HEALTH IMPACTS OF AIR POLLUTION FROM TRANSPORTATION, INDUSTRY AND RESIDENTIAL SOURCES IN CANADA

Estimates of premature mortality and morbidity outcomes at national, provincial, territorial, and air zone levels

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EXECUTIVE SUMMARY

Ambient (outdoor) air pollution is recognized globally as a major contributor to the development of disease and premature death and represents a key environmental risk factor to human health (GBD, 2020; WHO, 2013). Adverse health effects associated with ambient air pollution exposures range in severity from respiratory symptoms to the development of disease and premature mortality from heart disease, stroke and lung cancer. Estimates of air pollution-attributable deaths have ranked air pollution as the fifth leading mortality risk factor with 12.8% of deaths globally in 2019 (or 4.5 million premature deaths worldwide) (GBD, 2020; IHME and HEI 2019). The most recent air pollution burden assessment carried out by Health Canada (2021) estimated that a total of 15,300 premature deaths annually were associated with ambient air pollution exposure to above-background levels of ambient $PM_{2.5}$, ground-level ozone (O_3) and nitrogen dioxide (NO_2) in 2016.

This report estimates sector-specific population health impacts and socio-economic valuations at multiple geographic scales for Canada (i.e., national, provincial, territorial, air zone). A total of 21 major Canadian transportation and mobile equipment, industry, and residential source sectors were assessed by a modelling framework combining a multi-pollutant emissions inventory for the year 2015 with spatial allocation modelling, followed by air quality modelling, followed by health impact and socio-economic valuation modelling. Sector-specific estimates of air quality impacts are presented for fine particulate matter ($PM_{2.5}$), nitrogen dioxide (NO_2), ground-level ozone (O_3), and sulphur dioxide (SO_2). Sector-specific health impact estimates, comprising morbidity and mortality endpoints and corresponding socio-economic valuations, are presented for three key air pollutants: $PM_{2.5}$, NO_2, and O_3.

The consistent and multi-sector modelling framework applied in this analysis supports quantitative comparisons across sectors. As such, this report identifies important sectors affecting national and provincial/territorial air quality and health impact burdens in order to inform air quality management at these geographic scales. Health impact results are also reported by air zone, in order to better support air zone management within Canada's Air Quality Management System (AQMS).

At the national scale, the modelled sectors found to contribute the most to Canadian premature deaths in 2015 are home firewood burning (2,300 deaths), on-road transportation (1,200 deaths), and ore and mineral industry (910 deaths). The monetized value attributed to the total health impacts (i.e., sum of fatal and non-fatal outcomes) from these three sectors reach \$18 billion (B) for home firewood burning, \$9.5 B for on-road transportation, and \$7.2 B for the ore and mineral industry (CAD 2015). High morbidity is also attributed to these three sectors, such as a high number of acute respiratory and asthma symptom days (home firewood burning, 5.9 million (M) days; on-road transportation, 3 M days; ore and mineral industry, 2.4 M days), hospital admission and emergency room visits (home firewood burning, 1,300 visits; on-road transportation, 780 visits; ore and mineral industry, 500 visits), and child bronchitis cases (home firewood burning, 9,300 cases; on-road transportation, 3,600 cases; ore and mineral industry, 3,800 cases).

As context, Health Canada (2021) estimated health impacts attributable to above-background air pollution in Canada, including air pollution ($PM_{2.5}$, NO_2, O_3) from human sources in North America, to be 15,300 premature deaths per year, based on population data for 2016 and average air pollution concentrations from 2014 to 2017. The present report is intentionally focused on Canadian sector impacts on air quality and health to inform domestic actions and air quality management. Although these two reports use different approaches for estimating air pollution exposure, a comparison of results provides broader context to the sector-specific health burden results. The total number of deaths attributed to the 21 sectors assessed in the present analysis was approximately 6,900 deaths. This represents approximately 45% of the overall 15,300 total premature deaths previously attributed to air pollution (Health Canada, 2021). The nationally top-ranked sectors of home firewood burning, on-road transportation, and ore and mineral industry activity are estimated to contribute approximately 15%, 8%, and 6%, respectively, of total annual air pollution-related health impacts in Canada. Taken together, these three sectors are estimated to contribute approximately 30% of total estimated premature deaths attributable to air pollution in Canada in 2015. Other sources not assessed in this analysis are expected to also contribute to total air pollution-related deaths (e.g., agriculture, incineration and waste, dust, wildfires, and transboundary air pollution).

Nationally, across all modelled sectors and pollutants, the majority of air pollution-related premature deaths are associated with sector contributions to ambient $PM_{2.5}$ levels (5,900 deaths), followed by NO_2 (670 deaths), summer O_3 (270 deaths) and annual O_3 (100 deaths). The pollutants driving premature mortality estimates varied by region, although $PM_{2.5}$-related impacts are always dominant: $PM_{2.5}$-related deaths are often approximately ten times higher than NO_2-related deaths, particularly in Quebec, where they are approximately twelve times higher. However, in some Western provinces (Alberta, Saskatchewan) and several Atlantic provinces (Newfoundland and Labrador, Nova Scotia, Prince Edward Island) sector contributions to annual mean NO_2 and summer mean O_3 levels contribute comparably more to premature deaths than attributed to these pollutants elsewhere in Canada. For the modelled residential combustion sectors (home firewood burning, residential fuel combustion), related premature deaths are mostly attributed to sector contributions to ambient annual mean $PM_{2.5}$ levels (i.e., releases of $PM_{2.5}$ and precursors). For transportation and mobile equipment sectors (on-road, off-road, marine, rail, air), most related deaths are attributed to sector contributions to ambient annual mean $PM_{2.5}$ levels along with sector contributions to annual mean NO_2 levels. For industry sectors (upstream oil and gas, electric power generation, and pulp and paper manufacturing), the majority of premature deaths are attributed to sector impacts on annual mean $PM_{2.5}$ levels but deaths are also attributed to sector impacts on ambient annual mean NO_2 and annual/summer mean O_3.

Regionally, the highest number of air pollution-related premature deaths are estimated for the highly populated Central provinces of Quebec and Ontario, followed by next-highest deaths in Western region provinces. A comparably smaller number of deaths are estimated in Atlantic region provinces and none are estimated for the Northern territories. Regional trends for modelled morbidity endpoints are consistent with the mortality results.

By sector, the health impacts of the top-ranked home firewood burning, on-road transportation, and ore and mineral industry sectors are high in most provinces. Other sectors are strongly regional in their health impacts, ranking highly (within top three) in only one or few provinces. These more regional sectors include: oil and gas industry sector in Alberta and Saskatchewan; coal-fired electric power generation in Alberta, Saskatchewan and several Atlantic provinces; off-road vehicles and mobile equipment in British Columbia and Manitoba; marine transportation in Nova Scotia and Newfoundland and Labrador.

The sectors that dominate air pollution-related health impacts at the national or provincial/territorial scale may differ at the air zone scale, reflecting variations in air zone characteristics (e.g., population density, degree of urbanization, local industry) as well as potential influence of transported emissions released from sector sources in neighbouring air zones. Generally, higher health impacts were estimated in air zones with highly populated urbanized centres. By modelled sector, the on-road transportation and home firewood burning sectors dominated air pollution-related death in most air zones, while death from industry sector air pollution exhibit strongly regional trends, reflecting the concentration of proximal industry facilities: oil and gas industry emissions contribute to high air pollution-related deaths in all Alberta and Saskatchewan air zones; coal-fired electric power generation emissions contribute to high air pollution-related deaths in Alberta, Saskatchewan, and most Atlantic province air zones; and ore and mineral industry emissions contribute to high air pollution-related deaths in nearly all Manitoba, Ontario, Quebec, New Brunswick and Nova Scotia air zones.

Individual sector results within this multi-sector health impact assessment compare well with Health Canada's prior sector-based assessments completed for gasoline exhaust emissions (Health Canada, 2017) and diesel vehicle exhaust emissions (Health Canada, 2016). Comparison against a prior assessment of health impacts for wildfire $PM_{2.5}$ in recent years in Canada (Matz et al., 2020) indicates that, for some regions, home firewood burning emissions may contribute a similar number of annual deaths (2,300) as wildfire emissions during a year with a severe wildfire season exposing populated areas (i.e., 600 - 2,700 deaths annually over 2013-2018; Matz et al., 2020). Estimates of air quality and health impact for the top-ranking sectors identified in the current analysis are also consistent with prior multi-sector assessments in the scientific literature (Meng et al., 2019; McDuffie et al., 2021), notwithstanding modelling and data differences.

Efforts have been made to use the best available air quality and health modelling tools and data for Canada with inherent limitations and uncertainties (e.g., availability and quality of Canadian emissions inventory data and Canadian health data supporting selection of concentration-response functions). The air pollution-associated health impacts presented in this report are based solely on exposure to ambient concentrations of $PM_{2.5}$, NO_2 and ground level O_3. These pollutants are included because there is robust epidemiological evidence of their adverse health impacts and the spatial distribution of their ambient concentrations across Canada can be accurately estimated. However, owing to data limitations and knowledge gaps, not all associative health effects demonstrated for exposure to $PM_{2.5}$, NO_2 and O_3 can currently be quantified. Further, there are other air contaminants that contribute to air pollution health impacts that are beyond the scope of this work. Thus, the quantitative estimates of population health impacts provided in this report are assumed to underestimate the full impact of exposure to air pollution in Canada. In addition, the current analysis provides a regional evaluation of health burden, rather than an assessment of local risks for communities in direct proximity to emissions sources, such as locations near high-traffic roadways and those near industrial facilities.

This health impact assessment has quantified health burdens and monetary costs that can be attributed to air pollution emissions from multiple transportation, industry, and residential sectors at multiple geographic scales, including at the national, provincial/territorial, and air zone level. The current analysis has identified several key sectors contributing health impacts and thus contributes to our understanding of the health risks associated with exposure to transportation and mobile equipment, industry, and residential emissions in Canada. It is intended that this information on sector-specific air pollution-related population health burden will inform provincial, territorial and regional stakeholders, including air zone managers, and support further development of effective air quality management strategies.

1 Introduction

1.1 Background

Ambient (outdoor) air pollution is recognized globally as a major contributor to the development of disease and premature death, and represents a key environmental risk factor to human health (GBD, 2020; WHO, 2013). Adverse health effects associated with ambient air pollution exposures range in severity from respiratory symptoms to the development of disease and premature mortality from heart disease, stroke and lung cancer.[1] The health and atmospheric sciences have advanced meaningfully in the past two decades, making it possible to estimate the number of deaths and illnesses associated with ambient air pollution exposure. These values are estimated using information from peer-reviewed scientific literature relating population-level pollution exposure, both short-term and long-term, to the risk of adverse health outcomes such as premature death and hospital admission and emergency room visits.

Estimates of air pollution-attributable deaths and other adverse health outcomes have been developed globally and for many individual countries, including recently by McDuffie et al. (2021), Thakrar et al. (2020), Liu et al. (2019), Burnett et al. (2018), Cohen et al. (2017), the Institute for Health Metrics and Evaluation (IHME) and the Health Effects Institute (HEI) (2018), and the World Health Organization (WHO) (2016). According to the Global Burden of Disease (GBD) project, air pollution is the fifth leading mortality risk factor in the world and long-term exposure to ground-level ozone (O_3) and outdoor fine particulate matter ($PM_{2.5}$) was responsible for 12.8% of deaths globally in 2019 (or 4.5 million premature deaths worldwide) (GBD, 2020; IHME and HEI, 2019). Estimates of total air pollution-attributable deaths in Canada have previously been developed by Health Canada (2021, 2019, 2017), Stieb et al. (2015), the Canadian Medical Association (2008), and as part of the GBD project (GBD, 2020; IHME and HEI, 2019). The most recent air pollution burden assessment carried out by Health Canada (2021) estimated that a total of 15,300 premature deaths were associated with ambient air pollution exposure to above-background levels of ambient $PM_{2.5}$, ground-level ozone (O_3) and nitrogen dioxide (NO_2) in 2016. Health Canada's prior sector-based assessments have examined single sources (i.e., gasoline exhaust emissions, diesel exhaust emissions, wildfire-generated $PM_{2.5}$) (Health Canada, 2017, 2016; Matz et al., 2020).

This report presents a multi-sector and sector-specific health impact and economic benefits assessment for Canadian exposures to ambient air pollution. The assessment quantifies and compares sector-specific air quality impacts, health impacts, and socio-economic valuations associated with air pollutant releases from a comprehensive list of Canadian sectors representing transportation, industry, and residential source types.

