimates are based on the number of homes that use biomass as cooking fuel, which is a much more common practice globally, and may undercount the number of North American home that use biomass fuels

Canadian wildfires turn the sun a bright red hue over Toronto, with hazy skies.
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in fireplaces or woodstoves for heating. Other recent estimates find that up to 9,200 premature deaths may be attributable to residential wood burning for heating in high-income North American households (WHO 2015).

In contrast to many other areas of the world, ground-level O_3 is a larger concern in North America than household air pollution, and leads to more than 13,000 premature deaths each year across the region (Health Effects Institute 2020).

The gender-related aspects of air pollution also need to be further investigated. Emerging evidence (and in some cases strong evidence) links air pollution to adverse pregnancy outcomes for women, leading to preterm births and low birth weights (Trasande, Malecha and Attina 2016; WHO 2016). The majority of 62 studies using searches of bibliographic databases and reference lists of relevant papers showed increased risks of low birth weight following exposure to carbon monoxide (CO), nitrogen dioxide (NO_2), and particulate matter less than 10 and 2.5 microns (Stieb *et al.* 2012). However, further research is required in this area for more conclusive results.

In addition to serious public health consequences, air pollution has a significant impact on human welfare and economic activity. In 2011, the United States Environmental Protection Agency (U.S. EPA) estimated that by 2020, air pollution controls implemented under the 1990 CAA Amendments would result in combined quantified benefits (i.e. the value of avoided premature mortality and morbidity from $PM_{2.5}$ and O_3 and avoided loss of ecosystem services including visibility) valued at approximately USD 2 trillion, representing a 30:1 benefit to cost ratio (U.S. EPA 2011; United Nations Environment Programme [UNEP] 2016a).

Recognizing the growing global threat of air pollution, the United Nations Environment Assembly (UNEA) adopted resolution 1/7 on *Strengthening the role of the United Nations Environment Programme in promoting air quality* in June 2014. The third session of UNEA built on this commitment through UNEA resolution 3/8 requesting, in its paragraph 7(j), that UNEP "undertake an assessment of progress being made by Member States to adopt and implement key actions that can significantly improve air quality, in time for UNEA 5 and thereafter, synchronized with the Global Environment Outlook cycle." The 2016 report *Actions on Air Quality* (UNEP 2016b) presented results at that time in an online catalogue of 193 countries. UNEP has since developed an updated global assessment of policy action. To develop the global report, UNEP conducted a survey of Member States, the results of which are complemented by six regional reports covering Africa, Asia and the Pacific, Latin America and the Caribbean, Europe, North America (this report) and West Asia. Each regional report includes national-level case studies which capture actions happening at the global, regional and national levels. This regional report builds on that effort to document the status of key actions being undertaken by the Canadian and U.S. governments to improve air quality and the significant public health, environmental and economic benefits that have resulted.

Chapter 1 Endnotes

1. Air pollution encompasses a large number of gases and particles emitted into the air, each of which may have different and varied health effects. Given the significant burden of disease associated with $PM_{2.5}$ and ground-level O_3, there is greater information available on these forms of air pollution globally. However, in North America, both Canada and the United States of America have various programmes that address many different pollutants, as described further in this report.

2. Throughout this report, the term "North America" is used to refer to the two countries of UNEP's North America region – Canada and the United States of America.

3. This burden listed is due to ambient concentrations of fine particulate matter with a diameter of 2.5 micrometres or smaller (i.e. fine particle pollution). This represents the vast majority (approximately 92 per cent) of the burden currently estimated for all air pollution. Ground-level O_3 contributes a significantly smaller burden (around 8 per cent). These studies consider six primary causes of death associated with air pollution. Other air pollutants contribute to the burden of disease but are not assessed in global statistics that are readily available.

4. While the acronym HAP is used globally to refer to household air pollution in the context of residential solid biomass combustion for cooking and/or heating, North American air quality professionals use the acronym to refer to hazardous air pollutants or "air toxics". To avoid confusion, this report does not use the HAP acronym and uses the term air toxics to refer to hazardous air pollutants.

Both countries in the region **have made great progress** towards **reducing air pollution** by establishing air quality management planning.

Regional status of air quality policy

UNEP's North America region comprises two countries: Canada and the United States of America. In both countries, environmental management is a shared responsibility between the federal government and provincial/territorial (Canada) and state (United States of America) governments. Information from air quality monitoring stations across the region indicates that air quality has generally improved significantly over the last few decades as described in this chapter, though it remains an issue of concern for environmental quality and public health. Exceedances of legal or recommended maximum values in certain places still occur, especially for particulate matter (during wintertime and – increasingly – during the wildfire season, although many fire-related exceedances qualify as "exceptional events" and may be excluded from attainment designations) and O_3 (in summer months). In some cases, this is because environmental standards have been tightened over time as scientific reviews have indicated that more stringent standards are warranted to protect public health or the environment. Thus, exceeding a standard does not necessarily indicate that air quality has not improved over time. This chapter provides context for air pollution issues in the region, presents the key sources and policy approaches within each sector, and the trends in air pollution regulation more broadly.

a. Background

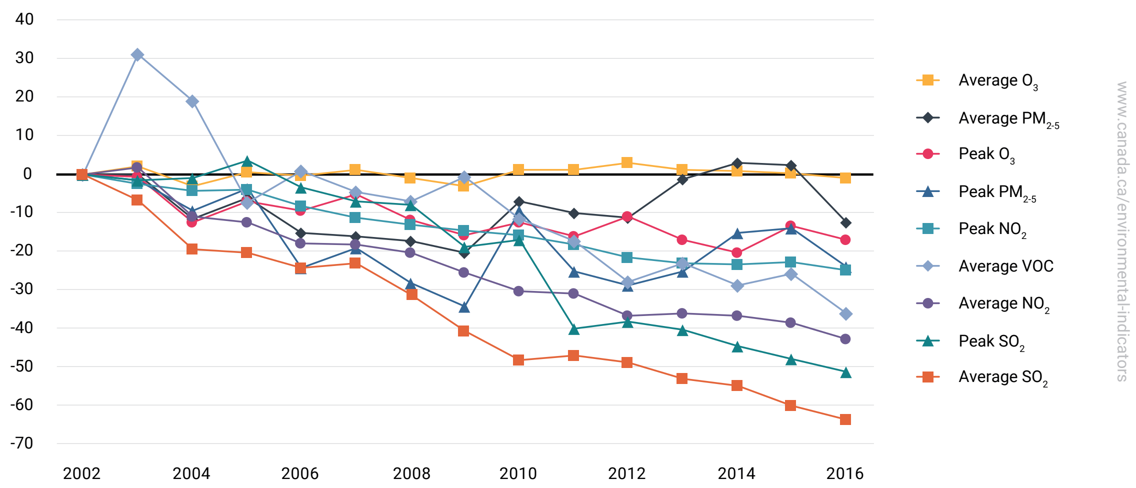
Both countries in the region have made great progress towards reducing air pollution by establishing air quality management planning. Effective air quality management has occurred following decades of sustained effort due to the extraordinary level of technical and scientific information needed to establish effects-based standards, measure key pollutants, inventory sources and their emissions, develop and estimate costs for alternative control scenarios, and forecast and assess results. Underpinning these efforts are legislative and regulatory frameworks that mandate careful monitoring and establish accountability through airshed management approaches that result in continuous improvement and reduced exposure over time. Although Canada and the United States of America have different approaches to achieve these goals, both systems have resulted in a long-term reduction in exposure for their populations. Despite this progress, more work is needed to reduce the negative health and environmental impacts of air pollution. Emissions of most major air pollutants have declined over decades, but progress is uneven for some pollutants and progress has been difficult to maintain as levels have been reduced overall.

In Canada, in 2018, emissions of sulphur oxides (SO_x), nitrogen oxides (NO_x), volatile organic compounds (VOCs), carbon monoxide (CO) and $PM_{2.5}$ from anthropogenic sources ranged from 73 per cent lower (SO_x) to 11 per cent lower ($PM_{2.5}$) than in 1990 (Environment and Climate Change Canada [ECCC] 2021a). Emissions of ammonia (NH_3) increased by 25 per cent (Ibid.). The federal government, including Environment and Climate Change Canada and Transport Canada, implements measures to address emissions of air pollutants from industrial and transportation sources and consumer and commercial products. Environment and Climate Change Canada and Health Canada set the ambient air quality objectives and standards in coordination with provincial and territorial governments, which then implement these through a wide range of environmental management tools. Provinces and territories also set their own emission and air quality standards and guidelines for an expanded number of pollutants.

In addition, Canada has put in place the Air Quality Management System (AQMS). The AQMS is a Canada-wide approach for reducing air pollution and is the product of an unprecedented collaboration by the federal, provincial and territorial governments and stakeholders.[1] The system is implemented by federal, provincial and territorial governments, each with clear roles and responsibilities. Canada's National Air Pollution Surveillance (NAPS) network has tracked ambient pollution in populated areas of the country since 1970. Since monitoring began in 1990, NAPS has recorded a decrease in lead of 97 per cent, SO_2 of 96 per cent, particulate matter of 50 per cent and a significant decrease in VOCs (ECCC 2020b[2]). Figure 1 shows the trends in peak and annual average ambient concentrations of several pollutants for 2002–2016, during which time, average and peak SO_2 concentrations decreased by 64 per cent and 52 per cent, respectively. Although annual average O_3 concentrations have not changed, peak O_3 concentrations decreased by 17 per cent. Average $PM_{2.5}$ concentrations fluctuated between years, while the peak concentration in 2016 was 24 per cent lower than in 2002. Average and peak NO_2 concentrations were 43 per cent and 25 per cent lower, respectively, in 2016 than in 2002. In 2016, the average VOC concentration was 36 per cent lower than the 2002 level. Despite this progress, exceedances of the Canadian Ambient Air Quality Standards (CAAQS) continue to occur in some communities across Canada. Based on data from 2016 to 2018, 32 per cent of Canadians live in areas where one or more of the CAAQS are exceeded (ECCC 2021b).[3]

Emissions of most major air pollutants have declined over decades, but progress is uneven for some pollutants.

Figure 1. Trends in air pollution concentrations across populated regions of Canada between 2002 and 2016

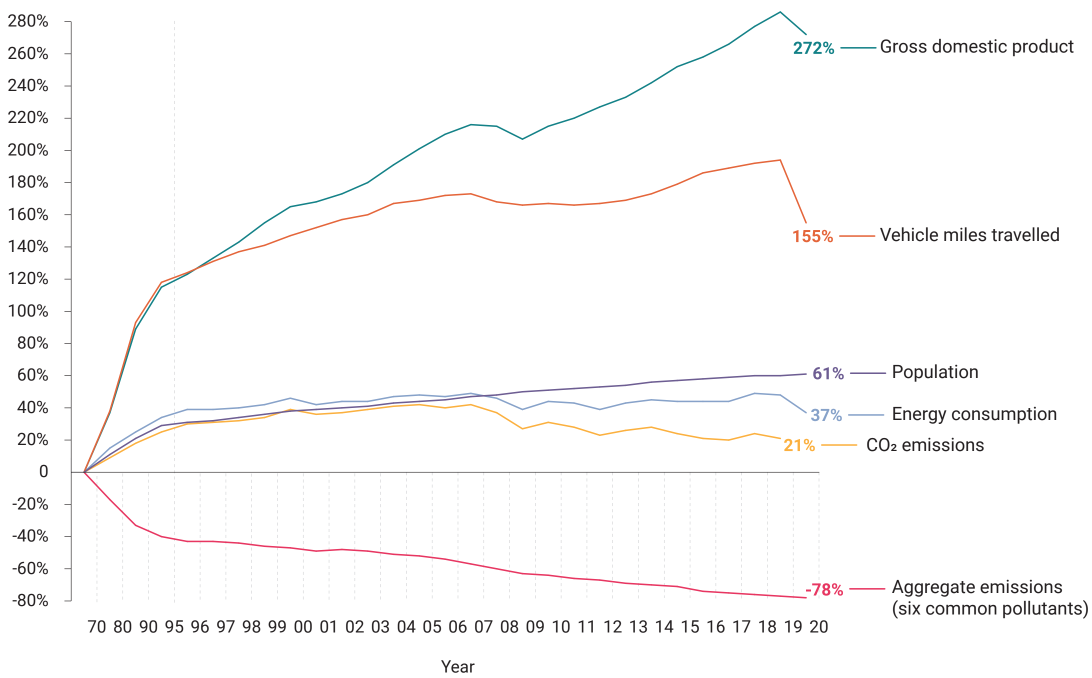


Source: ECCC (2021c).

In the United States of America, 2020 represented the fiftieth anniversary of the establishment of U.S. EPA[4] and the 1970 CAA. From 1970 to 2020, aggregate national emissions of the six common[5] pollutants alone declined 78 per cent on average, while gross domestic product (GDP) grew by 272 per cent. This progress reflects efforts by state, local and tribal governments, U.S. EPA, private sector companies, environmental groups and others (U.S. EPA 2020). The emissions reductions have led to dramatic improvements in air quality in the United States of America. Between 1990 and 2020, national concentrations of air pollutants declined 86 per cent for lead, 73 per cent for CO, 91 per cent for sulphur dioxide (SO_2) (1-hour), 61 per cent for NO_2 (annual) and 25 per cent for O_3. $PM_{2.5}$ concentrations (24-hour) declined by 30 per cent and coarse particle concentrations (24-hour) by 26 per cent between 2000 – when the observation record started for $PM_{2.5}$ – and 2020 (U.S. EPA 2021a).

As Figure 2 shows, these large emission reductions occurred despite a significant increase in population and economic growth and consequent increases in energy and transportation demand. Total emissions of the six principal air pollutants declined by 78 per cent. The graph also shows that between 1970 and 2019, carbon dioxide (CO_2) emissions increased by 21 per cent.[6]

Figure 2. **Comparison of growth areas and emissions in the United States between 1970 and 2020**



Source: U.S. EPA (2021).