1.2 Objective and scope

This assessment evaluates and compares sector-specific air quality and health impacts for 21 Canadian sectors representing transportation, industry, and residential source types. While comprehensive, the list of modelled sectors does not include all possible sectors in the Canadian Air Pollution Emissions Inventory (APEI). Sectors not assessed in the current analysis are: Agriculture, Incineration and Waste, Paints and

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[1] Exposure to air pollution is a contributing risk factor to the development or worsening of adverse health effects, among multiple risk factors. While air pollution can contribute to increased risk of population health impacts, this does not necessarily imply that air pollution is the sole cause.

solvents, Dust, Fires, and Commercial / Residential / Institution. However, within Commercial / Residential / Institution, the key residential sectors of Home Firewood Burning and Residential Fuel Combustion are modelled.

The multi-sector approach of this health impact assessment is intended to help better identify sectors affecting national and provincial/territorial air quality and population health across Canada. To better support risk management decision-making and air pollution policy, air quality impacts and health impact results are presented at multiple geographic scales (national, provincial, territorial) and health impact results are also presented by air zone.

This analysis is aligned with the federal government's role and responsibility under Canada's Air Quality Management System (AQMS) to "identify and assess environmental and health-related knowledge gaps and use science-based information to assess the impact of identified air pollutants of concern and inform Canadians and decision-makers" (CCME, 2012). This assessment directly fulfils Health Canada's responsibility under AQMS to "investigate the impact of air pollution on human health" (CCME, 2012).

This assessment was led by Health Canada (HC) in collaboration with Environment and Climate Change Canada (ECCC). As in prior Canadian assessments (Health Canada, 2021, 2019, 2017, 2016; Stieb et al., 2015), health impact estimates and socio-economic valuation are presented for three key air pollutants for which there is robust epidemiological evidence of adverse health impacts: fine particulate matter ($PM_{2.5}$), nitrogen dioxide (NO_2), and ozone (O_3). Health impact estimates are not assessed for other toxic air pollutants such as sulphur dioxide (SO_2), carbon monoxide (CO), individual volatile organic compounds (VOCs; e.g., formaldehyde, benzene) or $PM_{2.5}$-associated metals. Sector-based health impact estimates are provided at the air zone level but more localized risk levels are not specifically assessed, such as for communities adjacent to intense source activity (e.g., near-roadside or near industry facilities).

1.3 Organization

This report organizes methods and results for the air pollution health impact analysis into five sections and an appendix as follows:

- **Introduction:** Overall objectives, scope, and value of the sector-based air pollution health impact analysis. (Chapter 1)
- **Methodology:** Technical summary of the sector-based emissions inventory modelling, air quality modelling, and health impact and socio-economic valuation modelling. (Chapter 2)
- **Results:** Sector air pollutant emissions and sector contributions to ambient air quality at national and provincial/territorial scales. Estimates of the health impact and socio-economic valuation attributable to air pollution associated with individual sectors at national, provincial/territorial, and air zone scales. (Chapter 3)
- **Discussion:** Identification of top-ranking sectors of interest based on higher health impacts, comparison of air quality and health impact estimates with prior sector-based assessments, methodological factors and sources of uncertainty in the analysis. (Chapter 4)
- **Conclusions:** Value of sector-based air quality and health impacts information to risk management decision-making and air pollution policy at provincial, territorial, and air zone levels. (Chapter 5)

- **Appendix:** Detailed total and sector-specific air quality impact and health impact estimates, by province/territory (Appendix A.1) and air zone (Appendix A.2).

A *Supplementary Material* document is available (upon request) alongside this report. The *Supplementary Material* includes detailed individual sector emissions data, emissions spatial allocation maps, additional maps of air quality model output (i.e., maps of sector contributions to ambient concentrations), additional health impact model results (i.e., morbidity cases by pollutant at national level), and additional technical information on modelling methodology.

2 Methodology

2.1 Modelling framework

This health impact assessment applied an integrated multi-model framework with four sequential steps:

1. *Emissions inventory* development via ECCC's *Air Pollutant Emissions Inventory* (APEI), referencing 2015 emissions data.[2]

2. Spatial allocation of air pollutant releases (from step 1) to a national grid surface using the United States Environmental Protection Agency's (US EPA) *Sparse Matrix Operator Kernel Emissions* (SMOKE) model.

3. *Air quality* modelling via ECCC's chemical transport model (CTM) *Global Environmental Multiscale model – Modelling Air quality and CHemistry* (GEM-MACH). GEM-MACH combines the SMOKE emissions allocations (from step 2) with meteorological data and specific algorithms to simulate atmospheric diffusion, transport and chemical transformation of gaseous and particle pollutants and thereby predict air pollutant concentrations over a continental grid surface.

4. *Health impact and socio-economic valuation* modelling via HC's *Air Quality Benefits Assessment Tool* (AQBAT) for multiple mortality and morbidity endpoints associated with population-level exposure to ambient concentrations of particle and gaseous criteria pollutants (from step 3).

To estimate the air quality impacts, health impacts, and socio-economic valuations associated with air emissions from individual sectors, the brute force sensitivity analysis "zero-out" method was used in the air quality modelling (i.e., step 3 of modelling framework). Briefly, this involves applying the air quality model to a "base case" where all inventoried emissions influencing air quality are included in the simulation across the gridded model surface. Next, the air quality model is run repeatedly in individual "sector scenarios" in each "sector scenario" simulation, the emissions of all pollutants from a particular sector or group of sectors are "zeroed out" (i.e., set to a value of 0). The sector's air quality impacts across the modelling domain are estimated as the difference between the "base case" and "sector scenario" model run pollutant concentrations. The sector-specific pollutant concentration estimates are then aggregated from the

[2] Modelling applied the 2015 annual year emissions inventory for all sectors with the exception of home firewood burning, which applied 2010 emissions inventory data as these were determined by ECCC to provide more accurate estimates for this sector.

modelling domain's grid scale (10 km x 10 km) to larger census division (CD) areas using area-weighting and are then used as input to the health impact model, yielding CD-scale estimates of mortality, morbidity, and socio-economic valuation. Finally, the CD-scale estimates of sector contributions to air pollutant concentrations and corresponding health impacts are aggregated to larger geographic scales. In this report, CD-scale sector impacts on air quality were aggregated via population-weighting and reported at the provincial, territorial, and national scales. CD-scale sector impacts on health were summed to report at the provincial, territorial, and national scales and further aggregated using area-weighting to report air zone scale health outcomes. Additional methodological details of the modelling are provided in the following sections and in the *Supplemental Material* (available upon request).

2.2 Sectors assessed

This assessment evaluated and compared sector-specific air quality and health impacts for 21 Canadian sectors representing transportation, industry, and residential source types. The complete list of sectors assessed by this analysis is presented in Table 2-1. Sector names used throughout this report reflect those in the Air Pollution Emissions Inventory (APEI) (ECCC, 2022).

The list of modelled sectors was comprehensive but did not include all possible APEI sectors. Sector classes not assessed were: Agriculture, Incineration and Waste, Paints and Solvents, Dust, Fires, and Commercial/Residential/Institution. However, within Commercial/Residential/Institution, key residential sectors of Home Firewood Burning and Residential Fuel Combustion were modelled.

2.3 Pollutants assessed

Emissions inventory data are presented in this report for fine particulate matter ($PM_{2.5}$), inhalable particulate matter (PM_{10}), and multiple gaseous pollutant species: oxides of nitrogen (NO_x), carbon monoxide (CO), oxides of sulphur (SO_x), volatile organic compounds (VOC), and ammonia (NH_3). These data were processed and applied in GEM-MACH to drive the air pollution estimates, in addition to emissions of other pollutants not reported here.

Sector-specific estimates of air quality impacts and health impacts, along with socio-economic valuations, are presented for three health-relevant air pollutants: fine particulate matter ($PM_{2.5}$), nitrogen dioxide (NO_2), and ozone (O_3). These pollutants are assessed because there is robust epidemiological evidence of their adverse health impacts at very low concentrations and no evidence of an exposure threshold (i.e., any incremental increase in air pollutant concentration is associated with an increased risk of adverse health outcomes) and because they are amenable to air quality modelling of the spatial distribution of their ambient concentrations across Canada. The three assessed pollutants account for the majority of population health impacts from air pollution (Health Canada, 2021).

Table 2-1 List of modelled sectors.

	Sector description and notes (adapted from ECCC, 2022)
TRANSPORTATION & MOBILE EQUIPMENT SECTORS	
ALL On-road	**Includes exhaust emissions, evaporative emissions, and tire/brake wear emissions for all on-road light duty vehicles (LDV) and heavy duty vehicles (HDV).**
On-road LDV	*Exhaust emissions, evaporative emissions, and tire/brake wear emissions from vehicles under 3,856 kg, including cars, trucks, motorcycles; all fuel types (gasoline, diesel, propane, natural gas).*
On-road HDV	*Exhaust emissions, evaporative emissions, and tire/brake wear emissions from vehicles > 3,856 kg; all fuel types (gasoline, diesel, propane, natural gas).*
Off-road vehicles & mobile equipment	*Exhaust emissions from off-road vehicles and mobile equipment using all fuel types (gasoline, diesel, propane, natural gas) in mining, construction, agriculture, commercial purposes, logging, railway maintenance, airport ground support, lawn and garden equipment, recreational vehicles.*
Air + Marine + Rail	**The sum of air and marine and rail transportation sectors was modelled separately in this analysis.**
Air transportation	*Includes landing and take-off exhaust emissions for all piston and turbine aircraft (commercial, private, military). Does not include cruise emissions (released at high altitude above troposphere thus minimal impact on ground-level ambient population exposures).*
Marine transportation	*Includes exhaust emissions from all marine vessels operating within Canadian waters (domestic, international, fishing, military).*
Rail transportation	*Exhaust emissions from freight and passenger trains, including yard switching activities.*
INDUSTRY SECTORS	
Ore and mineral industry	**Includes multiple subsectors. Within this group of sectors, modelled separately were: cement manufacturing, non-ferrous refining and smelting.**
Cement manufacturing	*Includes emissions from entire process of cement production in rotary kilns, and preparation of concrete and ready-mix concrete, lime manufacture and concrete batching and products.*
Non-ferrous refining and smelting	*Includes primary copper and nickel production, lead ore crushing, concentrating and metallurgic processing, zinc metal production, and smaller non-ferrous refining and smelting sources (e.g., magnesium, cobalt and uranium industry processes).*
Oil and gas industry	**Overall oil and gas industry sector impacts were estimated by summing the two sub-sector model results modelled individually (i.e., upstream, downstream).**
Upstream oil and gas	*Drilling, testing and servicing of wells, conventional oil and gas production, in situ bitumen extraction and open-pit mining, oil sands upgrading, natural gas processing, crude oil transmission, natural gas transmission and storage.*
Downstream oil and gas	*Refining and processing of crude oil to make fuels or other products (e.g., solvents, asphalt). Storage and distribution of refined petroleum products, natural gas distribution and liquid natural gas processing.*
Electric power generation	**Includes multiple subsectors. Within this group of sectors, coal-fired electric power generation was modelled separately.**
Coal-fired electric power gen	*Electric power generation from combustion of coal by utilities (publicly and privately owned) for commercial sales and/or private use.*
Manufacturing	**Includes multiple subsectors. Within this group of sectors, modelled separately were: chemicals, pulp and Paper.**
Chemicals	*Product industries including fertilizer manufacturing, plastic resins, paints and varnishes, petrochemicals, inorganic chemicals, and pharmaceuticals.*
Pulp and paper	*Chemical, mechanical, recycling and semi-chemical mills, including the production of energy through the combustion of process waste products.*
RESIDENTIAL SECTORS	
Residential fuel combustion	*Combustion of fossil fuels used for space/water heating in residences.*
Home firewood burning	*Burning of wood, pellets and manufactured logs as fuel for space heating and hot water. Includes emissions from fireplaces, wood stoves and wood-fired boilers.*

2.4 Emissions inventory

For this assessment, a detailed emissions inventory for the year 2015 was developed by Environment and Climate Change Canada (ECCC), referencing Canadian emissions data as published in the Air Pollutant Emissions Inventory (APEI) in the 2017 release year.[3] When this multi-sector assessment project was initiated, the 2015 inventory year was the most current complete year of data available for use in the air quality modelling (step 2). The APEI 2015 dataset was used for modelling of all sectors with exception of home firewood burning, which referenced an earlier APEI 2010 dataset release due to that year's data being considered by ECCC as more representative.[4]

Depending on the source sector, the emissions inventory used in this analysis was based on either calculated data (i.e., transportation sectors, residential sectors) or reported data (i.e., industry sectors) (ECCC 2015, 2020). On-road transportation and off-road vehicles and mobile equipment sector emissions were estimated using mobile source emission models for distinct vehicle or equipment classes that together comprise the overall Canadian transportation vehicle fleet (i.e., US Environmental Protection Agency MOVES 2014b for on-road vehicles and US EPA NONROAD 2012c for off-road vehicles and mobile equipment, both of which were modified by ECCC to reflect Canadian conditions). In general terms, these emissions inventory models aggregate the sum of vehicle emissions releases, estimated as vehicle activity data multiplied by vehicle class-specific emission factors. (ECCC, 2022)

Industry sector emissions were estimated based on individual facility reporting of monthly and annual industrial pollutant releases to air (and other environmental compartments) to the National Pollutant Release Inventory (NPRI). Residential sector emissions were estimated as area sources based on activity data and best available emission factors.

The 2015 inventory database was further processed by ECCC to generate a dataset that can be used in the US EPA *Sparse Matrix Operator Kernel Emissions* (SMOKE) model (Sassi et al. 2016), which allocates all emissions to a national grid surface (SMOKE version 3.7 used for this work). Spatial surrogates in the form of geographic information system (GIS) shapefiles were also used to distribute emissions across Canada. The spatially allocated emissions were used as input to the CTM.

[3] The emission inventory for the United States was the 2017 projection based on the US EPA 2011 National Emissions Inventory (NEI; www.epa.gov/air-emissions-inventories/2011-national-emissions-inventory-nei-data). The 2008 inventory (*Inventario Nacional de Emisiones*, INEM; www.gob.mx/semarnat/documentos/documentos-del-inventario-nacional-de-emisiones) used for Mexico was also from the US EPA 2011 NEI. Wildfire emissions are not included in the emissions inventory.

[4] Through the review of preliminary modelling, the 2015 emissions dataset (2017 release version) for the home firewood burning sector was identified by ECCC as representing an overestimate. An earlier 2010 emissions dataset for home firewood burning was referenced to correct this and ensure that all modelled sectors used best available input data. The 2010 national total estimates of home firewood burning sector emissions of $PM_{2.5}$ and other pollutants presented in this report and used in this modelling are also better aligned with the most recent published updates to this sector's APEI data (ECCC 2022).

2.5 Air quality modelling

2.5.1 Chemical transport model (CTM)

The chemical transport model (CTM) used for this assessment was ECCC's operational model, the Global Environmental Multiscale – Modelling Air quality & CHemistry (GEM-MACH) model, version 2.3.1. GEM-MACH is a prognostic tool that integrates emissions inputs, meteorological data, and algorithms to simulate the diffusion, transport and chemical transformation of gases and particles in the atmosphere (e.g., Makar et al. 2018; Moran et al. 2010; Whaley et al. 2018, 2020). This version of GEM-MACH is used by ECCC to simulate hourly concentrations of air pollutants including $PM_{2.5}$, NO_2, SO_2 and O_3 over a North American domain, in support of air quality regulations and management decisions for Canada.

The general air quality modelling approach included simulations conducted over a continental domain with a horizontal grid spacing of 10 km and 80 hybrid vertical levels extending from the surface (1.5 m) to 0.1 hectoPascal (approximately 30 km). GEM-MACH simulations are done for a complete year, computing 24 hours of forecast for each day. The model's time step is 300 seconds, such that meteorological and atmospheric conditions are computed every five minutes. Hourly simulated output values include pollutant concentrations. Simulations were conducted using 2017 meteorology (i.e., ECCC forecasts produced operationally on a daily basis in 2017).

The post-processing of GEM-MACH results consists of computing different statistics using an automated suite of tools, such as Kornshell and Tcl scripts, as well as C/C++ and FORTRAN programs. The statistics include, for example, averages, rolling averages, maximum values and differences between scenarios, for different periods (monthly, annual and seasonal). Statistics are computed for the 10 km x 10 km model grid and can be interpolated on different geographical areas, such as Census Divisions (CDs) as used in AQBAT. The final products are available in formats such as ASCII, binary, Geographic Information System (GIS), and graphical format, depending on the research objectives.

From the gridded results, ambient air pollutant estimates were generated at the CD level for $PM_{2.5}$, NO_2, O_3, and SO_2 for linkage with AQBAT. The results represent regional air pollution conditions and do not reflect local effects and microenvironments that are unresolved by the 10 km horizontal grid size, such as roadways and street canyons, where air pollution levels may be higher.

2.5.2 "Zero-out" modelling approach

In this report, the brute force or "zero-out" modelling approach was used to estimate the air quality impacts associated with reductions in air pollutant emissions from individual sectors or sector groups. This is summarized as follows:

i. "Base case" air quality was modelled to include all inventoried emissions, from all sources. This generated air quality estimates for $PM_{2.5}$, NO_2, SO_2, and O_3 over a national gridded model surface.
ii. "Zeroed-out sector scenario" air quality was modelled for each scoped sector by systematically setting their emissions to zero over the same national gridded surface.
iii. For each modelling grid cell across the national gridded surface, the difference in air pollutant concentrations between the "base case" and "zeroed-out" sector scenarios represent an estimate of each sector's contribution to air pollutant concentrations.

2.5.3 Model output

For pollutants assessed ($PM_{2.5}$, NO_2, O_3, summer O_3, SO_2), ground-level concentrations were estimated for each model grid cell (10 km x 10 km resolution). Average ground-level concentrations were calculated using the following metrics:

- $PM_{2.5}$, NO_2, SO_2: annual average from hourly data;
- O_3: annual average based on daily maximum of hourly data (i.e., daily 1 h maximum); and
- summer O_3: May-September average based on daily maximum of hourly data (i.e., daily 1 h maximum).

The units for NO_2, O_3 and SO_2 are in parts per billion by volume (ppb) while $PM_{2.5}$ values are in micrograms per cubic metre (µg/m^3).

The ground-level concentration estimates output from GEM-MACH were then aggregated using area-weighting to larger area Canadian CDs, referencing Statistics Canada Census geographical data which divides the country into 293 CDs (2011 Census). Area-weighted concentrations for each CD were determined by summing the product of a grid cell concentration and the area of that grid cell occupied by the CD, for all grid cells intersecting with the CD, and then dividing the sum by the area of the CD. For example, if three grid cells intersect with a CD, the following formula would apply to determine its concentration (C_d):

$$C_d = (A_{d1} \times C_{g1} + A_{d2} \times C_{g2} + A_{d3} \times C_{g3}) \div A_d$$

where A_{dx} is the area of overlap between the model grid cells and the CD, C_{gx} is the concentration of the grid cell g*x*, and A_d is the area of the CD.

Population-weighting was then used to further aggregate the CD-scale air pollutant concentrations to provincial, territorial, and national air pollutant concentrations, thereby providing an estimate of the average exposure concentration for an individual within a province/territory or nationally. Population-weighted concentrations for all provinces and territories were calculated by summing the product of a CD concentration and the population of that CD, for all CDs in a province, and then dividing the sum by the provincial population. For example, if a province includes three CDs, the population-weighted concentration (C_{pw}) is determined by:

$$C_{pw} = (CD_{d1} \times CD_{pop1} + CD_{d2} \times CD_{pop2} + CD_{d3} \times CD_{pop3}) \div PT_{pop}$$

where CD_{dx} is the concentration of CD_x, CD_{popx} is the population of CD_x, and PT_{pop} is the population of the province. The same method was used to estimate the population-weighted national average.

Population-weighting assigns more influence or weight to CDs with high populations than CDs with low populations when averaging across a larger geographic area (e.g., province, territory), thereby yielding a more meaningful estimate of the average pollutant concentration to which Canadians are exposed. This is especially important in Canada as the majority of the population resides in urban areas in the southern portion of the country, with comparably low populations residing in rural and northern areas.

2.6 Health Impacts Assessment

2.6.1 Calculating population health impacts due to air pollution

The health impact modelling in this report was conducted using Health Canada's *Air Quality Benefits Assessment Tool* (AQBAT) (Judek et al., 2019), version 3.0.[5] AQBAT estimates the number of premature deaths and other adverse health outcomes in Canada associated with a specified change in ambient air pollution concentration. For this report, the change in air pollution concentrations was obtained from GEM-MACH model output at the CD-scale level. Health effect information for assessed air pollutants ($PM_{2.5}$, NO_2, O_3, summer O_3) is included in the form of concentration-response functions (CRFs), which describe the association between exposure to an air pollutant and a health response. A CRF represents the excess health risk for a given endpoint (e.g., asthma symptoms, chronic bronchitis, and acute exposure mortality) that follows a unit increase in ambient pollutant concentration. CRFs in AQBAT are statistically derived estimates from a single study or a meta-analysis of multiple studies.[6]

Health endpoints related to acute or chronic exposure, the associated CRFs, and the applicable population group(s) (e.g., age-specific groups) are predefined within AQBAT and represent Health Canada-endorsed values drawn from the peer-reviewed health science literature. The pollutants and associated health effects considered in this health impact analysis are listed in Table 2-2.

In the context of this analysis, short-term exposure contributes to effects that occur within a few days of an increase in ambient air pollution (i.e., acute health effects), while long-term exposure contributes to chronic health effects. Previous studies (e.g., Crouse et al., 2012; Judek et al., 2019; Shin et al., 2013; Stieb et al., 2015) contain background information on the CRF estimates used in this analysis (i.e., references to the scientific literature upon which the risk estimates are based) and the analysis undertaken to produce the estimates within AQBAT. Health outcomes were considered to have no threshold for effect (i.e., effects were assumed to occur at all levels of exposure).

CRFs can be input as a distribution function in AQBAT, accounting for inherent uncertainty in the CRF estimates. Monte Carlo simulations employing 10,000 iterations were used to propagate this uncertainty in the CRFs. The model generates a central estimate of the most likely health impacts equal to the median of the output distribution, as well as low- and high-end estimates equal to the 2.5 and 97.5 percentiles of the output distribution.

Baseline incidence rates in the Canadian population for each health endpoint (e.g., risk of death due to cardiovascular disease) are needed to estimate counts of health outcomes in a target population. General population and age-specific baseline incidence rates for a target population are included in AQBAT. For example, the *Restricted Activity Days* endpoint is assigned to 100% of all adults (20 years of age and older) and 85.7% of children aged 5 to 19 years (non-asthmatic). For each AQBAT morbidity and mortality health endpoint, baseline incidence rates are represented by a data file with estimated annual events per million specified population for every geographic area (e.g., census district), age group, scenario year and population projection. Baseline incidence rates are estimated by Health Canada from detection, observation and

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[5] Guoliang Xi and Dave Stieb, personal communications, Health Canada, 2019.

[6] The version of AQBAT used for the current analyses used linear CRFs. However, both linear and non-linear CRFs have been reported in the health science literature and can be used in AQBAT.

reporting through formal means (e.g., death certificates, hospital admission records), from data provided by Statistics Canada, or from epidemiological studies. Incidence rates are generally associated with many factors, such as age, gender, race, education, income, environmental factors and lifestyle habits. Exposure to pollutants typically has a minor influence on the baseline incidence rates. Additional details and references on derivation of baseline rates have previously been published (Judek et al., 2019; Stieb et al., 2015).

The health impacts were generated by AQBAT output at the CD-scale level (i.e., directly corresponding to the CD-scale change in air pollution concentrations obtained from GEM-MACH model output) and aggregated to the larger geographic scales presented in this report: national, provincial/territorial, and air zone.[7]

2.6.2 Calculating the economic value of health outcomes due to air pollution

In this report, estimates of the monetized costs (i.e., health-related welfare impacts) associated with exposure to air pollution factor in the potential social, economic and public welfare consequences of health outcomes including medical costs, reduced workplace productivity, pain and suffering, reduced risk of death, and the other outcomes of increased health risks. Expressing impacts using a monetized value provides a common metric across health endpoints (i.e., fatal and non-fatal outcomes) to estimate the overall health impacts of exposure to ambient air pollution. The sum of the monetized impacts provides an indication of the relative benefits or damages to society as a whole resulting from risks to health.

Each health endpoint assessed in this report was assigned a monetized value (i.e., health-related welfare impacts) derived from survey, accounting, economic or actuarial data. The endpoint value has an uncertainty reflected by a distribution of possible values with corresponding parameters (i.e., valuation estimates are entered as a distribution in AQBAT). The valuation estimates used in the model and references to the studies from which they are derived are provided in Judek et al. (2019). In this assessment, valuation estimates are expressed in Canadian dollars and were adjusted based on the Consumer Price Index as defined by Statistics Canada for estimating costs in 2015 currency (Judek et al., 2019; Statistics Canada, annual).