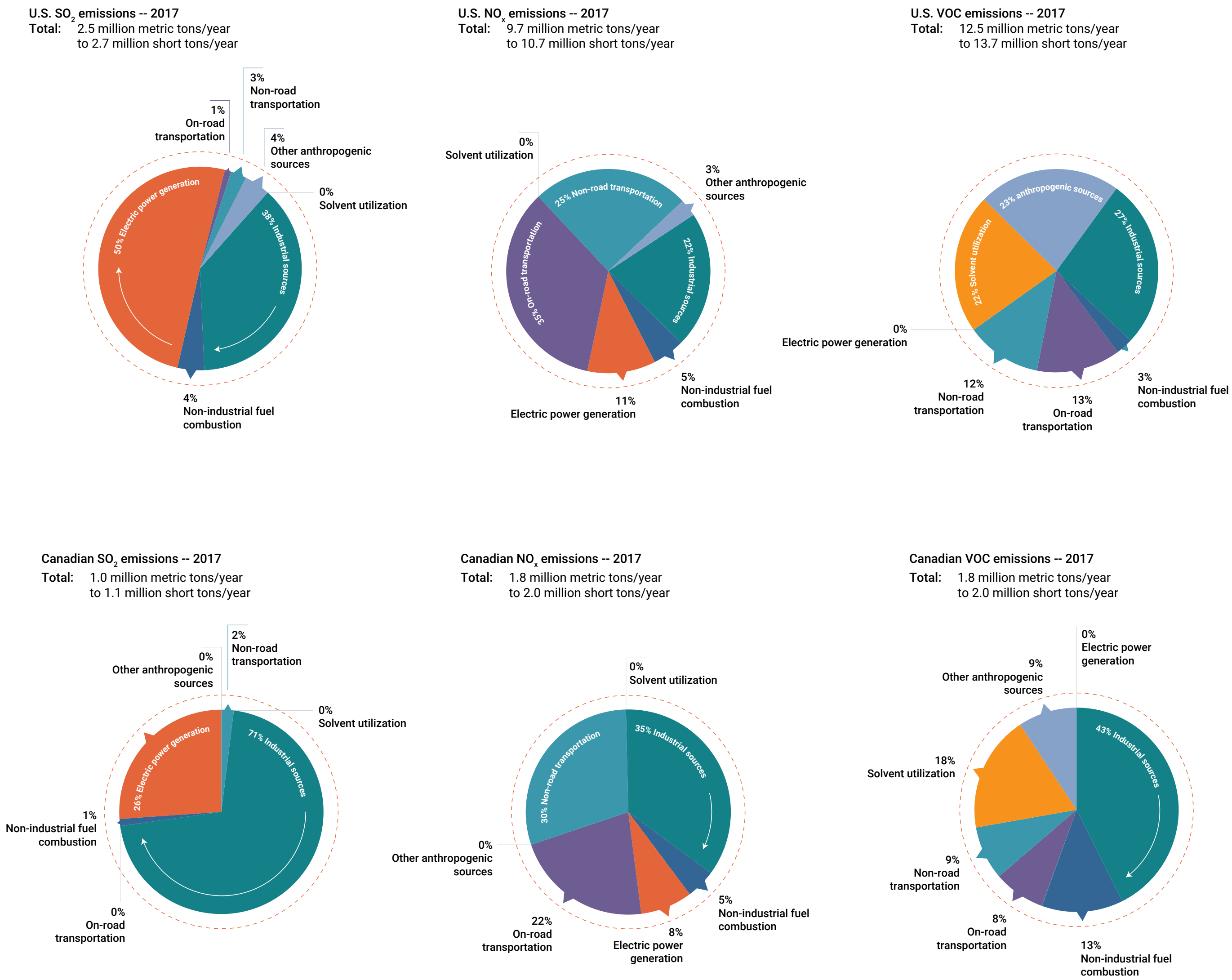
Large emissions reductions were achieved due to the U.S. Clean Air Act despite significant population and economic growth.

Despite great progress in improving air quality, approximately 97 million people (29 per cent of the U.S. population) lived in U.S. counties with air quality concentrations above the level of one or more primary National Ambient Air Quality Standards (NAAQS) in 2020, including 79 million people living in areas with O_3 (8-hour) exceedances, 36 million people living in areas with PM_{10} (24-hour) exceedances and 51 million people living in areas with $PM_{2.5}$ (annual or 24-hour) exceedances (U.S. EPA 2021).

This pollution derives from some of the same sectors that contribute to air pollution around the world: industry and energy generation, transportation, solid waste management, household air pollution and agriculture.[7] The following section reviews each of these sectors. Figure 3 shows an overview of emission inventories in both countries since 2017.

There are key sectoral differences between Canadian and U.S. emission inventories.

Figure 3. Canadian and U.S. emissions by sector for key pollutants, 2017



Notes: Emissions exclude natural sources (biogenics and forest fires). Percentages may not add up to 100 due to rounding.
Source: International Joint Commission (IJC) (2020).

Fayette Power Project, a coal power plant near La Grange, Texas. © Unsplash

Key sources of and trends in air pollutant emissions

i. Industry/energy efficiency

Since 2019, 63 per cent of U.S. utility-scale electricity comes from fossil fuels, 24 per cent of which is from coal (which is decreasing due to the increased availability of domestic natural gas as a result of expanded hydraulic fracturing or "fracking" techniques), 20 per cent from nuclear and 18 per cent from renewables (U.S. Energy Information Administration 2020). By contrast, since 2018, 67 per cent of Canadian electricity comes from renewables, 15 per cent from nuclear and 18 per cent from fossil fuels (Natural Resources Canada 2020). This is in part due to the early recognition by some provincial energy and environment ministers of the impact of fossil fuel-fired power plants on Canada's ecosystems and to federal regulations to phase out the use of coal-fired electricity. In 1998, the Canada-Wide Acid Rain Strategy for Post-2000 was signed, which led to the closure of many coal-fired power plants. The regulatory actions[8] to curb greenhouse gas (GHG) emissions from the electricity sector in Canada are expected to generate co-benefits in terms of air pollutant reductions. The phase out of coal plants by 2030 is an example that will produce commensurate reductions in SO_2 and NO_x emissions from the sector. For example, provincial regulatory mandates to ban coal-fired electricity generation has had positive results, such as in Ontario, where the power supply mix from coal has dropped from 25 per cent in 2003 to 0 per cent in 2014, with grid reliability and domestic supply also improving.[9]

A combination of emission performance standards on utility boilers and various regulatory programmes (including innovative market-based carbon pricing model emission reduction programmes) targeted aggregate reductions across the sector in both countries and resulted in sharp declines of NO_x and SO_2 emissions and the subsequent reduction in the cross-state transport of fine particle pollution, O_3 precursors and deposition of acid gases (see Figure 5 in the case study on bilateral cooperation).[10]

Both countries also have similar performance standards in place for other industrial sectors. Under the U.S. CAA, any new industrial facilities to be built must include the most effective pollution controls within their designs. This means that as new, cleaner facilities are built, the country's industrial sector will become cleaner overall. In areas that are not meeting air quality standards, new and modified large plants and factories must meet the lowest achievable emission rate and offset emission reductions from other sources to avoid making pollution worse. In areas that are meeting air quality standards, new and modified large plants and factories must apply the best available control technology considering the cost, and must avoid causing significant degradation of air quality or visibility impairment in national parks. State and local permitting authorities usually administer the pre-construction permit programmes that determine how to apply these requirements to facilities (U.S. EPA 2020).

In Canada, the Multi-Sector Air Pollutants Regulations (MSAPR) established the country's first mandatory national air pollutant emissions standards for major industrial sectors. Non-regulatory measures have also been developed, including guidelines for stationary combustion turbines, along with codes of practice, performance agreements and pollution prevention notices for sectors such as aluminium, iron, steel and ilmenite, iron ore pellets, base metals smelting, potash, and pulp and paper (ECCC 2020a).

A wide range of incentive programmes and government-industry partnerships are focused on pollution prevention and energy efficiency. In the United States of America, examples include the ENERGY STAR programme, the Combined Heat and Power Partnership and the Green Power Partnership, all run by U.S. EPA. In Canada, similar incentives are offered through the Energy Innovation Program, the Canadian Industry Partnership for Energy Conservation (CIPEC), and the energy management for industry activities (Ibid.).

ii. Vehicles and transport

Both countries in the region implement vehicle and engine emission standards for motor vehicles and non-road engines, such as those used in construction, agriculture, industry, trains and marine vessels. Compared with 1970 vehicle models, new cars, sport utility vehicles (SUVs) and pickup trucks in the United States of America are roughly 99 per cent cleaner for common pollutants (hydrocarbons, CO, NO_x and particle emissions), despite annual vehicle miles travelled having dramatically increased (Figure 4; U.S. EPA 2013).[11]

Vehicle emission standards in the United States of America, along with inspections and enforcement, have resulted in dramatically lower emissions, despite vehicle miles travelled having increased.

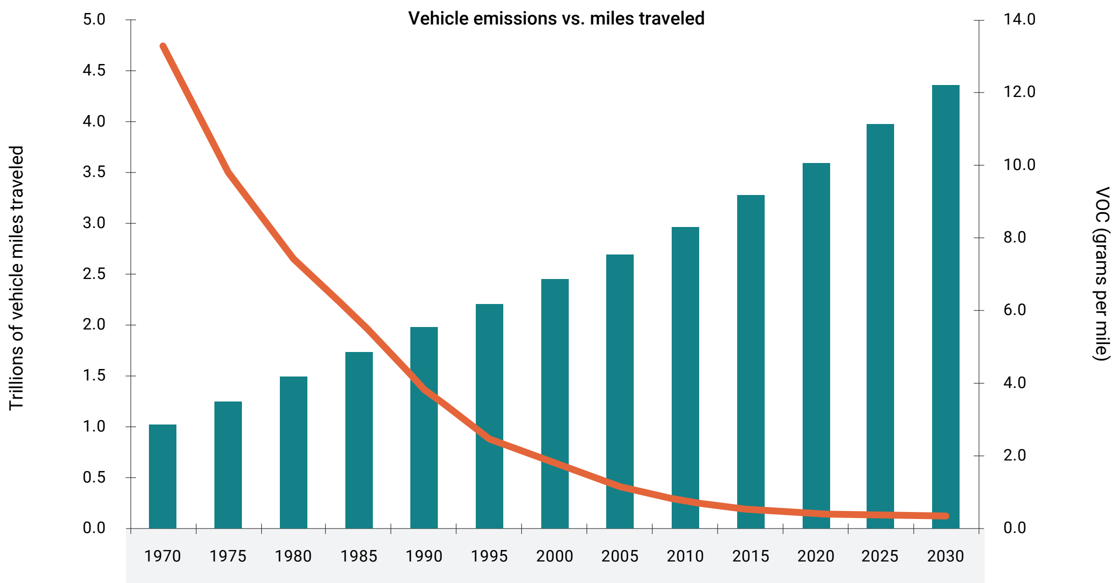
In 2014, U.S. EPA completed their Tier 3 standards for light-duty vehicles and gasoline. The Tier 3 standards, which are being phased in between 2017 and 2025, require further reductions of 70–80 per cent in emissions, compared with Tier 2 standards, and cut the remaining sulphur in gasoline significantly (Congressional Research Service [CRS] 2020).

New heavy-duty trucks and buses are roughly 99 per cent cleaner for common pollutants (hydrocarbons, CO, NO_x and particle emissions) than 1970 models, and diesel locomotives and new marine engines are about 90 per cent cleaner than pre-regulation models. U.S. EPA has begun to take action to reduce aircraft emissions and finalized GHG standards on 11 January 2021 that are equivalent to the International Civil Aviation Organization (ICAO) standards. However, since these adopted standards are no more stringent than business-as-usual projections, the new Administration is reviewing additional opportunities for this sector. Both Canada and the United States of America have adopted Emissions Control Areas (ECAs) regulating SO_2 and particulate matter for ships operating within 200 nautical miles of the coast. The ECAs for Canada and the United States of America became effective in 2013 and 2012, respectively.

Environment and Climate Change Canada implements six vehicle and engine emission regulations and nine fuel regulations under the CEPA. In addition, Environment and Climate Change Canada and U.S. EPA continue to collaborate closely under the framework of the Canada–United States Air Quality Committee towards the development of aligned vehicle and engine emission standards, related fuel quality regulations and their coordinated implementation (ECCC 2017a).

Canada's stringent (Tier 3) standards limit smog-forming emissions from on-road light-duty vehicles and engines, including cars and light-duty trucks. The On-Road Vehicle and Engine Emission Regulations also include stringent air pollutant emission standards for motorcycles and heavy-duty vehicles and engines. Several regulations have also been put in place to reduce emissions from a wide range of off-road vehicles and engines, including small spark-ignition engines used in lawn and garden equipment, recreational vehicles such as snowmobiles, off-road motorcycles and all-terrain vehicles (ECCC 2018a).

Figure 4. **U.S. Vehicle emissions and miles travelled over time**



Source: U.S. EPA (2021c).

These engine standards play a key role in several northern and remote communities in Canada that heavily rely on diesel-generated electricity (100 per cent in Nunavut), posing serious environmental risks and contributing to ambient air pollution in such communities.

Since 2010, regulations have been adopted in Canada to limit GHG emissions from on-road vehicles, including cars, light-duty trucks and heavy-duty vehicles and engines.

The regulatory regime for marine vessels falls under the Canada Shipping Act, 2001 and associated regulations. Air emissions are regulated under the Vessel Pollution and Dangerous Chemicals Regulations, which are largely based on requirements from the International Maritime Organization's (IMO) International Convention for the Prevention of Pollution from Ships. An ECA was established in 2013 to regulate SO_x and NO_x emissions in Canadian waters south of 60 degrees and extending to the limit of the exclusive economic zone.

iii. Waste management

In the United States of America, the Resource Conservation and Recovery Act (RCRA) is the public law that creates the framework for the proper management of hazardous and non-hazardous solid waste, typically implemented at the local or state level. The law describes the waste management programme mandated by Congress that gives U.S. EPA the authority to develop the RCRA programme (United States Department of State [USDOS] 2020). U.S. EPA also implements the conservation mandate of RCRA through its Sustainable Materials Management Program. Recycling and waste diversion programmes also are primarily implemented at the state and local levels (Ibid.).

Prior to 1990, non-hazardous solid waste incinerators, which emit a wide range of pollutants, were subject to varying degrees of U.S. state and federal regulations, depending on their size, age and the type of waste burned. The 1990 CAA Amendments established more consistent federal requirements specifying the regulation of emissions of nine pollutants and opacity at new and existing incinerators burning municipal solid waste, medical and infectious waste, commercial and industrial waste and other solid waste. Section 129 of the CAA in particular regulates sewage sludge incinerators and hazardous waste incinerators and specifies minimum destruction and removal efficiencies and emission limits of metals, dioxins/furans and other hazardous pollutants. The amendments also established emissions monitoring and operator training requirements (CRS 2020). U.S. EPA regulations for several large sources of mercury, such as utility coal boilers, municipal waste combustion and medical waste incineration, played a significant role in the decline of mercury emissions, which declined by about 87 per cent between 1990 and 2017 (U.S. EPA 2021b).

In Canada, provinces and territories mainly regulate municipal solid waste, which is managed by municipalities, either directly or through contracts with the waste management industry. Similarly, the waste management industry provides services under contract to industrial, commercial or institutional waste generators. Various policy frameworks are in place across Canada for solid waste management. Some jurisdictions have a dedicated solid waste management strategy or action plan, or a more generalized sustainability policy, which usually includes a solid waste goal or set of initiatives (ECCC 2020a).

Emission standards in both countries are complementary to other regulatory and voluntary initiatives that encourage recycling, waste management and medical device manufacturers and hospitals to eliminate mercury-containing sources from entering incineration facilities.

iv. Indoor air pollution

1. Biomass combustion

Indoor air pollution from residential biomass combustion is generally extremely limited in both countries of the North American region. A limited number of U.S. homes (about 127,000 or 0.1 per cent nationally) still use coal as a heating fuel, primarily in rural areas near coal mines, such as in Pennsylvania and rural New York state (Climate and Clean Air Coalition [CCAC] 2017). The health impacts of coal, however, may extend beyond the risks associated with $PM_{2.5}$, as coal often emits high levels of SO_2 and NO_x and often other poisonous toxins, such as fluorine, arsenic, selenium, mercury and lead (Ibid.).

In Canada, the proportion of Canadian homes heated by wood or wood pellets varies by region, with negligible wood heating in the Prairies and Nunavut, and up to around 20–30 per cent of homes using wood heating in the Atlantic provinces and Yukon (Tevlin *et al.* 2021). While a few, mainly rural homes rely on wood heat, a much larger number of homes burn wood for recreational/aesthetic reasons, which can result in a significant source of ambient air pollution outside the home. Many indigenous people in First Nations, Inuit and Native American communities, as well as homes in rural locations with a lack of grid connection, suffer from energy poverty and/or have no choice but to rely on wood. However, many of these same populations are not well captured by survey data, indicating that these estimates may undercount true exposure.