The monetized value for mortality endpoints is considerably higher than those for other health endpoints. The recommended central estimate of an avoided premature death for policy analysis is $6.5 M (in 2007 currency), based on a review of Canadian studies by Chestnut and De Civita (2009). It relies on analyses indicating that an average Canadian would be willing to pay approximately $65 in order to reduce the risk of premature death by 1 out of 100,000. The aggregate willingness to pay (WTP) of $65 over 100,000 Canadians (for which one death is avoided) equals the value of one avoided death. The recommended low value is $3.5 M and the recommended high value is $9.5 M. These values represent a reasonable range for a primary analysis and should not be considered as lower and upper bounds (Chestnut and De Civita, 2009). Moreover, the values are not equivalent to the economic worth of an identified person's life, but rather an aggregation of an individuals' willingness to pay for small changes in risk.[8] Following adjustments based on the Consumer Price Index, the central value of an avoided premature death in 2015 is $7.4 M (CAD 2015).

[7] CD boundaries are aligned with larger scale air zone, provincial/territorial, and national boundaries, enabling direct arithmetic summation of health impacts and economic value data.

[8] Empirical studies of willingness to pay (WTP) for mortality risk reductions estimate average monetized amounts that individuals are willing to pay for small reductions in premature mortality. The valuation context or an individual's circumstances influence their WTP values. WTP reflects all the reasons individuals put a value on to reduce their own risk of death. Therefore, it can exceed the value of the financial impact to an individual associated with the change in risk.

2.6.3 Health impact reporting at the air zone scale

In accordance with their responsibilities under the Air Quality Management System (AQMS), Canadian provinces and territories have each defined one or more air zones within their respective geographic boundaries. Individual air zones are considered to have unique air quality characteristics that influence ambient air concentrations of managed pollutants (i.e., $PM_{2.5}$, NO_2, SO_2, O_3), such as emission sources, topography, meteorology, or population density. Air zones are used by provinces and territories to manage and improve local air quality, maintaining air pollutant concentrations below the Canadian Ambient Air Quality Standards (CAAQS) (CCME, 2019, 2021). Air zone boundaries across Canada are shown in Figure 2-1. Additional detailed maps of air zone names and boundaries within each province are provided in *Appendix A* (Section A.2.11).[9]

The sectors that dominate air pollution-related health impacts at the national or provincial/territorial scale may differ at the smaller air zone scale. Thus, this report also presents sector-specific health impact analysis results by individual air zone. These results are provided to inform the management of air quality within each province and territory, identifying the dominant pollutants and sectors contributing to adverse health impacts within each provincial/territorial air zone.

Figure 2-1 Air zone boundaries across Canada.

[9] Additional information about Canada's Air Quality Management System (AQMS), along with an interactive map showing individual air zones, are available online at: https://ccme.ca/en/air-quality-report

Table 2-2 Pollutants assessed in health impact modelling (AQBAT), averaging periods and associated health endpoints.

Pollutant [a]	**Averaging period**	**Health endpoint**
NO_2	24 h	Acute exposure mortality [b,c]
O_3	1 h maximum	Acute exposure mortality [b]
O_3 summer (May–September)	1 h maximum	Acute respiratory symptom days
		Asthma symptom days
		Chronic exposure respiratory mortality
		Minor restricted activity days
		Respiratory emergency room visits
		Respiratory hospital admissions
$PM_{2.5}$	24 h	Acute respiratory symptom days
		Adult chronic bronchitis cases
		Asthma symptom days
		Cardiac emergency room visits
		Cardiac hospital admissions
		Child acute bronchitis episodes
		Chronic exposure mortality
		Respiratory emergency room visits
		Respiratory hospital admissions
		Restricted activity days

[a] Unless otherwise specified, concentration-response functions reflect an exposure to the pollutant at any time during the year.

[b] The CRF between acute exposure mortality and gaseous pollutants is from a model including CO, NO_2, O_3 and SO_2 and may not precisely reflect the true attribution of risk to individual pollutants.

[c] It is recognized that the concentration-response function for acute exposure mortality associated with NO_2 exposure may reflect a causal relationship with NO_2 or NO_2 may be acting as a surrogate for a specific component of the air pollution mixture, such as vehicle exhaust emissions.

2.7 Limitations and Strengths

Although effort was made to use the best available tools and data, there are inherent limitations and uncertainties in the modelling results presented in this report. Uncertainty in emissions, air quality, health and economic impact modelling, or imperfect spatial and temporal predictions, may arise for a variety of reasons (e.g., data limitations, simplified algorithms).

Health impact assessment results may be considered to be particularly dependent on the quality of emissions inventory data, since assumptions made during emissions inventory development are reflected in all subsequent stages of the analysis (e.g., air quality modelling, health impact analysis). All emission factor models were deterministic in nature (i.e., they provided single values). This did not allow for a probabilistic range of pollutant emissions from which best- and worst-case scenarios, for example, could be identified. In addition, the 'zero-out' method used in this report is not a true source apportionment method as all emissions sectors would not sum to 100% if modelled independently, a result of non-linear atmospheric processes. For these reasons, a primary goal of this analysis is to provide a comparative analysis of air quality and health impacts across sectors. Consideration should also be given to the spatial resolution of presented results: air quality impacts were generated at the 10 km x 10 km resolution and aggregated to larger provincial and territorial scales; health impacts were generated for specific individual CDs and aggregated to larger air zone, provincial, and territorial scales.

A primary strength of this multi-sector analysis approach is that it enables quantitative comparison of air quality and health impacts across sectors, including the ability to rank sectors by their relative contribution to air quality and health impacts or socio-economic costs. Prior national sector-focused air pollution health impact assessments for Canada have generally included only one or two sectors at a time (e.g., gasoline and diesel exhaust emissions; Health Canada, 2017, 2016). As different studies use different data and methods, this has made it challenging to compare impacts across a large number of sectors. In contrast, the analysis presented in this report was designed to simultaneously assess a large number of major transportation, industry, and residential sectors by applying a single modelling framework across all sectors (i.e., 'zero-out' each sector) and by using best available emissions datasets.

A second strength of this health impact analysis is the resolution at which results are reported. In addition to reporting health impact results at the national, provincial and territorial level, health impact results are also presented for individual air zones. These jurisdictional categories are represented under Canada's Air Quality Management System (AQMS), the framework for maintaining and improving air quality to protect the health of Canadians.

The sector-specific contributions to air pollutant concentrations and associated health impact results that this report presents at the national, provincial, territorial, and air zone scale are intended to inform air quality management at multiple jurisdictional levels. Results presented in this report are also expected to be of value to the general Canadian public interested in the comparative contribution of major transportation, industry, and residential sources influencing air quality and public health.

3 Health impacts of air pollution by sector

3.1 Air pollutant emissions by sector

3.1.1 National emissions by sector

Total annual 2015 calendar year Canadian air pollutant emissions are shown in Table 3-1 for each of the 21 sectors included in this assessment. These are listed for all modeled pollutants: $PM_{2.5}$, PM_{10}, NO_x, CO, SO_x, VOC, and NH_3.

As seen in Table 3-1, the 21 assessed sectors accounted for a high percentage (69% - 98%) of national total inventoried emissions of NO_x, CO, SO_x, and VOCs. Conversely, the 21 assessed sectors accounted for a lower percentage (<15%) of national total inventoried emissions of $PM_{2.5}$, PM_{10} and NH_3 since sectors outside the scope of this assessment account for high inventoried emissions of these pollutants (e.g., Dust, Fires/wildfires, Agriculture).

For each inventoried pollutant, the top-ranking aggregate modelled sectors contributing to emissions at the national level are summarized below:

- $PM_{2.5}$: Home firewood burning, ore and mineral industry, and approximately equal contributions from manufacturing and off-road vehicles and mobile equipment.
- PM_{10}: Home firewood burning, the ore and mineral industry, and manufacturing.
- NO_x: Oil and gas industry (i.e., largely upstream activities), on-road transportation (i.e., largely on-road heavy-duty vehicles), and air + marine + rail transportation (i.e., largely marine).
- CO: All on-road transportation (i.e., largely on-road light-duty vehicles), off-road vehicles and mobile equipment, and home firewood burning.
- SO_x: Ore and mineral industry (i.e., largely non-ferrous refining and smelting), electric power generation (i.e., largely coal-fired), and the oil and gas industry (i.e., largely upstream activities).
- VOC: Oil and gas industry (i.e., largely upstream activities), off-road vehicles and mobile equipment, and home firewood burning.
- NH_3: Manufacturing (i.e., largely chemicals), on-road transportation (i.e., largely on-road LDV), and the oil and gas industry (i.e., largely upstream activities). [10]

[10] The majority of nationally inventoried NH_3 emissions are attributed to the agriculture industry sector (APEI, 2015), which was not assessed in the present analysis.

Table 3-1 Total air pollution emissions in Canada by modelled sector (2015).

(Three highest-emitting sectors by pollutant shown highlighted: red indicates top-ranked, dark orange is second-ranked, light orange is third-ranked.)

	Total emissions (kilotonnes) per year [a, b]						
	$PM_{2.5}$	PM_{10} [c]	NO_x	CO	SO_x	VOC	NH_3
TRANSPORTATION & MOBILE EQUIPMENT SECTORS							
ALL On-road	**14**	**24**	**389**	**1,571**	**1.5**	**126**	**6.5**
On-road LDV	3.1	9.6	104	1,105	1.1	96	5.4
On-road HDV	10	14	285	466	0.3	30	1.1
Off-road vehicles & mobile equipment	**19**	**19**	**201**	**1,323**	**0.2**	**163**	**0.3**
Air + Marine + Rail	**7.8**	**8.4**	**369**	**74**	**11**	**19**	**0.4**
Air transportation	0.3	0.4	5.8	34	0.5	2.7	0
Marine transportation	4.6	5	238	22	10	10	0.3
Rail transportation	2.9	3	125	18	0.5	6.3	0.1
INDUSTRY SECTORS							
Ore and mineral industry	**33**	**96**	**82**	**515**	**483**	**14**	**1.2**
Cement manufacturing	1	1.9	31	9	21	0.4	0.5
Non-ferrous refining and smelting	2.1	3	1.6	14	365	0.1	0.3
Oil and gas industry	**10**	**13**	**434**	**526**	**229**	**691**	**2.1**
Upstream oil and gas	8.7	10	416	502	184	666	2
Downstream oil and gas	1.4	2.4	18	24	45	24	0.1
Electric power generation	**3.8**	**7.3**	**152**	**39**	**252**	**1.6**	**0.4**
Coal-fired electric power gen	2.8	6	115	16	242	0.4	0.2
Manufacturing	**19**	**43**	**74**	**136**	**48**	**110**	**11**
Chemicals	1.3	2	23	15	22	10	8.8
Pulp and paper	7.6	12	30	68	24	12	1.6
RESIDENTIAL SECTORS							
Residential fuel combustion	**2.5**	**2.6**	**34**	**13**	**0.2**	**1.8**	**0.4**
Home firewood burning	**104**	**104**	**10**	**683**	**1.4**	**150**	**0.9**
TOTAL 2015 EMISSIONS							
Total of 21 sectors assessed for air quality/health impacts	**212**	**317**	**1,744**	**4,880**	**1,026**	**1,275**	**24**
Total all other APEI sectors (not assessed)	1,414	6,980	71	697	18	579	461
All APEI sectors	1,626	7,297	1,815	5,577	1,044	1,854	485
% total 2015 APEI emissions represented by 21 assessed sectors [d]	13%	4%	96%	88%	98%	69%	5%

[a] Emissions inventory data from APEI 2015 (all sectors except home firewood burning) and APEI 2010 (home firewood burning).

[b] Top three highest-emitting sectors by pollutant are highlighted within each column. Top-ranked sector highlighted in red, second-ranked sector in dark orange, third-ranked in light orange. Ranking based on bolded sector categories (i.e., all on-road, off-road vehicles and mobile equipment, air + marine + rail, ore and mineral industry, oil and gas industry, electric power generation, manufacturing, residential fuel combustion, home firewood burning).

[c] PM_{10} emissions include $PM_{2.5}$.

[d] For NO_x, CO, SO_x, VOCs the 21 assessed sectors account for a high percentage (69% - 98%) of national total inventoried emissions. Conversely, for $PM_{2.5}$, PM_{10} and NH_3, the 21 assessed sectors account for a lower percentage of national total inventoried emissions (<15%); APEI sectors outside the scope of this assessment account for high inventoried emissions of these pollutants, notably Dust, Fires (i.e., wildfires), and Agriculture.

3.1.2 Provincial and territorial emissions by sector

Total 2015 emissions are shown by sector for each Canadian province and territory in Table 3-2 through Table 3-8. Inter-provincial and territorial trends are summarized below.

3.1.2.1 Geographic trends in Transportation sector emissions

On-road transportation emissions of modelled pollutants are greatest in the most populated provinces (Ontario, Quebec, Alberta, British Columbia) and are also substantial in essentially all provinces and territories. By pollutant, on-road transportation contributes substantial emissions of NO_x (Table 3-4), CO (Table 3-5), VOC (Table 3-7), and NH_3 (Table 3-8), ranking within the top three modelled sectors in most provinces for these pollutants. In comparing light-duty vehicle (LDV) and heavy-duty vehicle (HDV) emissions across the provinces, LDVs typically generate the majority of on-road transportation CO, SO_x, VOC and NH_3 emissions; conversely, HDVs generate the majority of on-road transportation $PM_{2.5}$, PM_{10}, and NO_x emissions. This dichotomy generally reflects differences in engine and fuel type (i.e., LDVs typically use spark-ignition engines fueled by gasoline, HDVs typically use compression ignition engines fueled by diesel) and exhaust emissions control devices.

In many provinces and territories, off-road vehicles and mobile equipment contributes to similar emissions as on-road transportation, with comparably high emissions of $PM_{2.5}$ (Table 3-2), PM_{10} (Table 3-3), and VOCs (Table 3-7), and comparably lower emissions of NO_x (Table 3-4) and CO (Table 3-5).

Across modelled sectors, marine transportation also contributes substantial $PM_{2.5}$ and PM_{10} emissions[11] (Table 3-2, Table 3-3) in coastal provinces (British Columbia, Nova Scotia, Newfoundland and Labrador), in Quebec, and in the north (Yukon, Northwest Territories, Nunavut). In several of these locations, $PM_{2.5}$ and PM_{10} emissions from the marine sector are comparable in magnitude to the on-road transportation sector (British Columbia, Yukon Territory, Northwest Territories) or even greater (Nova Scotia, Newfoundland and Labrador, Nunavut). Marine transportation emissions of NO_x (Table 3-4) are high in coastal provinces and also in Ontario and Quebec, consistent with activity on the Great Lakes and St. Lawrence River. Marine transportation VOC (Table 3-7) and NH_3[12] (Table 3-8) emissions are also high in Atlantic provinces and Northern territories. Marine SO_x emissions ranked in the top three in Prince Edward Island and all Northern territories (Yukon, Northwest Territories, Nunavut) and ranked fourth-highest in British Columbia, Nova Scotia, and Newfoundland and Labrador. These data demonstrate that marine transportation remains an important emissions source for multiple pollutants ($PM_{2.5}$, PM_{10}, NO_x, VOC, NH_3), including SO_x, even after the recent implementation of low-sulphur fuel regulations[13] that greatly reduced SO_x emissions (Anastasopolos et al., 2021). These low-sulphur fuel regulations were not implemented in Canada's Arctic region and thus marine transportation remained the top-ranked or second-ranked modeled sector for SO_x emissions in all Northern territories (Yukon, Northwest Territories, Nunavut).

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[11] Inventoried PM_{10} emissions include $PM_{2.5}$.

[12] The agricultural industry sector contributes the majority of Canada-wide NH_3 emissions (APEI, 2015).

[13] The Canadian "Regulations Amending the Sulphur in Diesel Fuel Regulations (SOR/2002–254)" were enacted 1st January 2015 and reduced the maximum permissible fuel sulphur content to 0.1% (i.e., from prior levels of 3.5% pre-2012 and 1% mid-2012-2015) for all large vessels operating within a North American Emissions Control Area (NA ECA).

3.1.2.2 Geographic trends in Industry sector emissions

Emissions from industry sectors are substantial in nearly all provinces and territories, with specific industry sectors showing inter-provincial/territorial variation in their ranking and in their characteristic emitted pollutants. In absolute terms, industry emissions are greatest in Ontario, Alberta, British Columbia, Quebec, and Saskatchewan.

The ore and mineral industry sector is active in many provinces and territories and emissions from this sector are highest in Ontario, Quebec, British Columbia and Saskatchewan, with large releases of $PM_{2.5}$ (Table 3-2) and PM_{10} (Table 3-3). Notably, only in Quebec, the ore and mineral industry is the second-highest ranked sector for CO emissions (Table 3-5), surpassing the individual sector emissions from on-road transportation and off-road vehicles and mobile equipment in this province. This industry sector also contributes substantial SO_x emissions (Table 3-6) in Newfoundland and Labrador, British Columbia, Ontario, and Quebec.

The pulp and paper industry sector is within the top three modelled sectors for emissions of $PM_{2.5}$ (Table 3-2), PM_{10} (Table 3-3), and SO_x (Table 3-6) in British Columbia, New Brunswick and Nova Scotia. The pulp and paper industry was also within the top three ranked sectors for CO (Table 3-5) in Saskatchewan and NH_3 (Table 3-8) in several provinces (British Columbia, Manitoba, Quebec, New Brunswick).

The manufacturing sector is among the top-emitting sectors in several provinces. For PM_{10} (Table 3-3), the manufacturing sector has comparatively high releases (ranked in top three or four across modeled sectors) in the western and Prairie provinces (Alberta, Saskatchewan, Manitoba), Ontario, Quebec and in New Brunswick; high manufacturing-related PM_{10} emissions also occur in Ontario and Quebec. The manufacturing sector also ranks third for emissions of $PM_{2.5}$ (Table 3-2) in multiple provinces (British Columbia, Quebec, New Brunswick, Nova Scotia) and contributes substantial VOC (Table 3-7) emissions (within top four modelled sectors) in many provinces (British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec and Nova Scotia). Across the modelled sectors, substantial releases of NH_3 emissions (Table 3-8) are also noted in British Columbia, Ontario, Quebec, and New Brunswick.

In Alberta, the upstream oil and gas industry is among the top three modelled sectors for emissions, with substantial pollutant releases for $PM_{2.5}$, PM_{10}, NO_x, CO, SO_2, VOCs, and NH_3. Comparably high releases of most of these pollutants were also attributed to upstream oil and gas activity in Newfoundland and Labrador (i.e., data in Table 3-2 to Table 3-8).

Coal-fired electric power generation was an important sector (i.e., top three ranked) for NO_x (Table 3-4) and SO_2 (Table 3-6) in some western provinces (Alberta, Saskatchewan) and Atlantic provinces (New Brunswick, Nova Scotia). For Northwest Territories and Nunavut in the north, non-coal-fired electric power generation contributes substantial emissions for multiple pollutants (NO_x, CO, $PM_{2.5}$, and PM_{10}).

3.1.2.3 Geographic trends in Residential Combustion sector emissions

In nearly all provinces, but not in the territories, home firewood burning is the dominant sector for emissions of $PM_{2.5}$ (Table 3-2), PM_{10} (Table 3-3), and VOC (Table 3-7). In several provinces, home firewood burning is also within the top three modelled sectors for CO (Table 3-5) and NH_3 emissions (Table 3-8).

Table 3-2 Sector $PM_{2.5}$ emissions by province and territory (2015).

(Three highest sector groups by province/territory shown highlighted" red indicates top-ranked, dark orange is second-ranked, light orange is third-ranked)

	Total annual $PM_{2.5}$ emissions (tonnes) [a, b]												
	BC	**AB**	**SK**	**MB**	**ON**	**QC**	**NB**	**NS**	**PE**	**NL**	**YT**	**NT**	**NU**
TRANSPORTATION & MOBILE EQUIPMENT SECTORS													
ALL On-road	**1,878**	**3,045**	**1,162**	**620**	**3,297**	**2,531**	**309**	**288**	**76**	**192**	**12**	**67**	**-**
On-road LDV	395	516	259	162	1,046	546	62	65	15	36	1	2	-
On-road HDV	1,483	2,528	903	458	2,251	1,985	247	223	60	156	11	64	-
Off-road vehicles & mobile equipment	**1,632**	**4,230**	**2,679**	**932**	**5,141**	**2,785**	**145**	**180**	**54**	**653**	**7**	**29**	**<1**
Air + Marine + Rail	**1,894**	**1,185**	**289**	**296**	**866**	**1,268**	**166**	**702**	**32**	**648**	**9**	**75**	**372**
Air transportation	58	41	14	18	69	38	6	6	<1	10	1	8	7
Marine transportation	1,576	1	1	21	234	930	82	656	31	638	8	61	365
Rail transportation	260	1,143	274	257	563	300	78	40	-	-	-	6	-
INDUSTRY SECTORS													
Ore and mineral industry	**5,097**	**2,398**	**2,078**	**1,529**	**11,212**	**8,380**	**840**	**269**	**25**	**788**	**8**	**296**	**55**
Cement manufacturing	114	176	-	-	441	226	-	15	-	-	-	-	-
Non-ferrous refining and smelting	68	<1	-	664	1,117	249	16	-	-	4	-	-	-
Ore and mineral - other	4,915	2,222	2,078	865	9,654	7,906	823	254	25	784	8	296	
Oil and gas industry	**869**	**6,323**	**1,157**	**117**	**536**	**122**	**248**	**76**	**-**	**693**	**-**	**15**	**-**
Upstream oil and gas	826	6,105	989	117	32	-	-	76	-	567	-	15	-
Downstream oil and gas	43	217	168	-	504	122	248	-	-	127	-	-	-
Electric power generation	**23**	**2,298**	**301**	**13**	**276**	**178**	**79**	**348**	**14**	**194**	**<1**	**61**	**39**
Coal-fired electric power gen	-	2,204	229	-	-	-	41	300	-	-	-	-	-
Electric power gen - other	23	94	72	13	276	178	39	48	14	194	<1	61	39
Manufacturing	**4,084**	**3,075**	**1,311**	**885**	**4,104**	**3,156**	**897**	**953**	**1**	**50**	**-**	**-**	**-**
Chemicals	8	599	101	9	469	135	-	-	-	-	-	-	-
Pulp and paper	2,630	611	2	502	1,623	947	419	823	-	34	-	-	-
Manufacturing - other	1,446	1,864	1,208	374	2,011	2,074	478	130	1	16	-	-	-
RESIDENTIAL SECTORS													
Residential fuel combustion	**245**	**560**	**117**	**75**	**1,287**	**137**	**17**	**46**	**9**	**13**	**<1**	**3**	**-**
Home firewood burning	**11,063**	**3,369**	**1,725**	**2,350**	**23,041**	**45,854**	**5,170**	**5,565**	**756**	**4,835**	**113**	**245**	**-**

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[a] Emissions inventory data from APEI 2015 (all sectors except home firewood burning) and APEI 2010 (home firewood burning).

[b] Top three highest-emitting sector groups in province/territory are highlighted within each column (top-ranked in red, second-ranked in dark orange, third-ranked in light orange). Ranking based on bolded sector categories (i.e., all on-road, off-road vehicles and mobile equipment, air + marine + rail, ore and mineral industry, oil and gas industry, electric power generation, manufacturing, residential fuel combustion, home firewood burning).

Table 3-3 Sector PM_{10} emissions by province and territory (2015).