For those who use biomass for heating and/or cooking, federal recommendations in both countries outline best practices for reducing exposure to smoke. Federal standards are comparable in each country, with many subnational actions regulating wood-burning appliances (such as provincial or state-level emission standards based on performance tests) (WHO 2015; ECCC 2020a).

2. Other sources inside the home

In addition to direct emissions from heating stoves and boilers, ambient air pollution can penetrate and contaminate indoor air, which can also be contaminated by emissions from building materials, products and activities inside the home (including cooking with propane or natural gas) and from the infiltration of naturally occurring radon from soil underneath the home, or odours and chemicals from trucked wastewater systems used in rural home (ECCC 2017a). Long-term exposure to radon gas in indoor air is the leading cause of lung cancer for non-smokers.

Between 2002 and 2010, a series of field studies were carried out, primarily in single-family homes, in eight cities across Canada to inform the development of Residential Indoor Air Quality Guidelines by establishing typical concentrations for key pollutants in different seasons, determining factors that lead to elevated concentrations (for example, attached garages) and evaluating the contribution of outdoor air infiltration to indoor levels of pollutants and personal exposure (Héroux *et al.* 2008; Héroux *et al.* 2010; Wheeler *et al.* 2011; MacNeill *et al.* 2014).

Subsequent indoor studies have evaluated important residential indoor air issues, including BTEX[12] infiltration from attached garages (Mallach *et al.* 2017), NO_2 and particulate matter emissions from indoor cooking (Sun *et al.* 2018), VOC/semi-volatile organic compound (sVOC) emissions from building materials in newly built homes (Health Canada 2019b), air pollution in schools (MacNeill *et al.* 2016), day-care centres (St-Jean *et al.* 2012), wood smoke infiltration (Wheeler *et al.* 2014) and indoor air quality in indigenous communities (Weichenthal *et al.* 2013). A Canadian study showed that more than 70 per cent of VOCs in Canadian homes were attributed to indoor sources, including household and personal care products (53 per cent), environmental tobacco smoke (11 per cent) and building materials (6 per cent) (Bari *et al.* 2015).

Regulating indoor VOCs is difficult. For example, while formaldehyde – classified as a human carcinogen and known to be emitted from building material – has a voluntary standard (CAN/CSA-0160 – Formaldehyde emissions standard for composite wood products) and regulations (Formaldehyde Emissions from Composite Wood Products Regulations proposed under the CEPA), for hundreds of other VOCs emitted indoors, specific information on their sources and contributions to indoor and outdoor air quality is still lacking.

Women are especially prone to indoor air pollution as they still do a disproportionate amount of the household cleaning. For example, during the cleaning process, pollutants leach out of PVC flooring which contains several additives, some of which are toxic, and are then emitted into the air and inhaled, leading to the development of asthma (Women Engage for a Common Future [WECF] 2017). Some household cleaning products may also be a source of pollution, leaving women and children who are exposed to their fumes at high risk (WECF 2017).

In the United States of America, indoor air quality is addressed through a combination of state and local mandates (such as smoke-free laws) and non-regulatory guidance, technical assistance and programme initiatives at the federal level. U.S. EPA's Indoor Environments Division develops guidance, sets action levels and provides outreach and technical assistance to build the capacity of states, tribes and communities to reduce the risk of indoor pollutants (U.S. EPA 2020c).

3. Inadequate ventilation and infectious diseases

More recent Canadian research on indoor air quality has focused on vulnerable populations (such as indigenous people in First Nations and Inuit communities) and interventions intended to improve indoor air quality.

In northern Canada, one of the obvious linkages to significantly overcrowded and inadequate housing is the prevalence and persistence of tuberculosis in northern and remote communities, especially Inuit communities. The rate of tuberculosis faced by Inuit people is almost 300 times that of non-indigenous Canadians. The linkages between the spread of respiratory illnesses and diseases and overcrowded and inadequate housing are well documented (Senate of Canada 2017).

Very high numbers of northern homes are filled with mould due to overcrowding (undersized ventilation systems) or ventilation systems failure (lack of maintenance and/or underperformance in the harsh cold climate), leading to a build-up of excess moisture in the homes, leading to the development of mould. In northern housing, mould adversely impacts indoor air quality and the health of community members, who have higher rates of respiratory tract infections (Weichenthal *et al.* 2013).

Guidance in both countries addresses the importance of adequate ventilation and regulation of indoor sources. Ventilation is addressed though local building codes (for example, required ventilation over cooktops or ranges and adequate ventilation rates in terms of air exchanges per day). Emissions from indoor sources are addressed through product regulations to limit indoor emissions, such as U.S. EPA certified wood-burning appliances (U.S. EPA 2020f).

Canada is moving towards Net-Zero Energy Ready Codes. Energy-efficient homes often incorporate measures such as foundation insulation, airtight construction and air sealing around doors, windows and vents, though the impact of these measures on indoor air quality and radon concentration are yet to be fully understood in Canada. Empirical data are scarce, which correlate potentially harmful concentrations of indoor pollutants (such as radon, combustion by-products) with airtightness of buildings, air change rates and negative pressure of occupied low-energy homes (for example, ENERGY STAR certified homes) across the country.

4. Climate change

Changing weather patterns have resulted in increasingly frequent flooding events (Bush and Lemmen 2019) and wildfires, both of which have serious impacts on indoor air quality in Canada. Increased indoor temperatures resulting from higher outdoor temperatures have also been associated with higher air pollutant emissions rates from building materials and higher indoor VOC and sVOC concentrations in homes (Wallace 1996; Héroux *et al.* 2010).

Renters or people lacking the necessary financial resources may be limited in their ability to make home modifications to limit air quality issues and protect their indoor air quality from climate change events such as increased flooding and wildfire smoke (Institute of Medicine 2011; Romero-Lankao *et al.* 2014).

v. Agriculture

Agricultural air pollution is mainly in the form of ammonia (NH3), which enters the air as a gas from heavily fertilized fields and livestock waste. It then combines with combustion pollutants, mainly NO_x and sulphates from vehicles, power plants and industrial processes, to crease aerosols (secondary particulate matter). When accounting for the ammonium fraction of sulphates and nitrates, as well as fugitive dust emissions, farms outweigh all other human sources of fine particulate air pollution in much of the United States of America, Europe, China and Russia (Bauer, Tsigaridis and Miller 2016). Primary particulate matter emissions are mostly associated with wind erosion and land preparation and, to a lesser extent, combine harvesting (Pattey *et al.* 2016 – for Canada).

Livestock and the degradation of manure is a significant source of methane (CH_4) that exacerbates ground-level O_3 if released, or results in a source of captive power generation, if captured.

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However, combustion of biogas through internal combustion engines can increase NO_x emissions if not properly maintained.[13] Burning of agriculture fields and NO_2 emissions associated with the use of nitrogen fertilizers can also be a significant source of air pollution.

Canada is taking action to support sustainable agriculture and food systems through major policy initiatives, including:

» The Pan-Canadian Framework on Clean Growth and Climate Change, which identifies increasing carbon storage in soils, generates bioenergy and bioproducts, and advances innovative GHG-efficient practices as action areas for the agriculture sector.

» The federal, provincial and territorial Canadian Agricultural Partnership, which supports the on-farm adoption of beneficial management practices and clean technologies, and invests in science and innovation research activities.

» The Food Policy for Canada, which includes reducing food loss and waste as a priority (ECCC 2020a),

» The Government of Canada's Strengthened Climate Plan, A Healthy Environment and a Healthy Economy, announced on 11 December 2020, which builds on the Pan-Canadian Framework on Clean Growth and Climate Change and Canadian Agricultural Partnership to support the adoption of cleaner practices and technologies that further reduce GHG emissions and protect the land, water and air that farmers depend on for their long-term sustainability. The Government of Canada is investing CAD 165.7 million over seven years to support the agriculture industry in developing transformative clean technologies and help farmers adopt commercially available clean technology. The Government has also set a national emission reduction target of 30 per cent below 2020 levels from fertilizer use, and will work with fertilizer manufacturers, farmers, provinces and territories to develop an approach to meet this.

In Canada, gaseous NH_3 is on the Schedule 1 Toxic Substances List under the CEPA as it has been identified as one of the principal precursors to fine particulate matter and is therefore a contributor to poor air quality, leading to adverse health impacts. Domestically, Canada has a number of nationwide guidelines on agricultural practices, though they focus on achieving environmental standards (such as safe nitrate concentration in drinking water), rather than requiring emission reductions. Recognizing the environmental, practical and economic benefits from improved nitrogen-use efficiency, the agriculture sector in Canada has been proactive in this regard and has moved towards improved nitrogen-use efficiency over the years, primarily for practical or economic reasons.

In October 2018, Environment and Climate Change Canada held a workshop on NH_3 which brought together scientists and policymakers from Canada, the United States of America and Europe to discuss the importance of NH_3, as well as the state of atmospheric NH_3 policy, science and mitigation. The workshop concluded with a number of key messages on the health and environmental impacts of NH_3, as well as tools and approaches available for mitigation. Discussions in Canada to assess appropriate policy tools and measures to reduce emissions of atmospheric NH_3 and increase awareness of these issues are ongoing.

The regulatory authority for agriculture in the United States of America is established under section 110 of the CAA, which requires states with areas that do not meet ambient air quality standards to identify sources of air pollution and develop plans that determine the reductions required to meet the standards.

Different parts of farming are regulated in the United States of America under more specific regulations in other sections of the CAA (such as farm equipment, boilers and engines). Some programmes offer grants and voluntary approaches to help farmers meet and/or go beyond these regulations, such as the National Clean Diesel Campaign, which helps farmers, ranchers and agribusinesses reduce emissions from older diesel engines, and U.S. EPA's Smart Sectors programme, which is a platform that enables collaboration with regulated sectors to develop sensible approaches that better protect the environment and public health. Other third-party organizations have also developed programmes, such as the Fertilizer Institute's Retailer Safety Resources, which helps retailers comply with regulations and ensure the safety of their workers and facilities (U.S. EPA 2020d).

U.S. EPA also provides guidance on a range of topics such as conservation agriculture, wildfire and prescribed fire management, dust control and emission standards for farm equipment (Ibid.).

b. Trends in policy formulation and implementation

The main sources of air pollution have been the subject of national legislation in both nations for several decades. The United States of America passed the CAA in 1970, which has been amended several times since. In Canada, CEPA,1999, which has existed since the 1970s, acts as the federal government authority to address air pollution. It provides a range of tools to take action on various sources of air pollution. The Canada Shipping Act, 2001 (signed in 1999) also includes air pollution mitigation measures, while the Railway Safety Act includes locomotive emissions regulations. Canada also has several other acts relating to issues in this area, and provinces and territories have passed extensive and detailed legislation. These national statutes target the key sources of air pollution outlined previously by allowing for an air quality management partnership of federal, state and tribal-level action (in the case of the United States of America) or the federal government (in the case of Canada).

i. U.S. Clean Air Act, 1970 (CAA)

The main federal legislation governing air pollution in the United States of America is the CAA. Since it was passed in 1970, U.S. EPA has been the governing body able to set regulations and standards regarding harmful substances in the atmosphere (CRS 2020).

In its current form the CAA requires:

- U.S. EPA to set health-based standards
- air quality monitoring requirements for population centres and specific sources
- deadlines for states/tribes[14] and local governments to achieve standards
- national emission standards for "large or ubiquitous" sources of pollution
- the control of 187 different air pollutants
- a cap and trade programme for acid rain
- prevention of further deterioration of air quality in regions with good air quality
- the restoration of visibility in national parks and wilderness
- the implementation of the Montreal Protocol guidelines.

The CAA has been amended and added to several times since 1970, with the most significant changes to its scope made under the 1990 CAA Amendments.

Although health-based standards with monitoring-based accountability sets the foundation for air quality action, the broad scope and structure of the CAA has allowed U.S. EPA and state and tribal partners to implement plans to reduce exceedances of standards over time, while also developing new or innovative programmes that focus on specific issues as they arise. This has allowed federal, state and tribal partners to achieve more targeted goals within smaller jurisdictions, where primary health-based standards may not adequately address specific types of exposure or environmental damage. For example, the market-based Acid Rain Program allowed for significant reductions of SO_2 and NO_x in the eastern part of the United States of America. (see Case Study A on bilateral cooperation) when air pollution exceeding secondary (public welfare) standards was found to be causing widespread ecological damage. Visibility impairment has been addressed through the Regional Haze Program, which establishes long-term reasonable progress goals for achieving natural visibility conditions in national parks and wilderness areas where visibility is an air quality-related value. While the CAA requires U.S. EPA to regulate toxic air pollutants from industrial facilities, it has enabled the agency to do so through various methods, including national inventory reporting, development of urban air toxics strategies, and by including these pollutants within existing point source and vehicle performance standards.

In general, federal regulation sets the framework for air quality management, but states retain the right to set more stringent standards (though some state legislature has restricted this right). This has allowed some states and air management districts to have a role in developing ambient standards that are more stringent than national standards, where needed to meet federal NAAQS.

ii. Canadian Environmental Protection Act, 1999 (CEPA)

The CEPA (Government of Canada 2021) is a key federal law aimed at preventing pollution and protecting the environment and human health. It enables action on a wide range of environmental and health risks from air pollution to water pollution, chemicals, waste and emergencies. The Minister of the Environment is directly accountable to Parliament for the administration of the CEPA.

The CEPA provides the federal government with various tools to control air pollutants and emissions. For example, the CEPA provides for authorities to regulate the manufacture and import of specific products that contribute to air pollution and GHG emissions, such as vehicles, engines, equipment and fuels. It also provides for authorities to regulate substances that are considered "toxic" under the Act.

In addition, the CEPA allows for the establishment of environment- and health-based air quality objectives, specifying goals or purposes for pollution prevention or environmental control that result in improved air quality, healthier communities and the protection of the environment. In contrast, the CAA requires U.S. EPA to set ambient air quality standards, which states must meet to avoid sanction.

The transportation sector is one of the largest sources of air pollution in Canada. The combustion of fossil fuels to power vehicles and engines (on- and off-road) has major adverse impacts on the environment and health of Canadians. The CEPA enables the incorporation of U.S. emissions standards and test procedures through references in Canadian regulations, recognizing the integrated nature of the North American market, while reducing the compliance burden on vehicle and engine manufacturers and minimizing costs for industry and consumers.

In 2012, the Canadian Ministers of the Environment agreed to implement the Canada-wide AQMS, which includes base-level industrial emission reduction requirements, CAAQS (for $PM_{2.5}$, O_3, SO_2 and NO_2) and an Air Zone Management Framework (AZMF).[15] The AZMF provides guidance to jurisdictions on the level of monitoring, reporting and management actions to be implemented in air zones depending on the level of prevailing concentrations of air pollutants with respect to the CAAQS. Actions become progressively more rigorous as ambient levels approach the CAAQS. The CAAQS have also been established as air quality objectives by the federal government under the authority of the CEPA.[16]

The federal government also administers a number of funding programmes that invest in actions taken at the subnational level. This includes investing in infrastructure, providing training and resources to help Canadian municipalities adapt to the impacts of climate change (multiple benefits for air pollution) and implementing innovative approaches to construction.

iii. Canada–United States Air Quality Agreement (1991) and Commission for Environmental Cooperation (1994)

In addition to national legislation, Canada and the United States of America are part of international forums that work to reduce air pollution in both countries. In 1991, the Canada–United

States Air Quality Agreement (AQA) was signed to reduce the impact of transboundary air pollution. This year, 2021, marks the thirtieth anniversary of the signing of the agreement in 1991. The agreement was originally developed to address the transboundary movement of pollutants that cause acid rain. In 2000, an annex was added to address ground-level O_3, a key component of smog. Since signing the agreement, Canada and the United States of America have both decreased acid rain-causing emissions of NO_x and SO_2 and ground-level O_3 precursors such as NO_x and VOCs. The biggest changes in NO_x and VOC emissions have come from transportation – both on-road and non-road. The agreement also includes requirements for scientific and technical cooperation, along with biannual reports on progress with the most recent report published in 2018 (IJC 2020).

Canada and the United States of America are also both part of the Commission for Environmental Cooperation (CEC) with neighbouring Mexico. The CEC is an international organization created in 1994 under the North American Agreement on Environmental Cooperation (NAAEC) between Canada, Mexico and the United States of America to address regional environmental concerns, help prevent potential trade and environmental conflicts and promote the effective enforcement of environmental law. As of 2020, the CEC operates in accordance with the Environmental Cooperation Agreement, which entered into force at the same time as the new trade agreement known as CUSMA, T-MEC and USMCA in each of these three countries, respectively.[17] The agreement addresses air quality specifically in article 24.11 and tasks the CEC with implementing cooperative environmental activities. The new agreement also includes clean air as one of its main areas of cooperation.

The CEC also publishes periodic reports on the three nations' progress towards environmental protection and sustainable development. They also annually update the North American Pollutant Release and Transfer Register (PRTR) database, which promotes public access to data and information reported by industrial facilities in North America.

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As part of the strengthened climate plan, A Healthy Environment and a Healthy Economy,[18] the Government of Canada proposes to:

- Engage the incoming U.S. Administration on approaches to increase the consumer availability of zero emission vehicles (ZEV) in both countries, given the integrated nature of the North American auto sector.
- Work to align Canada's light-duty vehicle regulations with the most stringent performance standards in North America post-2025, whether at the federal or state level of the United States of America.
- Work with partners in the year ahead on supply-side policy options to achieve additional reductions from Canada's light-duty vehicle fleet, including regulations and investments to accelerate and expand the consumer availability of ZEVs in Canada as demand grows.

The Roadmap for a Renewed U.S.-Canada Partnership[19] was announced on 23 February 2021 by the Prime Minister of Canada. It establishes a blueprint for an ambitious effort by the whole of government against the COVID-19 pandemic and in support of mutual prosperity. It also creates a partnership on climate change, advances global health security, bolsters defence and security cooperation and reaffirms a shared commitment to diversity, equity and justice. As part of this roadmap, there was a commitment to strengthen implementation of the Paris Agreement, including by working together and with others to increase the scale and speed of action to address the climate crisis and better protect nature. Given the integrated nature of the road transport, maritime, and aviation sectors, the President of the United States of America and the Prime Minister of Canada agreed to take aligned and accelerated policy actions, including efforts to achieve a ZEVs vehicle future.

On 25 February 2021, Transport Canada and the United States Department of Transportation issued a joint statement on the nexus between transportation and climate change.[20] The statement included support for the Roadmap for a Renewed U.S.-Canada Partnership and the bilateral Memorandum of Cooperation on Transport Matters of Mutual Interest signed in 2016. The two countries pledged to work together to accelerate policy actions that help the transport sectors grapple effectively with the climate challenge through ambitious vehicle standards to improve fuel efficiency and reduce GHGs from light-duty and heavy-duty vehicles, accelerate the achievement of 100 per cent ZEV sales for light-duty vehicles and increase the supply of and demand for zero emission medium- and heavy-duty vehicles, incentivize the installation of electric charging stations and refuelling stations for clean fuels, and ensure ongoing coordination of electric and alternative fuel corridors and the alignment of technical codes, standards and regulations to enable the seamless transportation of people and goods. The two countries also plan to work collaboratively on new innovative solutions to decrease emissions and advance the use of cleaner fuels in rail transportation.

Chapter 2 Endnotes

1. Although Quebec supports the general objectives of the AQMS, it will not implement the system since it includes federal industrial emission requirements that duplicate Quebec's Clean Air Regulation. However, Quebec collaborates with jurisdictions on developing other elements of the system, notably air zones and airsheds.
2. See also ECCC (2020c).
3. Between the 2015 to 2017 and the 2016 to 2018 reporting periods, the percentage of Canadians living in areas where outdoor concentrations of air pollutants were within the standards dropped from 77 per cent to 68 per cent. This decline can be attributed to large wildfires that negatively affected air quality in Alberta and British Columbia for the 2016 to 2018 period.
4. In a Canadian context, EPA stands for "Environmental Protection Act", while in a U.S. context, it refers to the "Environmental Protection Agency", the Canadian equivalent of which is Environment and Climate Change Canada. In this report, CEPA is consistently used for Canadian Environmental Protection Act and U.S. EPA will refer to the United States Environmental Protection Agency.
5. The six "criteria" pollutants in the United States of America include ground-level ozone (O_3), particulate matter (with standards for both $PM_{2.5}$ and PM_{10}), carbon monoxide (CO), lead (Pb), sulphur dioxide (SO_2) and nitrogen dioxide (NO_2).
6. Declines observed in gross domestic product, vehicle miles travelled and energy consumption during 2020 were associated with reduced industrial and consumer activity during the global pandemic.
7. Although not included in the routine emission inventory data collected for these charts, the increased frequency and severity of wildfires is a major source of intermittent emissions in both countries. While this source can be more challenging to manage than others, there are fire management policies that can be applied to potentially reduce exposure. This is also an important area for cross-border collaboration and a source that will continue to increase in future with climate change.
8. The Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations, first introduced in 2012 and last amended in 2018, are now driving the phase-out of traditional coal-fired electricity by 2030. To complement the accelerated phase-out of coal-fired electricity, the Regulations Limiting Carbon Dioxide Emissions from Natural Gas-fired Generation of Electricity were introduced in 2018. Together, these regulations aim to increase the amount of electricity generated from renewable and low-emitting sources.
9. See https://www.ontario.ca/page/end-coal.
10. In the United States of America, this included several sequential regulatory programmes, including the NO_x budget programme, the NO_x state implementation plans (SIP), the Clean Air Interstate Rule (CAIR), the Cross-State Air Pollution Rule (CSAPR) and the Mercury and Air Toxics Standards (MATS) for power plants.
11. Note that the 2013 projections of steadily increasing vehicle miles travelled (VMT) through 2030 do not reflect the short-term VMT declines that were experienced during the 2020 global pandemic.
12. Benzene (B), toluene (T), ethylbenzene (E) and xylene (X).
13. Siloxane removal systems that meet the requirements of selective catalytic reduction (SCR) technology can greatly increase the initial costs of a biogas power plant as well as the demand for on-site maintenance (including siloxane monitoring) in the future (SCAQMD 2014).
14. Section 301(d) of the CAA authorizes eligible tribes to implement their own tribal air programmes and stipulates that tribes will be treated in the same manner as states for almost all CAA programmes.
15. Although Quebec supports the general objectives of the AQMS, it does not implement the system since it includes federal industrial emission requirements that duplicate Quebec's regulation. However, Quebec is collaborating with jurisdictions on developing other elements of the system, notably air zones and airsheds.
16. For more information on the AQMS, see https://ccme.ca/en/resources/aqms.
17. The Canada–United States–Mexico Agreement (CUSMA), Tratado entre México, Estados Unidos y Canadá (T-MEC) and United States–Mexico–Canada Agreement (USMCA).
18. See https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/climate-plan-overview.html.
19. See https://pm.gc.ca/en/news/statements/2021/02/23/roadmap-renewed-us-canada-partnership.
20. See https://www.canada.ca/en/transport-canada/news/2021/02/joint-statement-by-transport-canada-and-the-us-department-of-transportation-on-the-nexus-between-transportation-and-climate-change.html.

Iterative review and refinement of air quality management programmes **are critical** to long-term progress and the equitable and effective improvement of air quality.

Measuring progress towards improved air quality: 2016–2020

a. National air quality standards and legislation

In the United States of America, national average concentrations of every criteria pollutant had declined in 2019 and were at the lowest levels on record, with the exception of 24-hour $PM_{2.5}$ concentrations. U.S. EPA finalized the reviews for both the particulate matter and O_3 NAAQS in 2020, retaining the existing standards in both cases. However, the Biden Administration has issued an executive order calling for a review of both standards and is in the process of conducting a review for the secondary NO_2, SO_2 and particulate matter standards. U.S. EPA and national partners are making progress to meet a number of attainment dates for all current NAAQS. In 2020, U.S. EPA also finalized over 20 of the risk and technology reviews to address air toxic emissions from stationary sources.

In the United States of America, subnational actors have had an increasing role in climate policy in the past four years, demonstrating the strength and resilience of the state-federal framework (highlighted in Case Study A). Thanks to the continued focus of city, state, industry and civil society actors to reduce GHG emissions (and by extension, many co-emitted criteria pollutants) within their jurisdictions, overall trends have maintained progress and emission reductions.

Canada introduced stricter ambient air quality standards for NO_x and SO_x in 2017 and for O_3 in 2019.[1] Canada has also committed to reducing black carbon emissions by 25 per cent of the 2013 baseline by 2025. As of 2016–2017, Canada had already cut emissions by 18 per cent from the 2013 baseline (ECCC 2017a). Several regulatory and non-regulatory measures to address emissions of air pollutants have also been implemented since 2016.

A 2017 parliamentary committee review of the CEPA recommended that Environment and Climate Change Canada consider ways to address the transport of air pollution across provinces and territories, while also requiring the federal government to develop legally binding and enforceable NAAQS (House of Commons of Canada 2017). The federal government stated that mandating legally binding and enforceable federal air quality standards could undermine the effectiveness of the AQMS collaborative approach, and, in recognition of the shared jurisdiction of federal, provincial and territorial governments on environmental matters, committed to continuing to take action to improve Canada's air quality through the AQMS and other processes for addressing inter-jurisdictional air pollution. The CAAQS, adopted by Ministers of the Environment under the AQMS and established under the CEPA, drive air quality improvements across the country and are reviewed on a regular basis for their adequacy to protect the environment and human health.

b. Actions for cleaner air

i. Integrated approaches

Both governments maintain robust air quality monitoring programmes that help provide cross-sectoral accountability for air quality management frameworks that include a variety of networks that inform compliance with national, provincial, territorial or tribal standards, as well as specialized monitoring programmes that enable specific sectoral regulatory initiatives to address special needs (for example, regional haze, air toxics). In Canada, this includes the NAPS network, which monitors criteria pollutants, the Canadian Air and Precipitation Monitoring Network (CAPMoN), which monitors ambient air concentrations and wet and dry deposition of acid rain pollution, and the Global Atmosphere Passive Sampling (GAPS) network, which measures persistent organic pollutants (POPs). In the United States of America, the State and Local Air Monitoring Stations (SLAMs) network was reorganized in 2011 to establish the National Core (NCore) network for criteria pollutant monitoring, which is supplemented with air toxics, lead and NO_2 monitoring, the Photochemical Assessment Monitoring Stations (PAMS) network to help understand ground-level O_3 formation and several fine particle monitoring networks, such as the $PM_{2.5}$

network, the Interagency Monitoring of Protected Visual Environments (IMPROVE) network and the Chemical Speciation Network (CSN).

With the success of combined approaches that blend "command and control" emission performance standards, including cap and trade market-based mechanisms and government supported voluntary programmes (such as ENERGY STAR, AgSTAR, CIPEC), both Canada and the United States of America are considering ways to further address climate pollution. Both countries' economies have experienced some degree of "decoupling" of GHG emissions and GDP growth, with their combined economies growing by 40 per cent in the past decade (World Bank 2020), and CO_2 emissions from fossil fuels decreasing by 9 per cent (International Energy Agency 2020), suggesting that this approach is working. This is largely due to reduced fuel use in the transportation sector and a transition from oil and coal to natural gas associated with the increase in fracking.

On 9 December 2016, Canada's federal, provincial and territorial governments adopted the Pan-Canadian Framework on Clean Growth and Climate Change, Canada's plan to reduce GHG emissions by 30 per cent below 2005 levels by 2030 and build resilience to a climate change. A key component of Canada's approach to climate change is carbon pollution pricing. In October 2016, the Government of Canada introduced the Pan-Canadian Approach to Pricing Carbon Pollution, with the Greenhouse Gas Pollution Pricing Act passed in 2018. Carbon pollution pricing systems are now in place in all provinces and territories across Canada (either provincial/territorial systems or the federal system). The pan-Canadian approach ensures that pricing systems across Canada are consistent and apply to a common and broad set of sources to ensure effectiveness, including a common price level. Several Canadian provinces challenged the constitutionality of the Greenhouse Gas Pollution Pricing Act, but the Supreme Court of Canada ruled the law constitutional on 25 March 2021.[2]

In 2019, the Government of Canada announced a commitment to exceed Canada's 2030 emissions reduction target and to begin work towards achieving net-zero emissions by 2050 (CEC 2019a). On 22 April 2021, the Government of Canada announced its commitment to reducing emissions to 40–45 per cent below 2005 levels by 2030, and achieving net-zero emissions by 2050. In November 2020, the Government of Canada tabled Bill C-12, the Canadian Net-Zero Emissions Accountability Act. This Act requires the Government of Canada to set national emissions reduction targets based on best available science at five-year intervals for 2030, 2035, 2040 and 2045, and to develop emission reduction plans for each target while explaining how each plan will contribute to reaching net-zero emissions in 2050. The Act will ensure that the Government provides an update on progress towards achieving the 2030 target at least two years prior to 2030. As part of its accountability and transparency mechanisms, it will also require Canada's Commissioner of the Environment and Sustainable Development to examine and report on implementation of the measures intended to achieve the target at least once every five years.

The strengthened climate plan, A Healthy Environment and a Healthy Economy, announced in December 2020, also includes steps to improve the energy efficiency of buildings, make clean, affordable transportation and power available in every Canadian community, continue to place a price on carbon pollution, build Canada's clean industrial advantage, and protect and enhance natural climate solutions. The Government of Canada is also committed to working with provinces and territories to advance shared priorities that will lower emissions, including on a regional and bilateral basis, and with First Nations, Inuit and the Métis Nation to advance indigenous climate leadership and ensure that federal policies and programmes are designed to address indigenous peoples' climate priorities.

In support of an integrated approach to actions for cleaner air and measuring progress towards improved air quality, Health Canada has developed the Air Quality Benefits Assessment Tool (AQBAT) which is used to estimate the burden of disease and to conduct cost-benefit analyses of the human health impacts of changes in Canada's ambient air quality. Recent applications of the AQBAT include risk assessments for wildfire smoke, air pollution co-damages in climate change, the burden of disease for O_3, NO_2 and $PM_{2.5}$, and damages from on- and off-road use of gasoline and diesel fuels.

ii. Solutions for industry/energy efficiency

With the passage of its Cessation of Coal Use Regulation in 2007, Ontario became the first jurisdiction in North America to phase out coal-fired electricity, marking the single largest greenhouse gas reduction action on the continent. By 2014, all coal-fired plants in the province had ceased operation. This was achieved by increasing the production of electricity from nuclear and non-hydro renewables. In addition to dramatically reducing the province's greenhouse gas emissions, the phase-out significantly reduced SO_x emissions, contributing to the successful implementation of the Canada-Wide Acid Rain Strategy for Post-2000. Over the course of the phase-out, Ontario's emissions of SO_x from the electricity sector dropped from 105 kt in 2007 to 0.5 kt in 2014, NO_x emissions dropped

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from 43.8 kt to 7.7 kt and greenhouse gas emissions from the sector dropped from 30.9 MtCO_2e to 5.4 MtCO_2e.