(Three highest sector groups by province/territory shown highlighted: red indicates top-ranked, dark orange is second-ranked, light orange is third-ranked)

	Total annual PM_{10} emissions (tonnes)[a, b]												
	BC	AB	SK	MB	ON	QC	NB	NS	PE	NL	YT	NT	NU
TRANSPORTATION & MOBILE EQUIPMENT SECTORS													
ALL On-road	**3,058**	**4,963**	**1,797**	**1,059**	**6,766**	**4,632**	**554**	**550**	**123**	**348**	**18**	**96**	**<1**
On-road LDV	1,078	1,437	621	442	3,519	1,923	206	233	47	128	3	5	-
On-road HDV	1,980	3,526	1,176	617	3,247	2,709	348	317	76	220	15	91	-
Off-road vehicles & mobile equipment	**1,686**	**4,338**	**2,746**	**962**	**5,311**	**2,874**	**150**	**186**	**57**	**689**	**7**	**30**	**<1**
Air + Marine + Rail	**2,059**	**1,231**	**302**	**312**	**920**	**1,369**	**176**	**761**	**34**	**706**	**11**	**84**	**405**
Air transportation	78	52	18	24	86	49	7	7	<1	13	2	10	8
Marine transportation	1,713	1	1	23	254	1,011	89	713	33	693	9	67	397
Rail transportation	268	1,178	283	265	580	309	80	41	-	-	-	7	-
INDUSTRY SECTORS													
Ore and mineral industry	**20,285**	**10,075**	**5,360**	**3,962**	**27,866**	**18,432**	**4,239**	**1,436**	**97**	**3,468**	**37**	**343**	**189**
Cement manufacturing	254	341	-	-	741	521	-	29	-	-	-	-	-
Non-ferrous refining and smelting	95	3	-	923	1,617	275	35	-	-	6	-	-	-
Ore and mineral - other	19,936	9,731	5,360	3,039	25,508	17,636	4,204	1,406	97	3,462	37	343	189
Oil and gas industry	**898**	**8,131**	**1,226**	**117**	**985**	**238**	**350**	**76**	**-**	**758**	**-**	**15**	**-**
Upstream oil and gas	827	7,778	992	117	32	-	-	76	-	567	-	15	-
Downstream oil and gas	71	353	235	-	953	238	350	-	-	191	-	-	-
Electric power generation	**26**	**4,787**	**874**	**20**	**355**	**224**	**96**	**520**	**31**	**228**	**1**	**62**	**40**
Coal-fired electric power gen	-	4,683	799	-	-	-	57	452	-	-	-	-	-
Electric power gen - other	26	104	75	20	355	224	39	68	31	228	1	62	40
Manufacturing	**6,819**	**7,974**	**6,370**	**2,816**	**8,795**	**6,016**	**2,348**	**1,725**	**1**	**60**	**-**	**-**	**-**
Chemicals	11	903	244	83	617	176	-	-	-	-	-	-	-
Pulp and paper	3,769	877	2	849	2,870	1,247	621	1,210	-	35	-	-	-
Manufacturing - other	3,039	6,194	6,125	1,884	5,307	4,592	1,727	515	1	25	-	-	-
RESIDENTIAL SECTORS													
Residential fuel combustion	**245**	**561**	**117**	**75**	**1,301**	**153**	**21**	**59**	**12**	**16**	**<1**	**4**	**-**
Home firewood burning	**11,081**	**3,380**	**1,727**	**2,353**	**23,075**	**45,908**	**5,172**	**5,567**	**757**	**4,836**	**113**	**245**	**-**

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[a] Emissions inventory data from APEI 2015 (all sectors except home firewood burning) and APEI 2010 (home firewood burning).

[b] Top three highest-emitting sector groups in province/territory are highlighted within each column (top-ranked in red, second-ranked in dark orange, third-ranked in light orange). Ranking based on bolded sector categories (i.e., all on-road, off-road vehicles and mobile equipment, air + marine + rail, ore and mineral industry, oil and gas industry, electric power generation, manufacturing, residential fuel combustion, home firewood burning).

Table 3-4 Sector NO_x emissions by province and territory (2015).

(Three highest sector groups by province/territory shown highlighted; red indicates top-ranked, dark orange is second-ranked, light orange is third-ranked)

	Total annual NO_x emissions (tonnes)[a, b]												
	BC	**AB**	**SK**	**MB**	**ON**	**QC**	**NB**	**NS**	**PE**	**NL**	**YT**	**NT**	**NU**
TRANSPORTATION & MOBILE EQUIPMENT SECTORS													
ALL On-road	**59,643**	**90,034**	**31,375**	**16,706**	**95,316**	**68,458**	**8,714**	**8,618**	**1,931**	**5,350**	**429**	**2,251**	**<1**
On-road LDV	16,756	16,075	8,368	5,103	32,531	18,558	2,389	2,386	591	1,153	32	57	-
On-road HDV	42,887	73,959	23,007	11,602	62,784	49,900	6,325	6,232	1,339	4,197	397	2,195	-
Off-road vehicles & mobile equipment	**15,640**	**54,485**	**34,092**	**11,033**	**50,379**	**26,432**	**1,242**	**1,531**	**492**	**5,599**	**55**	**371**	**4**
Air + Marine + Rail	**103,198**	**50,110**	**11,976**	**11,713**	**37,760**	**60,282**	**7,681**	**38,839**	**1,671**	**33,634**	**335**	**2,640**	**8,851**
Air transportation	1,095	1,033	129	234	2,040	785	68	146	8	118	16	55	49
Marine transportation	90,932	56	55	439	11,552	46,600	4,260	36,975	1,663	33,515	319	2,312	8,802
Rail transportation	11,171	49,021	11,792	11,041	24,168	12,897	3,353	1,718	-	-	-	273	-
INDUSTRY SECTORS													
Ore and mineral industry	**8,159**	**5,799**	**3,199**	**499**	**28,940**	**20,332**	**788**	**380**	**-**	**5,461**	**-**	**7,557**	**691**
Cement manufacturing	5,651	4,362	-	-	14,079	6,330	-	364	-	-	-	-	-
Non-ferrous refining and smelting	318	-	-	-	825	271	200	-	-	35	-	-	-
Ore and mineral - other	2,189	1,438	3,199	499	14,036	13,731	589	16	-	5,426	-	7,557	691
Oil and gas industry	**44,599**	**349,922**	**19,567**	**250**	**6,223**	**2,155**	**2,715**	**1,042**	**-**	**7,307**	**-**	**737**	**-**
Upstream oil and gas	44,341	346,257	17,993	250	745	-	-	1,042	-	5,700	-	737	-
Downstream oil and gas	258	3,664	1,573	-	5,478	2,155	2,715	-	-	1,607	-	-	-
Electric power generation	**1,510**	**71,299**	**32,305**	**509**	**9,572**	**6,081**	**5,425**	**15,647**	**131**	**4,261**	**59**	**2,461**	**2,605**
Coal-fired electric power gen	-	67,338	29,785	-	-	-	4,510	13,193	-	-	-	-	-
Electric power gen - other	1,510	3,961	2,520	509	9,572	6,081	915	2,454	131	4,261	59	2,461	2,605
Manufacturing	**13,409**	**24,826**	**1,301**	**1,528**	**14,542**	**13,143**	**3,884**	**636**	**62**	**169**	**-**	**-**	**-**
Chemicals	53	14,344	681	813	6,213	598	-	-	-	-	-	-	-
Pulp and paper	9,098	4,107	140	315	4,602	8,006	3,052	364	-	149	-	-	-
Manufacturing - other	4,257	6,374	480	400	3,728	4,539	832	273	62	20	-	-	-
RESIDENTIAL SECTORS													
Residential fuel combustion	**3,064**	**7,004**	**1,474**	**948**	**16,818**	**2,363**	**378**	**1,095**	**219**	**307**	**10**	**72**	**-**
Home firewood burning	**1003**	**312**	**170**	**218**	**2206**	**4629**	**502**	**540**	**76**	**454**	**11**	**24**	**-**

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[a] Emissions inventory data from APEI 2015 (all sectors except home firewood burning) and APEI 2010 (home firewood burning).

[b] Top three highest-emitting sector groups in province/territory are highlighted within each column (top-ranked in red, second-ranked in dark orange, third-ranked in light orange). Ranking based on bolded sector categories (i.e., all on-road, off-road vehicles and mobile equipment, air + marine + rail, ore and mineral industry, oil and gas industry, electric power generation, manufacturing, residential fuel combustion, home firewood burning).

Table 3-5 Sector CO emissions by province and territory (2015).

(Three highest sector groups by province/territory shown highlighted: red indicates top-ranked, dark orange is second-ranked, light orange is third-ranked)

	Total annual CO emissions (tonnes)[a, b]												
	BC	AB	SK	MB	ON	QC	NB	NS	PE	NL	YT	NT	NU
TRANSPORTATION & MOBILE EQUIPMENT SECTORS													
ALL On-road	253,743	292,000	141,543	78,088	435,918	272,365	33,255	34,825	8,104	18,255	812	1,728	<1
On-road LDV	158,122	171,640	87,179	54,644	346,864	211,379	25,864	27,276	6,387	14,016	408	672	-
On-road HDV	95,621	120,361	54,365	23,444	89,054	60,986	7,390	7,548	1,717	4,240	404	1,056	-
Off-road vehicles & mobile equipment	143,910	152,696	84,697	63,870	472,425	233,050	17,158	23,903	8,433	119,982	1,143	1,693	11
Air + Marine + Rail	18,499	11,772	3,578	3,518	12,991	11,153	2,443	4,132	251	3,793	194	844	944
Air transportation	8,661	4,646	1,862	1,874	8,356	4,843	1,468	330	60	510	167	619	164
Marine transportation	8,219	7	7	44	1,128	4,440	489	3,554	191	3,282	27	186	780
Rail transportation	1,618	7,119	1,709	1,601	3,506	1,870	486	249	-	-	-	40	-
INDUSTRY SECTORS													
Ore and mineral industry	33,334	3,679	3,247	1,008	62,108	389,106	14,099	250	-	5,942	-	1,943	296
Cement manufacturing	1,617	1,292	-	-	3,950	2,009	-	181	-	-	-	-	-
Non-ferrous refining and smelting	67	-	-	-	866	212	12,337	-	-	-	-	-	-
Ore and mineral - other	31,650	2,387	3,247	1,008	57,293	386,886	1,762	69	-	5,942	-	1,943	296
Oil and gas industry	58,353	419,319	26,696	611	13,521	1,217	2,037	328	-	2,487	-	906	-
Upstream oil and gas	58,033	413,125	25,819	611	981	-	-	328	-	2,064	-	906	-
Downstream oil and gas	320	6,193	877	-	12,540	1,217	2,037	-	-	423	-	-	-
Electric power generation	1,980	19,896	2,667	45	7,288	2,975	390	2,331	43	418	29	428	543
Coal-fired electric power gen	-	13,001	2,169	-	-	-	224	659	-	-	-	-	-
Electric power gen - other	1,980	6,895	498	45	7,288	2,975	166	1,672	43	418	29	428	543
Manufacturing	22,974	35,211	14,974	1,528	23,561	26,887	9,264	1,232	51	164	-	-	-
Chemicals	232	6,235	595	541	6,678	814	-	-	-	-	-	-	-
Pulp and paper	12,869	10,561	13,000	222	9,709	14,909	6,197	831	-	113	-	-	-
Manufacturing - other	9,873	18,415	1,379	766	7,175	11,164	3,068	401	51	51	-	-	-
RESIDENTIAL SECTORS													
Residential fuel combustion	1,289	2,947	616	396	6,796	759	98	271	54	75	2	18	-
Home firewood burning	69,730	20,809	11,385	14,450	152,613	309,716	32,991	35,647	4,829	28,653	707	1,541	-

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[a] Emissions inventory data from APEI 2015 (all sectors except home firewood burning) and APEI 2010 (home firewood burning).

[b] Top three highest-emitting sector groups in province/territory are highlighted within each column (top-ranked in red, second-ranked in dark orange, third-ranked in light orange). Ranking based on bolded sector categories (i.e., all on-road, off-road vehicles and mobile equipment, air + marine + rail, ore and mineral industry, oil and gas industry, electric power generation, manufacturing, residential fuel combustion, home firewood burning).

Table 3-6 Sector SO_x emissions by province and territory (2015).

(Three highest sector groups by province/territory shown highlighted: red indicates top-ranked, dark orange is second-ranked, light orange is third-ranked)

	Total annual SO_x emissions (tonnes)[a, b]												
	BC	**AB**	**SK**	**MB**	**ON**	**QC**	**NB**	**NS**	**PE**	**NL**	**YT**	**NT**	**NU**
TRANSPORTATION & MOBILE EQUIPMENT SECTORS													
ALL On-road	**152**	**186**	**80**	**45**	**575**	**301**	**37**	**50**	**8**	**22**	**<1**	**2**	**<1**
On-road LDV	103	115	55	36	469	244	29	39	7	18	<1	<1	-
On-road HDV	49	72	25	10	106	57	8	11	1	5	<1	1	-
Off-road vehicles & mobile equipment	**19**	**50**	**30**	**12**	**62**	**31**	**2**	**3**	**1**	**28**	**<1**	**<1**	**-**
Air + Marine + Rail	**2,416**	**185**	**44**	**203**	**806**	**2,418**	**118**	**978**	**16**	**1,206**	**38**	**279**	**2,498**
Air transportation	139	8	1	4	174	66	26	36	3	50	2	<1	10
Marine transportation	2,236	<1	<1	160	545	2,306	80	936	13	1,156	36	278	2,488
Rail transportation	40	177	43	40	87	46	12	6	-	-	-	<1	-
INDUSTRY SECTORS													
Ore and mineral industry	**7,544**	**979**	**1,296**	**151,249**	**210,427**	**93,209**	**10,696**	**425**	**-**	**6,838**	**-**	**279**	**-**
Cement manufacturing	180	714	-	-	10,905	8,972	-	410	-	-	-	-	-
Non-ferrous refining and smelting	4,070	-	-	151,155	180,321	19,027	10,486	-	-	25	-	-	-
Ore and mineral - other	3,294	264	1,296	94	19,202	65,211	210	15	-	6,813	-	279	-
Oil and gas industry	**38,176**	**133,725**	**18,619**	**1,225**	**21,560**	**5,866**	**1,822**	**1,089**	**-**	**6,551**	**-**	**287**	
Upstream oil and gas	37,285	125,887	16,770	1,225	1,149	-	-	1,089	-	-	-	287	-
Downstream oil and gas	890	7,837	1,849	-	20,410	5,866	1,822	-	-	6,551	-	-	-
Electric power generation	**61**	**98,745**	**80,382**	**202**	**436**	**1,429**	**4,859**	**60,227**	**111**	**5,019**	**-**	**82**	**-**
Coal-fired electric power gen	-	98,720	80,382	-	-	-	3,744	58,724	-	-	-	-	-
Electric power gen - other	61	25	-	202	436	1,429	1,115	1,504	111	5,019	-	82	-
Manufacturing	**9,091**	**13,221**	**30**	**752**	**14,020**	**6,614**	**3,782**	**373**	**-**	**38**	**-**	**-**	**-**
Chemicals	85	8,844	2	649	10,898	1,440	-	-	-	-	-	-	-
Pulp and paper	8,832	3,922	10	22	2,391	4,638	3,742	182	-	37	-	-	-
Manufacturing - other	173	456	18	81	732	535	40	191	-	<1	-	-	-
RESIDENTIAL SECTORS													
Residential fuel combustion	**19**	**45**	**9**	**6**	**100**	**7**	**<1**	**<1**	**<1**	**<1**	**-**	**-**	**-**
Home firewood burning	**143**	**45**	**24**	**31**	**315**	**661**	**72**	**77**	**11**	**65**	**2**	**3**	**-**

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[a] Emissions inventory data from APEI 2015 (all sectors except home firewood burning) and APEI 2010 (home firewood burning).

[b] Top three highest-emitting sector groups in province/territory are highlighted within each column (top-ranked in red, second-ranked in dark orange, third-ranked in light orange). Ranking based on bolded sector categories (i.e., all on-road, off-road vehicles and mobile equipment, air + marine + rail, ore and mineral industry, oil and gas industry, electric power generation, manufacturing, residential fuel combustion, home firewood burning).

Table 3-7 Sector VOC emissions by province and territory (2015).

(Three highest sector groups by province/territory shown highlighted: red indicates top-ranked, dark orange is second-ranked, light orange is third-ranked)

	Total annual VOC emissions (tonnes)[a, b]												
	BC	**AB**	**SK**	**MB**	**ON**	**QC**	**NB**	**NS**	**PE**	**NL**	**YT**	**NT**	**NU**
TRANSPORTATION & MOBILE EQUIPMENT SECTORS													
ALL On-road	**21,574**	**23,238**	**11,312**	**6,948**	**34,773**	**20,598**	**2,580**	**2,499**	**621**	**1,318**	**68**	**238**	**<1**
On-road LDV	16,410	15,667	8,134	5,529	28,441	16,118	1,988	1,925	495	936	34	66	-
On-road HDV	5,164	7,571	3,178	1,419	6,332	4,481	592	574	125	382	34	171	-
Off-road vehicles & mobile equipment	**14,747**	**19,471**	**13,329**	**10,627**	**49,618**	**24,423**	**1,781**	**1,954**	**1,438**	**25,264**	**260**	**348**	**<1**
Air + Marine + Rail	**4,758**	**2,906**	**719**	**725**	**2,481**	**2,820**	**442**	**1,802**	**116**	**1,630**	**33**	**143**	**353**
Air transportation	519	457	130	159	809	296	46	86	4	79	21	42	21
Marine transportation	3,682	2	2	17	467	1,882	229	1,631	112	1,552	12	88	332
Rail transportation	556	2,447	587	550	1,205	642	167	86	-	-	-	14	-
INDUSTRY SECTORS													
Ore and mineral industry	**1,191**	**2,405**	**1,515**	**489**	**1,557**	**2,011**	**3,841**	**46**	**-**	**77**	**-**	**351**	**-**
Cement manufacturing	101	17	-	-	175	82	-	-	-	-	-	-	-
Non-ferrous refining and smelting	13	-	-	-	51	2	-	-	-	-	-	-	-
Ore and mineral - other	1,076	2,388	1,515	489	1,331	1,927	3,841	46	-	77	-	351	-
Oil and gas industry	**36,945**	**460,581**	**165,982**	**12,111**	**7,134**	**2,481**	**862**	**1,133**	**162**	**3,144**	**32**	**1,028**	**-**
Upstream oil and gas	34,941	454,884	160,489	11,005	2,601	6	-	268	-	2,188	-	975	-
Downstream oil and gas	2,005	5,697	5,493	1,106	4,533	2,475	862	864	165	956	32	53	-
Electric power generation	**50**	**540**	**141**	**-**	**329**	**377**	**13**	**32**	**-**	**23**	**-**	**43**	**20**
Coal-fired electric power gen	-	411	-	-	-	-	<1	-	-	-	-	-	-
Electric power gen - other	50	128	141	-	329	377	13	32	-	23	-	43	20
Manufacturing	**16,589**	**14,101**	**4,343**	**7,031**	**38,650**	**23,854**	**2,861**	**2,126**	**44**	**226**	**-**	**-**	**-**
Chemicals	120	3,048	662	171	4,993	1,335	-	-	40	-	-	-	-
Pulp and paper	3,557	908	1,298	174	1,564	3,534	1,495	193	-	121	-	-	-
Manufacturing - other	12,913	10,145	2,383	6,685	32,094	18,986	1,365	1,933	4	105	-	-	-
RESIDENTIAL SECTORS													
Residential fuel combustion	**178**	**407**	**85**	**55**	**924**	**84**	**8**	**20**	**4**	**6**	**<1**	**1**	**-**
Home firewood burning	**14,935**	**4,011**	**2,524**	**3,419**	**32,635**	**66,963**	**7,930**	**8,461**	**1,167**	**7,517**	**174**	**379**	**-**

BC: British Columbia; AB: Alberta; SA: Saskatchewan; MB: Manitoba; ON: Ontario; QC: Québec; NB: New Brunswick; NS: Nova Scotia; PE: Prince Edward Island; NL: Newfoundland and Labrador; YT: Yukon; NT: Northwest Territories; NU: Nunavut

[a] Emissions inventory data from APEI 2015 (all sectors except home firewood burning) and APEI 2010 (home firewood burning).

[b] Top three highest-emitting sector groups in province/territory are highlighted within each column (top-ranked in red, second-ranked in dark orange, third-ranked in light orange). Ranking based on bolded sector categories (i.e., all on-road, off-road vehicles and mobile equipment, air + marine + rail, ore and mineral industry, oil and gas industry, electric power generation, manufacturing, residential fuel combustion, home firewood burning).

Table 3-8 Sector NH_3 emissions by province and territory (2015).

(Three highest sector groups by province/territory shown highlighted: red indicates top-ranked, dark orange is second-ranked, light orange is third-ranked)

	Total annual NH_3 emissions (tonnes)[a, b, c]												
	BC	**AB**	**SK**	**MB**	**ON**	**QC**	**NB**	**NS**	**PE**	**NL**	**YT**	**NT**	**NU**
TRANSPORTATION & MOBILE EQUIPMENT SECTORS													
ALL On-road	**816**	**1,067**	**389**	**284**	**2,198**	**1,307**	**141**	**154**	**31**	**82**	**3**	**10**	**<1**
On-road LDV	669	763	315	244	1,927	1,132	118	129	27	66	2	2	-
On-road HDV	147	304	74	41	271	175	23	24	3	16	1	8	-
Off-road vehicles & mobile equipment	**24**	**73**	**40**	**16**	**78**	**41**	**2**	**3**	**1**	**16**	**<1**	**<1**	**-**
Air + Marine + Rail	**122**	**23**	**6**	**6**	**26**	**62**	**6**	**47**	**2**	**42**	**<1**	**3**	**12**
Air transportation	<1	<1	<1	<1	1	<1	<1	<1	<1	<1	<1	<1	<1
Marine transportation	116	<1	<1	<1	13	55	5	46	2	42	<1	3	12
Rail transportation	5	22	5	5	11	6	2	<1	-	-	-	<1	-
INDUSTRY SECTORS													
Ore and mineral industry	**96**	**217**	**15**	**-**	**602**	**280**	**-**	**-**	**-**	**4**	**-**	**-**	**-**
Cement manufacturing	51	-	-	-	389	38	-	-	-	-	-	-	-
Non-ferrous refining and smelting	40	206	-	-	37	-	-	-	-	-	-	-	-
Ore and mineral - other	5	12	15	-	175	242	-	-	-	4	-	-	-
Oil and gas industry	**35**	**1,974**	**66**	**<1**	**40**	**2**	**-**	**-**	**-**	**-**	**-**	**2**	**-**
Upstream oil and gas	34	1,964	46	<1	3	-	-	-	-	-	-	2	-
Downstream oil and gas	<1	10	19	-	36	2	-	-	-	-	-	-	-
Electric power generation	**-**	**259**	**-**	**-**	**119**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Coal-fired electric power gen	-	168	-	-	-	-	-	-	-	-	-	-	-
Electric power gen - other	-	91	-	-	119	-	-	-	-	-	-	-	-
Manufacturing	**827**	**6,564**	**879**	**1,726**	**787**	**629**	**286**	**46**	**-**	**2**	**-**	**-**	**-**
Chemicals	-	6,006	862	1,636	306	19	-	-	-	-	-	-	-
Pulp and paper	511	306	-	53	155	331	249	37	-	-	-	-	-
Manufacturing - other	316	252	17	37	326	278	37	9	-	2	-	-	-
RESIDENTIAL SECTORS													
Residential fuel combustion	**18**	**39**	**9**	**6**	**143**	**69**	**18**	**52**	**11**	**15**	**<1**	**4**	**-**
Home firewood burning	**90**	**28**	**15**	**20**	**199**	**417**	**45**	**49**	**7**	**41**	**1**	**2**	**-**

BC: British Columbia; AB: Alberta; SA: Saskatchewan; MB: Manitoba; ON: Ontario; QC: Québec; NB: New Brunswick; NS: Nova Scotia; PE: Prince Edward Island; NL: Newfoundland and Labrador; YT: Yukon; NT: Northwest Territories; NU: Nunavut

[a] Emissions inventory data from APEI 2015 (all sectors except home firewood burning) and APEI 2010 (home firewood burning).

[b] Top three highest-emitting sector groups in province/territory are highlighted within each column (top-ranked in red, second-ranked in dark orange, third-ranked in light orange). Ranking based on bolded sector categories (i.e., all on-road, off-road vehicles and mobile equipment, air + marine + rail, ore and mineral industry, oil and gas industry, electric power generation, manufacturing, residential fuel combustion, home firewood burning).

[c] Agricultural industry sector contributes the majority of Canada-wide NH_3 emissions (APEI, 2015) but was not modelled in this assessment.

3.2 Sector contributions to ambient air quality

3.2.1 Modelled annual average air quality in Canada

Base case concentrations for the modelled air pollutants ($PM_{2.5}$, NO_2, SO_2, O_3, summer O_3) were obtained from air quality modelling of the base case emissions inventory, which included total 2015 emissions from all inventoried sectors (i.e., 21 modeled sectors evaluated in this report plus all remaining sectors not assessed in this report, see Section 2.2). Subsequent runs of the air quality model zeroed-out emissions from the individual transportation, industry, and residential combustion sectors assessed in this report. The concentration difference between the base case and the zeroed-out sector model run, aggregated over the gridded modelling domain (i.e., area-weighted to census division then population-weighted to province, territory and national scale; see Section 2.5.3), yielded an estimate of each sector's net impact or contribution to air quality (i.e., units in absolute mass concentration, either $\mu g/m^3$ or ppbv) and relative fraction (% of base case concentration).

Canadian provinces and territories were grouped into four regions to organize presentation of results and their discussion: West including British Columbia, Alberta, Saskatchewan, Manitoba; Central including Ontario and Quebec; Atlantic including New Brunswick, Nova Scotia, Prince Edward Island, Newfoundland and Labrador; and North including Yukon Territory, Northwest Territories, and Nunavut. Table 3-9 lists national, provincial and territorial population-weighted annual average base case concentrations for all modeled air pollutants. For $PM_{2.5}$, NO_2, and SO_2 the concentrations correspond to an annual average of daily mean concentrations. For O_3 and summer O_3, the concentrations correspond to an annual and summer (May to September) average of daily maximum concentrations, respectively.[14] For most pollutants, concentrations are higher in densely populated provinces (e.g., Ontario, Quebec, British Columbia) and those with substantial industrial emissions activity (e.g., Alberta, Manitoba) and lower in provinces and territories characterized by low populations and large rural or remote areas with lower concentration of industrial activity.