The 2016 MSAPR established nationally consistent industrial emissions performance standards and limits on nitrogen oxide (NO_x) emissions from large industrial boilers and heaters, as well as from stationary spark-ignition engines used in several industrial sectors, that burn gaseous fuels (such as natural gas). The MSAPR also limit NO_x and SO_2 emissions from kilns at cement manufacturing facilities. The MSAPR will contribute significantly to reducing emissions that contribute to smog and acid rain, including 2,000 kilotons of NO_x emission reductions in the first 19 years (ECCC 2019).

In April 2018, the final Regulations Respecting Reduction in the Release of Methane and Certain Volatile Organic Compounds (Upstream Oil and Gas Sector) were published to reduce fugitive and venting emissions of hydrocarbons, including CH_4, from the oil and gas sector. In November 2020, the final Reduction in the Release of Volatile Organic Compounds Regulations (Petroleum Sector) were published, which will reduce emissions of VOCs from petroleum refineries, bitumen upgraders and certain petrochemical facilities. Canada's oil and gas industry is taking important measures to reduce CH_4 and other fugitive emissions, including through investment in clean technology, and in some provinces, through incorporating more electrification upstream. In October 2020, Natural Resources Canada launched the CAD 750 million Emissions Reduction Fund, which offers repayable contributions to support onshore and offshore oil and gas companies to invest in green technologies to reduce CH_4 and other GHG emissions of VOCs from petroleum refineries, bitumen upgraders and certain petrochemical facilities.

In 2018, the Government of Canada launched the CAD 220 million Remote Communities Fund to support clean energy infrastructure projects that reduce reliance on diesel in off-grid industrial sites and remote communities. Industries in remote areas have already started transitioning away from diesel, such as mining operations in northern Quebec, which use liquified natural gas as an energy source rather than diesel, and have decreased GHG emissions at the power plant by 43 per cent, while also reducing NO_x and SO_x emissions.

In December 2018, Environment and Climate Change Canada published the final amendments to the 2012 Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations. The regulations require all coal-fired electricity generating units to comply with CO_2 emissions performance standards, with the objective of phasing out conventional coal-fired electricity by 2030. Environment and Climate Change Canada also published the final Regulations Limiting Carbon Dioxide Emissions from Natural Gas-fired Generation of Electricity to support the transition away from coal and enable greater use of renewables (ECCC 2019).

The United States of America will be moving forward to explore options for further addressing GHG emissions from priority emission sectors. The Biden Administration has identified certain climate programme priorities via Executive Orders issued in January 2021, with more action in this area likely forthcoming.

Both countries also collaboratively engaged in the 2017–2019 CEC project Increasing Industrial Energy Efficiency through ISO 50001. The project engaged multinational corporations to implement ISO 50001 at 19 facilities and pilot an ISO 50001 supply chain deployment model to improve competitiveness and decrease pollutant emissions (CEC 2019b).

iii. Solutions for vehicles and vehicle fuels

The United States of America implemented the Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021–2026 Passenger Cars and Light Trucks (SAFE Vehicles Rule) in 2018, which will reduce the current national automobile fuel economy and loosen GHG emissions standards (CEC 2019a). The rule would also prohibit California (and by extension other states that had adopted California's GHG standards and ZEV requirements) from keeping them. U.S. EPA will review its regulations for GHGs from these vehicles immediately in response to Executive Order 13990 (Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crisis), pointing towards the robustness of the overarching regulatory framework despite policy differences from one administration to the next.

In August 2016, U.S. EPA and the Department of Transportation's National Highway Traffic Safety Administration (NHTSA) jointly finalized standards for medium- and heavy-duty vehicles that will improve fuel efficiency and cut carbon pollution (U.S. EPA 2020). In November 2018, U.S. EPA announced the Cleaner Trucks Initiative, which will include a future rule to establish updated standards to address NO_x emissions from highway heavy-duty trucks and engines. California also adopted its own Advanced Clean Truck (ACT) regulation in 2020, which includes electric truck requirements and is in the process of tightening truck engine standards for NO_x that are on a faster timeline than the federal Cleaner Trucks Initiative process. Upon adoption by California, these regulations could be adopted by other states.

Significant progress with respect to vehicles is also being made in the United States of America thanks to a large number of projects funded through the Diesel Emissions Reduction Act (DERA), which provides funding for projects that typically include retrofitting or replacing legacy school buses, transit buses, heavy-duty diesel trucks, marine engines, locomotives, and other heavy-duty equipment with new, cleaner technologies. This programme received a significant injection of funds through the settlement of litigation against Volkswagen and Daimler AG that resulted in more than USD 4 billion for new projects (U.S. EPA 2020b).

Canada has made significant investments to support action under the Pan-Canadian Framework, including CAD 28.7 billion to support public transit (CEC 2018). In December 2020, Environment and Climate Change Canada published the final

Off-Road Compression-Ignition (Mobile and Stationary) and Large Spark-Ignition Engine Emission Regulations. Upon coming into force in June 2021, these regulations will repeal and replace the current Off-Road Compression-Ignition Engine Emission Regulations and introduce new emission standards in alignment with U.S. EPA's standards for large spark-ignition engines and stationary compression-ignition engines, while also improving the requirements for mobile compression-ignition engines (ECCC 2019). Canada has plans to reform its CEPA to provide Environment and Climate Change Canada with the authority to regulate small marine engines in the near future (ECCC 2018a).

First announced in 2016, the Clean Fuel Standard is a key component of Canada's 2020 strengthened climate plan, A Healthy Environment and a Health Economy. The Clean Fuel Standard will focus on liquid fossil fuels, such as gasoline, diesel and oil, which are used mostly in transportation, and to a lesser extent in industry and buildings. It will require fossil fuel suppliers to reduce the life cycle carbon intensity of liquid fossil fuels and will incentivize the implementation of GHG reduction projects at oil and gas facilities (for example, carbon capture and storage), use of low-carbon fuels (such as ethanol in gasoline) and the uptake of ZEV. The Clean Fuel Standard has been informed by extensive engagement with provinces, territories and stakeholders. In December 2020, Environment and Climate Change Canada published the proposed Clean Fuel Regulations in Part I of the Canada Gazette for a 75-day public comment period. Final regulations are expected late 2021, with reductions requirements expected to come into force in late 2022.

Canada also continues to align air pollution and GHG policies and regulatory requirements for marine vessels and marine engines with those set down by the IMO through International Convention for the Prevention of Pollution from Ships (MARPOL) with the Vessel Pollution and Dangerous Chemicals Regulations under the Canada Shipping Act, 2001.

Both countries have worked collaboratively through the CEC (with Mexico) on the Reducing Pollution from Maritime Transport Project that: (i) supports Mexico's effort to establish an ECA for ships, similar to those in Canada and the United States of America; (ii) encourages the exchange of information relative to compliance with the International Maritime Organization's (IMO) standards for sulphur in fuel; and (iii) supports best environmental practices for port operations.

iv. Solutions for waste management

Following U.S. EPA's Maximum Achievable Control Technology (MACT) regulations in the 1990s that strictly control emissions of dioxins and furans (common toxic emissions from municipal waste combustors), most existing facilities had to be retrofitted with air pollution control systems or shut down. There are currently approximately 75 waste-to-energy facilities in the United States of America, mostly in the north-east of the country, with one new facility in south Florida. With land more available and expensive controls required for waste burning, this practice is less common than sending waste to landfill (U.S. EPA 2020e). In October 2020, U.S. EPA selected 12 recipients who will receive approximately USD 3 million in funding to help reduce food loss and waste and to divert food waste from landfills by expanding anaerobic digester capacity throughout the United States of America. The project types selected for funding include feasibility studies, demonstration projects, and technical assistance and training.[3]

In 2016, 4 per cent of Canada's plastic waste generated was incinerated, with 3 per cent incinerated at waste-to-energy facilities. Most Canadian incinerators are decades old, and most recent proposals in Ontario were cancelled either because they were too expensive or because developers were uncertain of a steady supply of waste, given Canadian trends towards reducing and recycling waste. Under its G7 presidency in 2018, Canada championed the Ocean Plastics Charter, to move towards a more sustainable and circular approach to eliminating or reducing plastic pollution and waste. By February 2021, 26 governments and 71 businesses and organizations had endorsed the charter, committing to improve how they produce, use and manage plastics to address plastic pollution and waste.

v. Solutions for indoor air pollution

In 2018–2019, Health Canada continued risk assessments on indoor CO_2 and acrolein. The department also began a new round of risk assessments based upon a recently completed prioritization process. Work has commenced on an assessment of xylenes and a reassessment of benzene (ECCC 2019). Prohibition of Asbestos and Products Containing Asbestos Regulations came into force in 2019, prohibiting the import, sale and use of asbestos and the manufacture, import, sale and use of products containing asbestos (ECCC 2020c).

Health Canada is proposing regulations that would address the adverse health impacts of formaldehyde in indoor air by regulating formaldehyde emissions from composite wood products manufactured, sold, offered for sale, or imported in Canada. Health Canada also worked with standardization organizations to improve carbon monoxide monitoring, notably in long-term care facilities.

Residential indoor air quality guidelines include risk management for reducing exposure to several pollutants that are common in

Canadian homes.[4] Assessing and evaluating interventions for improving indoor air quality in Canadian indigenous housing in particular is an ongoing interest for the Government of Canada (Weichenthal *et al.* 2013).

Indoor air research has focused on developing interventions and risk management strategies for reducing exposure to indoor air pollution. Canadian residential indoor air studies have tested interventions to reduce pollutant exposure from cooking (Sun *et al.* 2018), traffic emission infiltration into schools (MacNeill *et al.* 2016), and benzene, toluene, ethylbenzene and xylene (BTEX) infiltration from attached garages (Mallach *et al.* 2017). Health Canada has published Guidance for Cleaner Air Spaces during Wildfire Smoke Events to address the increasing issue of poor indoor air quality due to forest fires (Health Canada 2020).

Regarding radon, the most common reduction method in Canada is sub-slab depressurization. This simple and very effective system draws radon from beneath the house, routes it through a pipe to an outside vent in a side wall or at the roofline, and expels it directly outside. The system can work using natural differences in pressure (passive system) or a small fan can be attached to the pipe to increase the draw (active system). Passive systems typically reduce indoor radon levels by about 50 per cent, while active systems can achieve more than 80 per cent reductions. These radon reduction techniques have been around for decades. In 2014, a Canadian certification programme was established to set guidelines, training and resources for the provision of radon mitigation services by professionals.

U.S. EPA's programmes focus on rising awareness of indoor air quality risks and how to reduce exposure to contaminants such as mould, radon and indoor asthma triggers. The agency also provides technical guidance to assist in disaster preparedness, response and recovery efforts, such as flood/mould clean-up and wildfire smoke exposure. In addition, it also supports numerous capacity-building initiatives, including learning collaboratives (the Asthma Community Network, and Radon Leaders Saving Lives) and research initiatives on clean cooking in developing countries (U.S. EPA 2020c). The U.S. Department of Housing and Urban Development runs the Healthy Homes Program, which aims to improve health conditions, including by improving indoor air quality. Grants focus on raising awareness and demonstrating low-cost solutions to mould, lead, allergens, asthma, carbon monoxide, home safety, pesticides, and radon (U.S. Department of Housing and Urban Development 2021).

In addition, both countries continue to focus on residential combustion of biomass and its contribution to ambient air pollution. For example, Canada has a federal Code of Practice for Residential Wood-Burning Appliances (Canadian Council of Ministers of the Environment 2012), while U.S. EPA maintains the Burn Wise programme which "promotes the importance of burning the right wood, the right way, in the right appliance" (U.S. EPA 2020g).

Both countries have collaborated through the CEC (with Mexico) on the Improving Black Carbon Emission Inventory Data for Small Scale Biomass Combustion project that seeks to address data gaps in black carbon inventories in Canada, Mexico and the United States of America in order to improve the accuracy and completeness of inventories to support air quality management and climate change mitigation efforts. The work in Canada focused on improving the quantification of emissions ($PM_{2.5}$ and black carbon) from underrepresented sectors in the Canadian emissions inventory, namely residential appliances, commercial/institutional/small industrial heat facilities, and maple syrup producers/evaporators. In the United States of America, the focus was on residential wood combustion. The outputs of this project resulted in improvements in the 2017 national emission inventories and were shared with state/local reporting agencies.

vi. Solutions for agriculture

Launched on 1 April 2018, the Canadian Agricultural Partnership is a five-year CAD 3 billion investment by the federal, provincial and territorial governments to help the agriculture and agrifood sector ensure continued innovation and growth while addressing priority environmental issues related to water, soil, air, biodiversity and climate change. The partnership includes up to CAD 690 million for research, science and innovation, with an emphasis on environmental sustainability and clean growth. In addition, up to CAD 436 million is available for cost-shared programmes designed to raise producers' awareness of environmental risks and accelerate their adoption of improved manure management and storage, precision farming practices for fertilizer use and nutrient management plans, among others (ECCC 2020a).

U.S. EPA supports a number of partnerships and programmes to address emissions from the agriculture sector, including by offering guidance and education on the successful operation and maintenance of anaerobic digestion facilities for livestock manure management through AgSTAR, its collaborative programme with the United States Department of Agriculture (USDA) (USDOS 2020). U.S. EPA and USDA collaborate to reduce air emissions from agriculture through memorandums of understanding that outline the agencies' roles in various initiatives, including USDA's Agricultural Air Quality Taskforce.

The success of biodigesters in the region is highlighted in Case Study E.

c. Key takeaway messages

Ambient air quality standards with widespread monitoring provide a foundational accountability framework for air quality management planning. In Canada, the CAAQS are established as objectives and are not legally enforceable. However, these standards are related to a federal, provincial and territorial air quality management framework which calls for the implementation of actions that become progressively more rigorous as ambient levels approach the CAAQS. Given the shared jurisdiction between federal, provincial and territorial governments on environmental matters, continued progress on air quality depends on a collaborative approach such as the AQMS.

The U.S. CAA has sanctions provisions for states that fail to meet certain CAA planning requirements, but sanctions[5] are not applied for failing to meet applicable NAAQS. In addition, if a state fails to submit an approvable plan or if U.S. EPA disapproves a plan, the state is required to develop a federal implementation plan. While the imposition of sanctions is a relatively rare event, their invocation to prompt state action is not. Between 1990 and 1997, U.S. EPA made formal findings that could trigger sanctions 855 times, but had to impose sanctions in only 14 cases, and only two of these resulted in the temporary withholding of highway funds (CRS 1997). Thus, many view sanctions as a useful tool to focus a state's attention on its responsibilities under the CAA.

Clean air quality standards (whether at the national or provincial/territorial or state level) with widespread and routine air quality monitoring serve a critical role in understanding where action on air quality is required. They can also, in part, address environmental inequalities (see Case Study C on environmental justice) because addressing "non-attainment" conditions – when the standards are not met – is a key element of the environmental justice action agenda to reduce disproportionately high and adverse human health or environmental effects on minority and low-income populations. For example, in the U.S., declaration of non-attainment status triggers further interventions in these areas.

Air pollution does not respect political boundaries, giving rise to the need for regional cooperation. The combined contribution of many dispersed emission sources can be as important as – or sometimes more important than – the contribution of local emission sources in maintaining clean air. Thus, while it is critical for any jurisdiction to understand and regulate emissions within its boundaries, it is also important to work collaboratively with neighbouring jurisdictions whose emissions may contribute to local non-attainment or whose non-attainment (downwind) may be in part attributable to local emissions.

Pollution Monitoring Device © Pixabay

Iterative review and refinement of air quality management programmes are critical to long-term progress and the equitable and effective improvement of air quality. Air quality monitoring should be continually used in conjunction with air quality modelling to track progress and identify whether programme goals are being achieved. If not, standards can be strengthened, additional areas of non-attainment can be identified, or additional regulatory programmes may be needed to ensure that specific source categories or specific geographical areas reduce emissions necessary to achieve standards. In the North American region, this has included many specialized programmes to address specific issues that have been identified over time (see for example section 3.B.i, which discusses acid rain, visibility, air toxics, marine emissions and so on).

Strong legal and regulatory frameworks make programmes resilient over time. Air quality management frameworks in the North American region have provided sustained and long-term air pollution reductions, despite routine change of political administrations and governing philosophies. By embedding standards in legal instruments that require action when standards are not met, air quality planning in North America has demonstrated significant resilience in the face of changing political parties or popular sentiment regarding environmental regulation.

Stakeholder engagement should focus on shared, reliable data (disaggregated by sex where relevant)[6] and understanding of tools. Public processes should begin with agreement on the data and tools to be used for policy assessment. In order to build trust, ownership and a sense of shared responsibility, it is critical that citizens, cities, states and federal agencies ensure that their industry and public stakeholders buy into the assessment methods and process. A process utilizing a multi-level governance approach will enable solutions that address air and climate pollution in both a horizontally (cross-sectoral) and vertically (federal, state and local governments) integrated framework. It is essential that there be active engagement of federal and local officials as well as across ministries, affected industries and civil society organizations representing the public interest.

Air quality is one element of a larger sustainability framework. The United Nations Sustainable Development Goals (SDGs) include many targets related to air quality, including air quality indicator 11.6.2 on population-weighted annual mean levels of $PM_{2.5}$. However, many of the other goals, targets and indicators of the 2030 Agenda for Sustainable Development relate to, and depend on, integrated planning efforts that can deliver not only improved air quality, but also mitigate climate change, improve public health, enhance resilience and preserve ecosystems to name just a few benefits. Integrated climate and air quality planning efforts should place special emphasis on reduction targets for both $PM_{2.5}$ and GHGs.

To protect public health and deliver multiple benefits simultaneously, there should be further prioritization of short-lived climate pollutants i.e. the black carbon component of $PM_{2.5}$ and ground-level O_3, and of the CH_4/short-lived hydrofluorocarbons component of GHG emissions reductions. This is to ensure that i) in the case of short-lived climate pollutants, policies targeting health benefits will skew towards those with additional climate benefits and ii) in the case of CH_4/short-lived hydrofluorocarbons, climate policies will skew towards those with additional health benefits through ground-level O_3 formation and near-term climate stabilization, while not losing sight of the long-term CO_2 targets.

Chapter 3 Endnotes

1. See https://www.canada.ca/en/environment-climate-change/services/climate-change/greenhouse-gas-emissions/projections-2018/backgrounder.html.
2. See https://www.scc-csc.ca/case-dossier/cb/2021/38663-38781-39116-eng.aspx.
3. See https://www.epa.gov/newsreleases/epa-announces-selection-12-organizations-receive-3-million-funding-support-anaerobic.
4. See https://www.canada.ca/en/health-canada/services/air-quality/residential-indoor-air-quality-guidelines.html.
5. Section 179 of the CAA authorizes U.S. EPA to use two types of sanctions: 1) withholding of certain federal highway funds and 2) imposing "2:1 offsets" on new or modified sources of emissions.
6. As reported in UNEP (2019), "The absence of gender data undercuts the momentum towards further gender-environmental analysis – 'what's not counted is assumed to not count'. In the absence of data, environmental assessments remain partial; establishing baselines, monitoring progress and assessing outcomes are almost impossible. Progress towards SDG commitments to gender equity and equality in all domains, including the environment, will be impossible to measure without substantial improvement in gendered data."

Canada and the United States of America have a **successful history of cooperation** on air quality.

Case studies

a. Bilateral cooperation for cleaner air

Canada and the United States of America have a successful history of cooperation on air quality through the AQA and other initiatives that address regional transboundary air quality issues, such as the Michigan–Ontario Air Working Group and the Georgia Basin–Puget Sound International Airshed Strategy.

i. Canada–United States Air Quality Agreement (AQA)

The AQA is a successful model of bilateral cooperation that has achieved tangible environmental improvements during its 30-year history. Signed in 1991, the AQA committed both countries to reducing emissions and the impacts of transboundary air pollution. It was originally developed to address acid rain, which was damaging aquatic and terrestrial ecosystems in the eastern parts of Canada and the United States of America. The Acid Rain Annex (Annex I) to the AQA committed the two countries to reducing emissions of SO_2 and NO_x, the pollutants that cause acid rain, from stationary and mobile sources. There have since been large reductions in SO_2 and NO_x emissions on both sides of the border, with subsequent reductions in acid deposition and soil and surface water acidification, and improvements in air quality. By 2017, Canadian and U.S. emissions of SO_2 had decreased by 69 per cent and 88 per cent, respectively, from 1990 emission levels. Between 1990 and 2017, significant reductions occurred in the deposition of wet sulphate and wet nitrate (the primary indicators of acid deposition) in eastern Canada and the eastern United States of America (see Figure 5).

By the late 1990s, smog caused by ground-level O_3 was recognized as contributing to thousands of premature deaths across Canada and the United States of America each year, as well as to increased hospital and doctor visits. The Ozone Annex (Annex III) was added to the AQA in 2000 to address the issue of smog and reduce transboundary O_3. It committed Canada and the United States of America to reducing emissions of NO_x and VOCs – key precursors to O_3 – from stationary and mobile sources, solvents, paints and consumer products. The commitments apply to a defined region in both countries where emission reductions are most critical for reducing transboundary O_3, known as the Pollutant Emission Management Area (PEMA). This area covers central and southern Ontario, southern Quebec, and 18 U.S. states as well as the District of Columbia.

Both countries have made significant progress in reducing ground-level O_3 in the PEMA. Between 2000 and 2017, Canadian and U.S. emissions of NO_x decreased by 59 per cent and 61 per cent, respectively, in the transboundary O_3 area covered by the AQA. Annual O_3 levels in the Canada–United States of America border region decreased between 2000 and 2017. Regulatory programmes and non-regulatory programmes designed to meet emission reduction commitments in the Ozone Annex, as well as programmes designed to meet programme goals for Canada and the United States of America individually, have contributed to the reduction in O_3 concentrations.

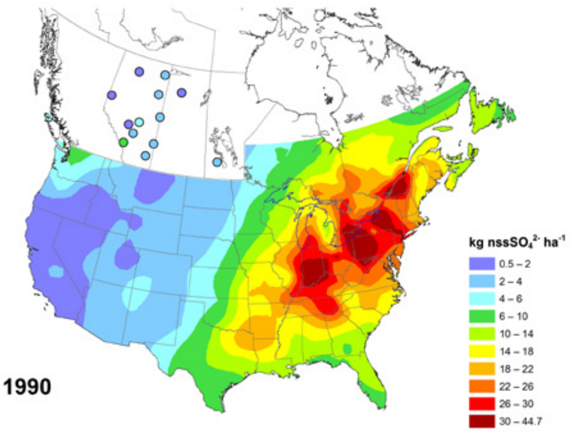
The AQA also includes an annex on scientific and technical cooperation and information exchange related to air quality, acid deposition and other areas of mutual interest (Annex II). This has strengthened cooperation between Canada and the United States of America on issues related to transboundary air pollution by establishing both common and comparable analytical techniques and atmospheric models to define air quality issues and by producing several binational science assessments.

The AQA requires Canada and the United States of America to notify each other about potential new sources and major modifications to existing sources of transboundary air pollution within 100 kilometres (62 miles) of the Canada–U.S. border. There is also an obligation to assess and carry out appropriate mitigation activities related to transboundary air pollution. Under the agreement, either country can request formal consultations concerning ongoing activities that may be causing significant transboundary pollution. The two countries have developed guidelines for such consultations, which lay out practical steps on how to proceed if one country has concerns about a source of pollution in the other country.

Under the AQA, Canada and the United States of America have also established workplans for developing and implementing harmonized regulations to reduce vehicle and engine emissions, and for addressing emissions from the oil and gas sector. These workplans have served as important mechanisms for cooperation on both air pollutant and GHG emissions from these sources. The oil and gas workplan provides that the cooperation may be extended to include other stationary sources in the future.

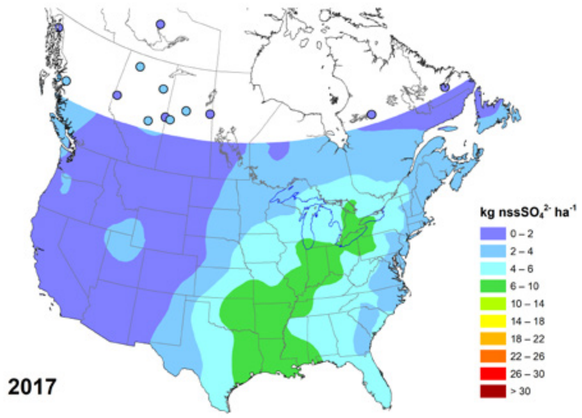
Figure 5. Annual wet deposition of nitrate and sulphate between 1990 and 2017 in Canada and the U.S.

1990 annual wet sulphate deposition



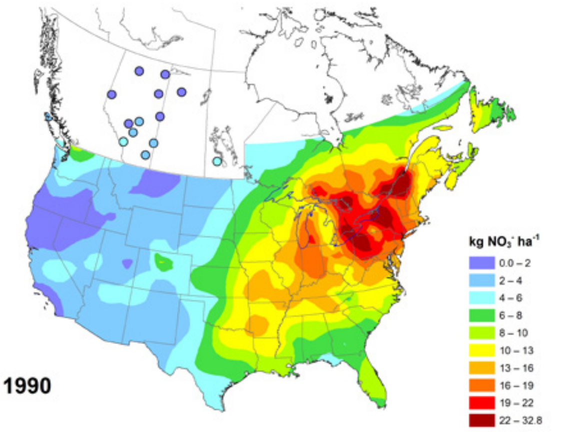
Sources: The Canadian National Atmospheric Chemistry Database and Analysis Facility (www.canada.ca/en/environment-climate-change/services/air-pollution/monitoring-networks-data/national-atmospheric-chemistry-database.html) and the United States National Atmospheric Deposition Program (http://nadp.slh.wisc.edu/)

2017 annual wet sulphate deposition



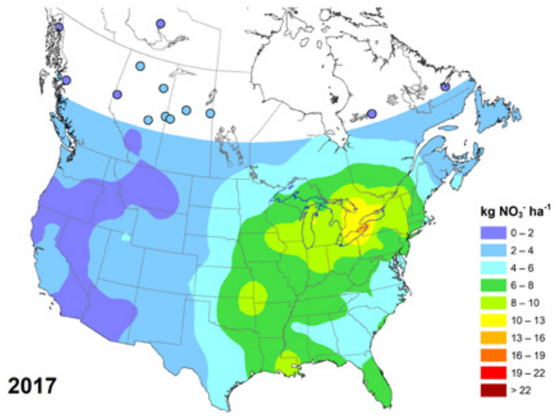
Sources: The Canadian National Atmospheric Chemistry Database and Analysis Facility (https://www.canada.ca/en/environment-climate-change/services/air-pollution/monitoring-networks-data/national-atmospheric-chemistry-database.html) and the United States National Atmospheric Deposition Program (http://nadp.slh.wisc.edu/)

1990 annual wet nitrate deposition



Sources: The Canadian National Atmospheric Chemistry Database and Analysis Facility (www.canada.ca/en/environment-climate-change/services/air-pollution/monitoring-networks-data/national-atmospheric-chemistry-database.html) and the United States National Atmospheric Deposition Program (http://nadp.slh.wisc.edu/)

2017 annual wet nitrate deposition



Sources: The Canadian National Atmospheric Chemistry Database and Analysis Facility (www.canada.ca/en/environment-climate-chanae/services/air-pollution/monitoring-networks-data/national-atmosDheric-chemistry-database.html) and the United States National Atmospheric Deposition Program (http://nadp.slh.wisc.edu/)

Source: IJC (2020).

Disclaimer: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

The AQA established a bilateral Air Quality Committee as its decision-making body. This committee is responsible for coordinating the AQA's overall implementation and is the primary forum for dialogue on air quality issues between the two countries. It meets annually to review progress on implementing the AQA, to share research, and to discuss air quality science- and policy-related issues of mutual interest. It also publishes a report on progress in implementing the agreement every two years. Two bilateral subcommittees, one focused on policy (Program Monitoring and Reporting) and the other on science (Scientific Cooperation), carry out yearly activities. Their annual workplans are approved by the Air Quality Committee, to which they report annually.

The AQA provides a formal, yet flexible, vehicle for addressing transboundary air pollution. As such, it provides a framework under which the two countries continue to cooperate to address ongoing, emerging and future air quality issues.

ii. Michigan–Ontario Air Working Group

Representatives from U.S. EPA; the Michigan Department of Environment, Great Lakes and Energy; Environment and Climate Change Canada; and the Ontario Ministry of the Environment, Conservation and Parks share updates on air quality issues, policy, and programme development in the cross-border airshed through the Michigan–Ontario Air Working Group. This ongoing interaction aims to develop a shared understanding of current and future air quality in the south-east Michigan and south-west Ontario airshed and to identify the factors that contribute to overall air quality. The working group's discussions have been conducted through quarterly phone or video calls, as well as through informal calls or e-mails between working group members to share information on questions that arise, or about air emission incidents, as needed, in order to keep organizations on both sides of the border informed.

Beginning in 2016, efforts focused on SO_2 due to exceedances of ambient air standards in the Sarnia/Port Huron region. Continued efforts to address SO_2, including the Sarnia Air Action Plan and other regulatory action taken in recent years, have contributed to recent air quality improvements in the region.

Given that south-east Michigan and southern Ontario have continued to experience episodes of elevated ground-level O_3, the Michigan–Ontario Air Working Group is interested in developing a better understanding of O_3 formation and circulation in this shared airshed. A technical subgroup was therefore established to develop and implement the Michigan-Ontario Ozone Source Experiment (MOOSE). MOOSE is a collaborative scientific study designed to improve understanding of how meteorology and various emission sources contribute to elevated O_3 levels in the south-east Michigan/south-west Ontario airshed. Efforts are currently under way to conduct field measurements in 2021 and 2022 that will help identify additional actions that may be needed to address ground-level O_3 in the region.

iii. Georgia Basin–Puget Sound International Airshed Strategy

The Georgia Basin–Puget Sound International Airshed Strategy is a multi-agency, cooperative effort between Canada and the United States of America to address shared air quality management concerns in the transboundary Georgia Basin–Puget Sound region. This region includes the west coast border cities of Vancouver and Victoria in Canada and Seattle and Olympia in the United States of America.

The Georgia Basin–Puget Sound International Airshed Strategy aims to:

- reduce the impacts of air pollution on human health, ecosystems and visibility
- prevent future deterioration and work towards continuous improvement of air quality and
- establish efficient instruments to address shared concerns regarding transboundary air pollution in the Georgia Basin–Puget Sound region.

Environment and Climate Change Canada and U.S. EPA serve as co-chairs of the International Airshed Strategy Coordinating Committee, which is responsible for this strategy. This committee, which includes representatives from regional, provincial, federal and state air quality and health agencies in the Georgia Basin–Puget Sound region, meets twice a year to exchange information on agency activities and share best management practices.

In recent years, the committee has been interested in the following issues and topics:

- air quality and health impacts from wildfire and woodsmoke
- regulations and emissions associated with cannabis growing facilities
- climate action strategies
- small sensors and community-scale monitoring and
- community engagement.

iv. Cooperation on air toxics

Several air pollutants known as air toxics are associated with cancer or other serious health effects. Though these are not included in global estimates of disease burden due to air pollution, national efforts have been established to examine their impacts. The United States of America produces regular reports through its National Air Toxics Assessment (NATA) programme, whereby the risk of various disease endpoints is estimated for almost 200 air toxics at fine geographic scale. More recently, Canada has started examining these pollutants through its Air Toxics in Canada project. These national efforts are improving understanding of the cumulative effects of a variety of air pollutants beyond particulate matter and O_3, and preliminary steps towards binational communication of results are being taken.

b. Subnational action

Case study: North American states/provinces, cities and industry step up

Canada continues to advance its environmental air quality priorities by tackling both climate change and air quality through an integrated planning lens (CEC 2019a; CCAC 2019). As the Government of the United States shifted its focus away from regulatory and enforcement actions between 2016 and 2020, much environmental progress has necessarily been directed by individual states and cities (America's Pledge Initiative on Climate 2018). Both countries have seen an increase in subnational action for both air quality and climate change, with some jurisdictions explicitly recognizing the synergies between the two.

Both Canada and the United States have seen an increase in subnational action for both air quality and climate change, with some jurisdictions explicitly recognizing the synergies between the two.

Examples include state/provincial action:

» California has always had the ability to independently set emission standards for vehicles that are more stringent than federal standards. This has enabled other U.S. states to opt in to reduce air pollution.

» Twelve north-eastern U.S. states launched the Transportation and Climate Initiative, a market-based cap and trade approach to reducing transportation emissions (with three states and the District of Columbia already committing to a declining cap for pollution allowances). This builds on the actions of 10 eastern states that have regulated power sector emissions through the Regional Greenhouse Gas Initiative (RGGI), a regional cap and trade programme introduced in 2009.

» Ten U.S. states signed on to a ZEV programme requiring increased sales of light-duty ZEVs in their states. Fifteen states and the District of Columbia signed on to develop a coordinated ZEV action plan for medium- and heavy-duty ZEVs with explicit consideration of deployment in disadvantaged communities.

» Forty-three U.S. states and the District of Columbia took actions related to electric vehicles and charging infrastructure during 2019.

» Fifteen U.S. states and Canadian territories have taken legislative or executive action to move towards a 100 per cent clean energy future.

» British Columbia's CleanBC Plan includes new goals for electric vehicles by 2040, improving 50,000 public housing units over the next 10 years, and a climate plan that will support communities with undertaking municipal action.

» The Made-in-Ontario Environment Plan sets the goal of continuing working towards reducing GHG emissions to 30 per cent below 2005 levels by 2030, having already shut down Ontario's coal-fired generation in recent decades.

» Through the Pacific Coast Collaborative, British Columbia, Washington, Oregon, California and the cities of Vancouver, Seattle, Portland, San Francisco, Oakland and Los Angeles are aiming to reduce their GHG emissions by 80 per cent by 2050 and facilitating collaboration on actions that cross borders and jurisdictional boundaries.

And city action:

» Indianapolis has started moving towards carbon neutrality. After reducing emissions by 16.4 gigatons between 2010 and 2016, it established a City-County Council on climate in 2020.

» Vancouver has established its own Clean Air Plan that strives to reduce GHG emissions by 45 per cent from 2010 levels, meet or exceed ambient air quality standards set by Metro Vancouver, British Columbia and the federal government and increase the amount of time that visual air quality is classified as "excellent" by 2030.

» In 1996, Hamilton in Ontario, Canada established the Hamilton-Wentworth Air Quality Initiative/Clean Air Hamilton, initially focusing on airborne hazardous contaminants before expanding to include more traditional pollutants and GHGs. Polycyclic aromatic hydrocarbons, benzene and odorous compounds (including total reduced sulphurs) have been reduced by over 90 per cent and PM_{10} and NO_2 by approximately 50 per cent. The Hamilton-Wentworth Air Quality Initiative was awarded the UN-Habitat/Dubai International Award for Best Practices and has thus been widely and internationally replicated as an effective approach to multi-stakeholder air quality improvement.

» In 2010, the town of Oakville in Ontario, Canada established the Health Protection Air Quality by-law which protects the health of Oakville residents from the negative effects of $PM_{2.5}$ by requiring the collection of emissions information from Oakville facilities and by implementing regulatory controls for major emitters.

» The city of Montreal in Quebec, Canada has regulations in force to reduce atmospheric emissions from the activities of thousands of manufacturing plants and factories. It has also implemented a number of measures to monitor air quality.

» In 2019, 88 North American cities (57 per cent of cities in the United States of America and Canada surveyed by the Carbon Disclosure Project) reported retrofitting buildings, 67 (44 per cent) reported updating building codes, 56 (36 per cent) reported increasing on-site renewable energy generation, 54 (34 per cent) reported increasing low- or no-carbon energy production and 39 (25 per cent) reported decarbonizing vehicles. Importantly, 76 per cent of cities surveyed in this project worldwide reported co-benefits of climate action, including air quality.

» Five North American cities (Boston, Indianapolis, Seattle, Washington, D.C. and West Palm Beach) aim to be climate neutral or carbon neutral by 2050. Cities with climate action plans that are "Paris Agreement compatible" include Montreal, Boston, New York, Washington, D.C., Miami, Houston, Los Angeles, Portland, Seattle and Vancouver.

» Minneapolis and San Francisco have committed to 100 per cent renewable energy by 2030.

» Many North American cities are part of global city networks, such as C40 Cities, the Compact of Mayors and other forums that are pushing for significant emission reductions for both climate and health reasons.

» Austin, Houston, Los Angeles, Portland and Washington, D.C. have all signed the C40 Clean Air Cities Declaration, pledging to meet a variety of air quality commitments.

And industry action:

» Positively reinforcing "ambition loops" between corporate environmental commitments and reinforcing government policies are helping drive system-wide change needed to meet science-based targets.

» More and more North American and global businesses with a North American footprint are seeing the opportunity offered by the zero-carbon economy and are making various low-carbon commitments through coalitions and partnerships such as: the We Mean Business Coalition, Ceres (Coalition for Environmental Responsible Economies), The Ambition Loop, the American Sustainable Business Council, the World Business Council for Sustainable Development (WBCSD) North America, and the Carbon Pricing Leadership Coalition.

c. Recent action to incorporate environmental justice into air quality management

i. Environmental justice in Canada

Although there are case studies of disparities in exposure to air pollution in Canada, especially in relation to industrial sources – for example in Sarnia Ontario's "Chemical Valley" (Ecojustice 2007) and impacts on the Aamjiwnaang First Nation – there has been little systematic evaluation in Canada until recently. Studies reviewed in this section indicate general disparities in exposure along various socioeconomic indicators, but racial/ethnic disparities are more complex than those identified in the United States of America, where clear racial disparities are present due to, for example, long-standing housing segregation policies.

In Canada, patterns of disparity tend to be more location-specific and reflect settlement patterns that are less consistent between cities. For example, Giang and Castellani (2020) combined national $PM_{2.5}$, NO_2, SO_2, and O_3 concentration data into a cumulative hazard index to evaluate disparities by racial/ethnic and income categories. They observed different inequality patterns between major cities. In Vancouver, indigenous populations had higher cumulative exposure burdens, while in Montreal and Toronto the highest burdens were experienced by immigrants and low-income populations, respectively.

The potential to address environmental justice issues through federal legislation is being explored in Canada.

Doiron and colleagues (2020) evaluated NO_2 along with built environment measures in the same three cities and reported a relationship between NO_2 and high material and social deprivation, also suggesting the occurrence of environmental inequity within the largest cities in Canada. Specific indicators of material and social deprivation were evaluated in detail in these cities by Pinault *et al.* (2016), who reported that areas with a greater proportion of tenants and residents who do not speak either English or French had higher NO_2 levels, while other indicators were also associated with higher NO_2 levels in specific cities (e.g. the proportion of persons living alone in Toronto, and the proportion of persons who were unmarried/not in a common-law relationship in Vancouver). Among children, those in lower income areas were exposed to higher NO_2 concentrations in all three cities, while in Toronto and Vancouver, areas with more single-parent families had higher NO_2 as did areas in Montreal and Vancouver with higher percentages of visible minority children (Statistics Canada 2016b).

Relationships for $PM_{2.5}$ were also different than those for NO_2, reflecting the spatial patterns in these pollutants and their interaction with population distributions. For example, unlike for NO_2, differences in $PM_{2.5}$ exposure by socioeconomic status were not observed at the national level. However, within urban cores, residents of low-income households had somewhat higher $PM_{2.5}$ exposures. On a national scale, immigrants (versus Canadian-born) and visible minorities (versus white populations) were consistently more highly exposed to $PM_{2.5}$, with elevated exposures for immigrants persisting even for those who had lived in Canada for 30 years (Statistics Canada 2017).

These patterns persisted across all income levels. They were less pronounced or not present within cities and tend to reflect that such population groups preferentially live in large urban centres which in turn tend to be more highly polluted. Outside urban areas, including in First Nations communities, residential woodsmoke is frequently an air quality concern (Hong *et al.* 2017; West Coast Environmental Law (WCEL) 2005). In addition, remote communities without access to the electrical grid can be affected by diesel generators, although a number of clean energy initiatives have been undertaken to reduce reliance on diesel power (Heerema and Lovekin 2019).

This analytical process is used by policymakers to examine the potential impacts (both intended and unintended) and opportunities of a policy, plan, programme or other initiative on diverse groups of people, taking into account gender and other identity factors (e.g. race, ethnicity, religion, age, and mental or physical disability).

In Canada, the federal government has mechanisms in place to support environmental justice objectives. For example, the federal government is committed to using Gender-based Analysis Plus (GBA+).

The federal government has also called on its ministers to support these objectives. For example, the December 2019 mandate letter of the Minister of Environment and Climate Change outlined the federal government's commitment to using evidence-based decision-making that takes into consideration the impacts of policies on all Canadians (Prime Minister of Canada 2019). Likewise, the Prime Minister's January 2021 supplementary mandate letter directed that decisions made by the minister consider public policies through an intersectional lens in order to address systemic inequities including systemic racism, unconscious bias, gender-based discrimination, barriers for persons with disabilities, discrimination against lesbian, gay, bisexual, transgender, queer, two-spirited (LGBTQ2) communities, and inequities faced by all vulnerable populations (Prime Minister of Canada 2021).

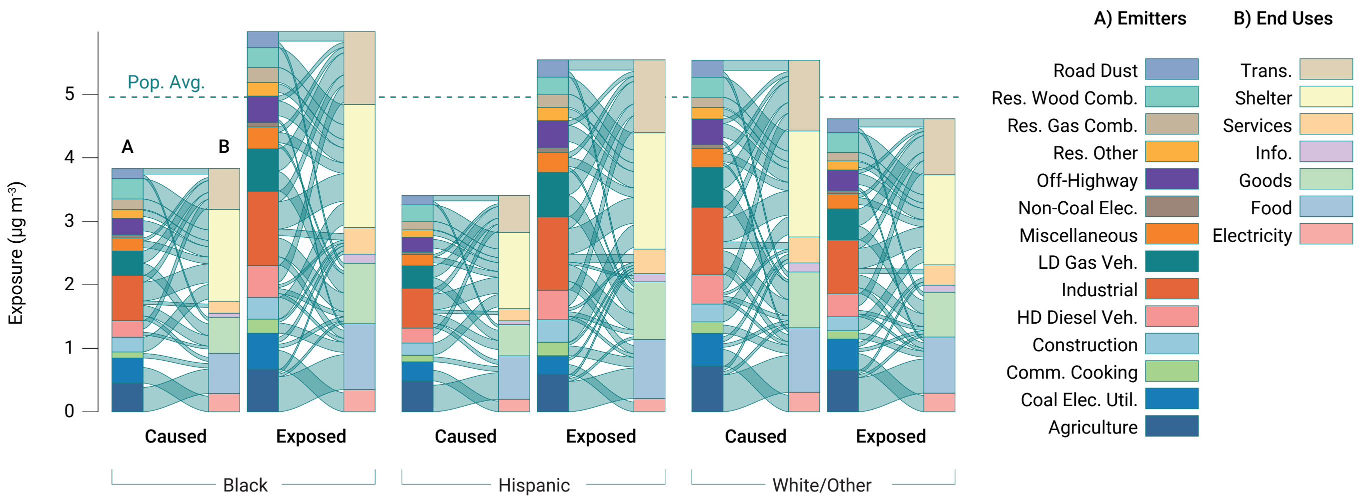
The potential to address environmental justice issues through federal legislation is also increasingly being explored in various contexts in Canada. For example, Bill C-230 (An Act respecting the development of a national strategy to redress environmental racism) proposes a new act requiring the Minister of the Environment to develop and report on a national strategy to promote efforts across Canada to redress the harm caused by environmental racism. This private member's bill was introduced in February 2020 and is currently being considered by Parliament.

ii. Environmental justice in the United States of America

Air quality has improved dramatically in the United States of America since the passing of the 1970 CAA and its 1990 Amendments (U.S. EPA 2020a). However, while the act's successes were widely recognized during its fiftieth anniversary year in 2020, it is also apparent that air quality has not improved equitably.

Disparities in air pollution exposure have persisted despite the large improvements in air quality that have been achieved by regulatory measures implemented under the CAA (Colmer *et al.* 2020). Throughout the United States of America, lower-income, minority, and marginalized populations experience higher exposure levels and associated health effects. These communities often live near major air pollution sources, including industrial facilities, major roadways, and ports. As a result, these populations have been shown to experience more air pollution than they cause (Tessum *et al.* 2019) (Figure 6).

Figure 6. Average $PM_{2.5}$ exposure experienced and caused by racial-ethnic groups in the United States



Source: Reproduced from Tessum *et al.* (2019).

Note: These results indicate that $PM_{2.5}$ exposure is disproportionately caused by consumption of goods and services mainly by the non-Hispanic white majority, but disproportionately inhaled by black and Hispanic minorities.

Over the last few years, several U.S. states have implemented ground-breaking programmes to address air pollution inequality in their air quality management programmes. California and New Jersey, in particular, have established first-of-their-kind initiatives to address environmental justice in air quality management. Connecticut, Indiana, Minnesota and Oregon have also taken more limited steps to address disparities in air pollution exposure.

California has become the first state in the United States of America to formalize efforts aimed at addressing inequities in air pollution exposure at the community level, as research has revealed substantial differences in air pollution exposure among population subgroups in this state (see, for example, Apte *et al.* 2017; Benmarhnia *et al.* 2017; Do *et al.* 2021; Southerland *et al.* 2021). Studies using CalEnviroScreen (https://oehha.ca.gov/calenviroscreen), an environmental justice screening tool developed specifically for California, have also revealed differences in cumulative pollution exposure burdens between population subgroups (Cushing *et al.* 2015; Liévanos 2018).

To address these inequities in air pollution exposure, in 2017 California established the Community Air Protection Program (CAPP), a state-wide air pollution programme focusing on reducing exposures in the communities most impacted by air pollution. The programme was created in response to California

Assembly Bill 617 (A.B. 617) and builds on the California Air Resources Board's (CARB) earlier efforts to incorporate environmental justice into the state's existing air quality programmes. The CAPP is designed to reduce exposures in high-risk communities by:

» conducting community air monitoring and emissions reductions programmes

» using targeted incentive funding and grants to deploy cleaner technologies that address localized air pollution

» requiring accelerated retrofit of pollution controls on industrial sources (including increased penalty fees) and

» enhancing transparency and availability of air pollution and emissions data.

In 2019, air districts deployed monitors and adopted emission reduction programmes in 10 selected communities. At the time of writing this document in 2020, CARB was selecting additional communities to participate in the CAPP. Communities are selected by a consultation group that includes individuals representing environmental justice organizations, air districts, industry, academia, public health organizations and local government. As the California programme is implemented and evaluated, it is expected to serve as a model for other states experiencing large disparities in air pollution exposure.

New Jersey has taken a different approach to incorporating inequities into environmental management. In September 2020, the state passed a new law (S232) requiring the New Jersey Department of Environmental Protection (NJDEP) to only grant or renew permits for certain facilities if there are no disproportionate, cumulative environmental impacts on overburdened communities. "Overburdened communities" are defined as any Census Block Group with low-income, minority or non-English speaking populations exceeding specified thresholds. Approximately 310 municipalities in the state have overburdened communities within their municipalities. The new law covers major air pollutant facilities under the CAA, such as incinerators or resource recovery facilities; sludge processing facilities, combustors, or incinerators; large sewage treatment plants; transfer stations, large recycling facilities landfills; and other industrial facilities. The NJDEP must review environmental justice-specific impact statements when considering permit applications and evaluate the impacts on overburdened communities before approving permit applications. Covered facilities must also hold a public hearing in the overburdened community, accept oral and written comments from any interested parties, and submit a transcript of the public hearing to NJDEP.

The administration of U.S. President Joe Biden has committed to environmental justice as one of its top priorities. In January 2021, the Administration released Executive Order 14008 on Tackling the Climate Crisis at Home and Abroad, which directs federal agencies to integrate environmental justice into their programmes, policies and activities. It establishes both a White House Environmental Justice Interagency Council and a White House Environmental Justice Advisory Council and sets of a goal of delivering 40 per cent of the benefits of relevant federal investments to disadvantaged communities. It also initiates the development of a national-scale Climate and Environmental Justice Screening Tool, building from EPA's EJSCREEN tool (see https://www.epa.gov/ejscreen).

These state-level and federal actions represent significant advances towards environmental justice for marginalized communities in cities, in rural areas, and among tribal nations throughout the United States of America.

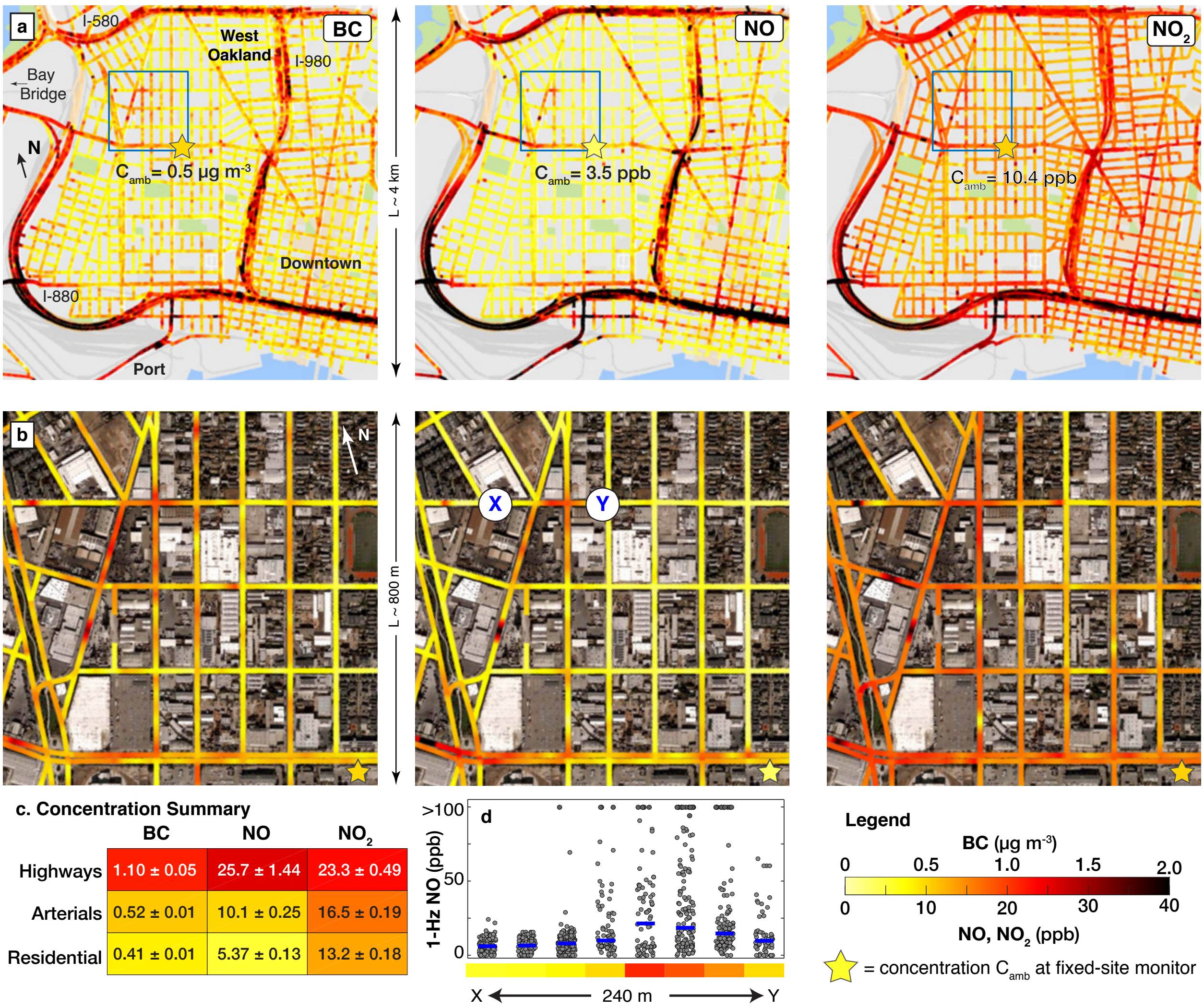
d. Mapping environmental justice: recent advances in technologies to characterize neighbourhood air quality

Addressing environmental injustice requires information about air pollution exposure levels within at-risk communities. This is beyond the intent and capability of the existing networks of federal reference monitors throughout North America. A range of new and maturing technologies are being deployed to conduct air quality characterization and surveillance at high spatial resolutions, though there are limitations in the use of these complex devices.

"Mobile monitoring" (air pollution sensors mounted on vehicles as they drive around) is a novel technique that captures air pollution concentrations at the street level. On-road monitoring of NO_x emissions using portable emissions measurement systems (PEMS) revealed substantially higher NO_x emissions from diesel passenger vehicles during in-use driving compared with emissions testing, leading to the discovery of "defeat devices" on some vehicle models (Thompson *et al.* 2014; U.S. EPA 2015). More recently, air quality sensors have been mounted on Google Street View mapping cars to create street-level spatial maps of black carbon and nitrogen dioxide concentrations, including in Oakland, CA and Houston, TX, revealing acute, small-scale variability in pollutant levels attributable to local emission sources (Apte *et al.* 2017; Miller *et al.* 2020) (Figure 7).

Several cities, including the Imperial Valley, CA; Los Angeles, CA; Portland, OR; Denver, CO; Chicago, IL; Baltimore, MD; and Pittsburgh, PA, have implemented networks of tens to hundreds of stationary "low-cost sensors" – instruments that measure pollution levels at much lower cost than federal reference monitors, but that do not meet the quality standards of federal reference methods. Lower-cost, distributed sensor networks are providing quantitative evidence of fine-scale (but often large) differences in short-term and long-term air quality. They are also becoming indispensable during events such as wildfire smoke episodes, where air quality can vary widely and change rapidly over densely populated areas and near-real-time information is needed to protect public health (see, for example, the AirNow Fire and Smoke Map available at https://fire.airnow.gov/ that uses low-cost sensor data to increase information on wildfire smoke exposure). However, the results must be appropriately adjusted and used with caution as the sensors operate differently to federal reference monitors and are often limited by significant

Figure 7. High-resolution map of black carbon, NO and NO_2 concentrations in West Oakland, California, using measurements from sensors mounted on Google Street View mapping cars



Source: Reproduced from Apte *et al.* (2017).

Note: Results indicate acute small-scale variability (up to between five and eight times) attributable to local sources, within individual city blocks.

Disclaimer: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

challenges with calibration and drift. U.S. EPA has developed guidance for setting up and maintaining low-cost sensors, and interpreting results from them (see https://www.epa.gov/air-sensor-toolbox).

Satellite remote sensing is also emerging as a critical information source for air quality surveillance, with the key advantages of complete geospatial coverage and relatively high spatial resolution (Duncan *et al.* 2014; Anenberg *et al.* 2020). Satellite observations have been used to derive surface NO_2 and $PM_{2.5}$ concentrations but are not yet able to observe tropospheric O_3 concentrations. New geostationary satellites may revolutionize air quality surveillance, with their full geographic coverage (over the region they are observing) and high spatial and temporal resolution compared with their polar-orbiting predecessors. Several studies demonstrate the utility of satellite remote sensing for exploring air pollution disparities within cities (Demetillo *et al.* 2020; Kerr, Goldberg and Anenberg 2021).

In addition to observations, chemical transport models and dispersion models are rapidly advancing in terms of spatial resolution, speed and accuracy, enabled by advances in computing power and scientific understanding. An increasing number of reduced form models, which simulate pollutant concentrations given a set of emissions inputs, also now enable users to estimate pollution changes from hypothetical retrospective or prospective emissions changes with limited computational needs. However, these reduced form approaches have many uncertainties and may not be able to tease out spatial distributions of pollution levels to assess disparities (Gilmore *et al.* 2019).

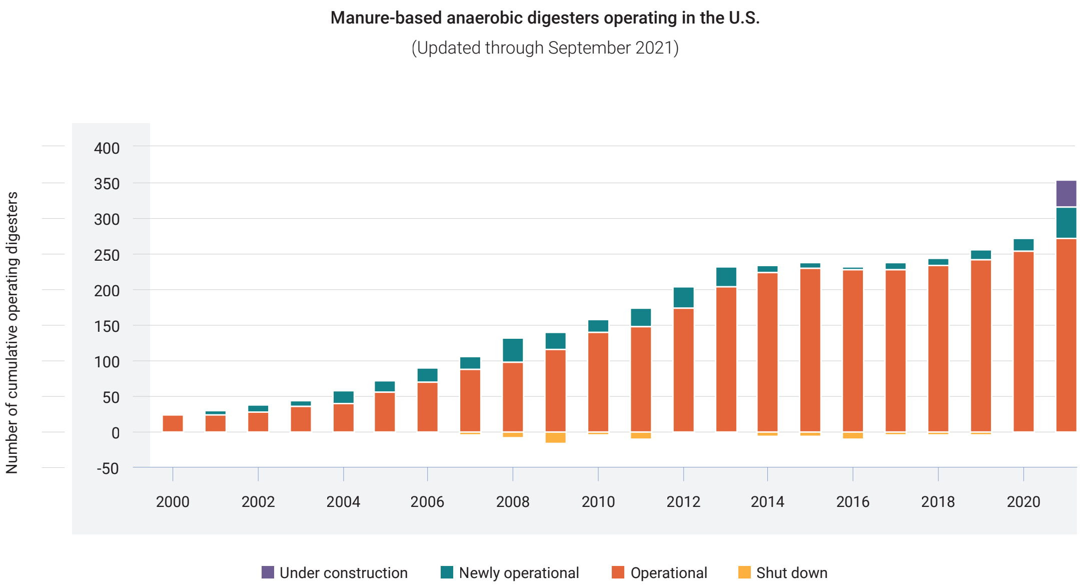
The recent, rapid proliferation of spatially-explicit air quality assessment tools is opening new avenues for assessing and tracking inequities in air pollution exposure. Combining these tools with personal exposure measurements, observations from federal reference monitors, and statistical techniques to predict air pollution levels with full spatial coverage and high spatial resolution can leverage the strengths of each of these approaches. In the future, these tools may provide governments at all scales access to more complete, refined and accurate air pollution information to potentially enable air quality management approaches to include community-level mitigation.

e. Agriculture: navigating climate and air quality trade-offs

Both countries in North America have supported efforts to reduce greenhouse gas emissions and short-lived climate pollutants from the agriculture sector. In the United States of America, the AgSTAR programme promotes the use of biogas recovery systems to reduce CH_4 emissions from livestock waste. AgSTAR assists those who enable, purchase or implement anaerobic digesters by identifying project benefits, risks, options and opportunities. Biogas can be collected from manure to meet on-farm energy needs. Excess capacity can be combusted to generate electricity and sold to the grid or upgraded to pipeline-quality renewable natural gas, which is injected into natural gas pipelines and used interchangeably as natural gas. This is becoming increasingly attractive in regions where renewable natural gas is used to meet low-carbon fuel standards, such as California and Oregon.

In September 2021, AgSTAR estimated that more than 317 manure anaerobic digester biogas recovery systems were in operation at commercial livestock facilities in the United States of America. In addition to the 44 systems that have come online to date in 2021, 38 more are under construction or undergoing modification. However, the potential is estimated to be far greater, with more than 8,000 candidate farms identified by U.S. EPA (U.S. EPA 2020d). USDA also provides direct financing for digesters through several programmes that are described in the Biogas Opportunities Roadmap (U.S. Department of Agriculture, U.S. Environmental Protection Agency and U.S. Department of Energy 2015).

Figure 8. Biodigesters have steadily increased in the United States of America



Source: U.S. EPA (2021d).

Canada has provided direct financing for farms under the Canadian Agricultural Strategic Priorities Program, which includes CAD 50 million over five years to encourage adoption of technologies such as biogas digesters. The programme has a similar number of operational projects as the United States of America. Millions more in funding is available for research and technology development (ECCC 2020a).

While this approach is seemingly a triple win for climate, air quality and rural economic development (itself an urgent priority for many governments), care is needed to ensure that biogas digesters are implemented within a solid regulatory framework that navigates potential trade-offs between all three dimensions. For example, it is critical that the potential CH_4 reductions are achieved in the context of emission performance standards for reciprocating engines, gas turbines or electrical generators used for biogas combustion, whether it be in combined heat and power applications or simply for electricity generation.

A critical aspect of this framework is recognizing that in addition to removal of water vapour and hydrogen sulfide gas that can lead to engine corrosion as well as SO_2 emissions, NO_x controls are important and often make use of selective catalytic reduction technology that requires periodic replacement of the catalyst to efficiently control NO_x emissions. An important consideration for this application is the mismatch between the cleanliness standards relative to siloxanes, a by-product of biogas digestion, for the engines themselves as opposed to the selective catalytic reduction control technology (South Coast Air Quality Management District 2014). The result is that combustion of high-siloxane biogas can significantly degrade the catalyst far more quickly than anticipated. This can either drive up maintenance costs (and eat into profits) for owners or result in early failure of control systems, leading to excess NO_x emissions and potentially degrading air quality if sources are not carefully monitored and maintained.

The North American region has successfully navigated these potential trade-offs by ensuring that regulatory performance standards for digester equipment reflect these nuances. It is important that air quality and climate objectives are reflected in national and subnational enforcement frameworks in all countries that move towards this significant advance for reducing agricultural air pollution.

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