[14] The modelled air quality concentrations are population-weighted at the national, provincial and territorial scales, and as such, are not intended for comparison with monitored concentration levels at specific locations (e.g., NAPS central site monitors) or for comparison with regulatory standards (e.g., CAAQS).

Table 3-9 Modelled base case annual average $PM_{2.5}$, NO_2, SO_2, O_3, and summer average O_3 – national, provincial,territorial (population-weighted, 2015).

			Ambient concentration (population-weighted modelled annual average) [a, b]				
REGION [c]		**Population**	**$PM_{2.5}$** ($\mu g/m^3$)	**NO_2** (ppbv)	**SO_2** (ppbv)	**O_3** (ppbv)	**summer O_3** (ppbv)
CANADA		35,851,774	**5.3**	**5.1**	**0.7**	**36.3**	**40.0**
WEST	**BC**	4,683,139	4.2	4.8	0.3	35.4	39.5
	AB	4,196,457	2.7	5.1	0.8	37.3	41.4
	SK	1,133,637	1.4	1.2	0.3	34.5	36.2
	MB	1,293,378	2.6	3.7	0.3	31.3	32.7
CENTRAL	**ON**	13,792,052	6.4	6.2	0.9	38.6	43.8
	QC	8,263,600	7.8	5.6	0.9	33.9	36.5
ATLANTIC	**NB**	753,871	1.2	0.5	0.2	34.4	33.5
	NS	943,002	1.1	0.5	0.2	36.5	36.2
	PEI	146,447	1.3	0.5	0.2	35.4	34.2
	NL	527,756	0.5	0.3	0.1	36.4	34.8
NORTH	**YT**	37,428	0.2	< 0.1	< 0.1	32.0	28.5
	NT	44,088	0.2	0.1	< 0.1	30.3	29.2
	NU	36,919	0.1	< 0.1	< 0.1	31.6	30.5

[a] Annual average of daily mean concentration for $PM_{2.5}$, NO_2, SO_2.

[b] Annual and seasonal (May – September) average of daily maximum concentration for O_3 and summer O_3, respectively.

[c] BC: British Columbia; AB: Alberta; SA: Saskatchewan; MB: Manitoba; ON: Ontario; QC: Québec; NB: New Brunswick; NS: Nova Scotia; PEI: Prince Edward Island; NL: Newfoundland and Labrador; YT: Yukon; NT: Northwest Territories; NU: Nunavut

3.2.2 Sector impacts to national air quality

Table 3-10 presents the contribution of each modeled sector to 2015 population-weighted base case air pollutant concentrations (i.e., see Table 3-9) for mean annual $PM_{2.5}$, NO_2, and SO_2, and mean annual/summer O_3. In addition to the absolute mass concentration results, Table 3-10 also includes relative estimates of each sector's contribution, or 'impact', calculated as a percentage of the base case pollutant concentrations (i.e., sector contribution to average national air quality divided by base case national average air quality).

By relative contribution to base case national average air quality, the top three modeled sectors for each modelled pollutant were:

- National annual average population-weighted $PM_{2.5}$ concentrations were most impacted by releases (i.e., primary $PM_{2.5}$ and secondary $PM_{2.5}$ formed from reactions of NO_x, SO_x, VOC, and NH_3 releases) from home firewood burning (21%), on-road transportation (7%; 4% from HDVs, ~3% from LDVs), and the ores and mineral industry (7%).
- National annual average population-weighted NO_2 concentrations were most impacted by NO_2 emissions from on-road transportation (38%; 25% from HDVs, 11% from LDVs), off-road vehicles and mobile equipment (12%), and residential fuel combustion (6%).
- National annual average population-weighted SO_2 concentrations were most impacted by SO_2 emissions from the ore and mineral industry (39%, including 17% from non-ferrous refining and smelting facility emissions), oil and gas industry (14%, approximately equal contributions from upstream and downstream operations), and manufacturing (11%, including 6% from the chemicals industry).
- National average population-weighted summer O_3 concentrations were impacted comparably by emissions (i.e., O_3 precursors such as NO_x and VOCs) from on-road transportation (2%), off-road vehicles and mobile equipment (2%), and the oil and gas industry (2%).

Table 3-10 Sector contributions to modelled base case annual average $PM_{2.5}$, NO_2, SO_2, O_3, and summer average O_3 in Canada (population-weighted, 2015).

	Impact to national average ambient concentration (population-weighted modelled annual and summer averages)				
	$PM_{2.5}$ µg/m³ (%)	**NO_2** ppbv (%)	**SO_2** ppbv (%)	**O_3** ppbv (%)	**summer O_3** ppbv (%)
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On-road	**0.4 (7%)**	**2.0 (38%)**	**< 0.1 (2%)**	**- 0.1 (< 1%)**	**0.9 (2%)**
On-road LDV	0.1 (3%)	0.6 (11%)	< 0.1 (1%)	- 0.1 (< 1%)	0.2 (1%)
On-road HDV	0.2 (4%)	1.3 (25%)	< 0.1 (1%)	- 0.2 (< 1%)	0.4 (1%)
Off-road vehicles & mobile equipment	**0.3 (5%)**	**0.6 (12%)**	**< 0.1 (< 1%)**	**0.2 (1%)**	**0.8 (2%)**
Air + Marine + Rail	0.1 (1%)	0.5 (9%)	< 0.1 (2%)	0.1 (< 1%)	0.4 (1%)
Air transportation	< 0.1 (< 1%)	0.1 (2%)	< 0.1 (1%)	< 0.1 (< 1%)	< 0.1 (< 1%)
Marine transportation	< 0.1 (1%)	0.1 (3%)	< 0.1 (1%)	0.1 (< 1%)	0.2 (1%)
Rail transportation	< 0.1 (1%)	0.2 (4%)	< 0.1 (< 1%)	< 0.1 (< 1%)	0.2 (< 1%)
INDUSTRY SECTORS					
Ore and mineral industry	**0.4 (7%)**	**0.1 (3%)**	**0.3 (39%)**	**< 0.1 (< 1%)**	**< 0.1 (0%)**
Cement manufacturing	0.1 (1%)	0.1 (1%)	0.1 (7%)	- 0.1 (< 1%)	< 0.1 (< 1%)
Non-ferrous refining and smelting	0.1 (2%)	< 0.1 (< 1%)	0.1 (17%)	< 0.1 (< 1%)	< 0.1 (< 1%)
Oil and gas industry [a]	**0.1 (2%)**	**0.3 (5%)**	**0.1 (14%)**	**0.2 (1%)**	**0.7 (2%)**
Upstream oil and gas	0.1 (1%)	0.2 (4%)	0.1 (7%)	0.2 (1%)	0.6 (2%)
Downstream oil and gas	< 0.1 (1%)	< 0.1 (1%)	0.1 (7%)	< 0.1 (< 1%)	< 0.1 (< 1%)
Electric power generation	**0.1 (1%)**	**0.1 (1%)**	**< 0.1 (6%)**	**< 0.1 (< 1%)**	**0.1 (< 1%)**
Coal-fired electric power gen	< 0.1 (1%)	< 0.1 (1%)	< 0.1 (6%)	< 0.1 (< 1%)	0.1 (< 1%)
Manufacturing	**0.1 (2%)**	**0.1 (2%)**	**0.1 (11%)**	**0.1 (< 1%)**	**0.3 (1%)**
Chemicals	0.1 (1%)	0.1 (1%)	< 0.1 (6%)	< 0.1 (< 1%)	0.1 (< 1%)
Pulp and paper	< 0.1 (1%)	< 0.1 (< 1%)	< 0.1 (1%)	< 0.1 (< 1%)	0.1 (< 1%)
RESIDENTIAL SECTORS					
Residential fuel combustion	**0.1 (1%)**	**0.3 (6%)**	**0.01 (1%)**	**- 0.1 (< 1%)**	**< 0.1 (< 1%)**
Home firewood burning	**1.0 (21%)**	**< 0.1 (< 1%)**	**< 0.1 (< 1%)**	**< 0.1 (< 1%)**	**< 0.1 (< 1%)**

[a] Total oil and gas industry sector contribution to ambient air quality was not modelled separately but is estimated as the sum of individual comprising sector model runs (upstream oil and gas, downstream oil and gas).

3.2.3 Sector contributions to provincial and territorial air quality

3.2.3.1 Overall trends - top three sectors by contribution to ambient pollutant concentrations

To assess the relative air quality impact of major transportation, industry, and residential combustion sectors and identify regional trends, the estimated contribution of each modelled sector on air quality (% contribution to 2015 modelled base case annual mean population-weighted pollutant concentration) is tabulated by pollutant in Table 3-11 through Table 3-13.

Sector contributions to ambient $PM_{2.5}$ concentrations

Sector contributions to 2015 modelled base case $PM_{2.5}$ concentrations[15] (i.e., annual average of daily mean, population-weighted) at the national, provincial and territorial scales are shown in Table 3-11. At the national scale, the modelled sectors with the largest contribution to annual mean $PM_{2.5}$ levels were home firewood burning, on-road transportation, and the ore and mineral industry (i.e., see top row Table 3-11, see also Section 3.2.2).

Across the provinces and territories there is considerable regional variation in the dominant sectors:

- Home firewood burning is the dominant modelled sector contributing to annual mean $PM_{2.5}$ levels in most provinces (i.e., British Columbia, Ontario, Quebec, and all Atlantic provinces), contributing between 15% and 40% of modelled base case annual average $PM_{2.5}$; the impact is particularly high in Quebec (40%). Conversely, home firewood burning has much lower contributions to annual mean $PM_{2.5}$ levels in the western provinces of Alberta, Saskatchewan, and Manitoba (<10%).
- Among modelled transportation sectors, the greatest contributor to annual mean $PM_{2.5}$ levels is on-road transportation emissions. Contributions to annual mean $PM_{2.5}$ levels are between 6% and 10% in all West and Central provinces. The next-highest contributing transportation sector is off-road vehicles and mobile equipment. Notably, the off-road vehicles and mobile equipment sector contribution to annual mean $PM_{2.5}$ levels in British Columbia (5%) corresponds to the third-highest sector in that province.
- Among modelled industry sectors, the oil and gas industry is a top contributor to the annual mean $PM_{2.5}$ levels in Alberta (17%), Saskatchewan (14%), Northwest Territories (14%), and Nunavut (4%). Electric power generation impacts annual mean $PM_{2.5}$ levels substantially in Alberta (9%) and Saskatchewan (12%), in all Atlantic provinces (between 3% and 9%), and in the Northwest Territories (8%) and Nunavut (1%). The ore and mineral industry is within the top three modeled sectors contributing to annual mean $PM_{2.5}$ levels in all Atlantic provinces (5% to 16%), and in Ontario (9%), Quebec (8%), Manitoba (7%), as well as in the North (3% in Northwest Territories and Nunavut).

[15] Sector-specific pollutant concentration estimates are first aggregated from air quality model's grid scale (10 km x 10 km) to larger census division areas via area-weighting and then aggregated to provincial, territorial, and national scales via population-weighting.

Sector contributions to ambient NO_2 concentrations

Sector contributions to 2015 modelled base case NO_2 concentrations (i.e., annual average of daily mean, population-weighted) at the national, provincial, and territorial scales are shown in Table 3-11. The sectors with the largest contributions to modelled annual mean NO_2 levels at the national scale were on-road transportation and off-road vehicles and mobile equipment sectors. Provincial and territorial trends are summarized below:

- On-road transportation is the top-ranked modelled sector contributing to annual mean NO_2 levels in nearly all provinces and in the Yukon, with contributions between 22% and 51%; it is ranked second-highest in Alberta (25%). Off-road vehicles and mobile equipment contributions to annual mean NO_2 levels are also within the top three modelled sectors in several provinces (all Western provinces excepting Alberta, all Central provinces, and in Newfoundland and Labrador), with contributions of 7% to 15%. Marine transportation sector contributions to annual mean NO_2 levels were highest in British Columbia (7%), the Atlantic provinces (10 - 20%), Quebec (6%), and Nunavut (12%), consistent with marine vessel traffic in Pacific, Atlantic, and Arctic coastal waters and the St. Lawrence Seaway.
- Reviewing modelled industry sectors, the oil and gas industry is the top-ranked sector contributing to annual mean NO_2 levels in Alberta (34% of modelled base case annual average NO_2 and thus even higher than on-road transportation) and second-ranked sector in Saskatchewan (17%) and Northwest Territories (10%). Electric power generation is within the top three sectors contributing to annual mean NO_2 levels in the Atlantic provinces of Nova Scotia (12%) and Prince Edward Island (11%), and in Nunavut (33%). The ore and minerals industry is the top-ranked sector contributing to annual mean NO_2 levels in the North (Northwest Territories (48%) and Nunavut (33%)).
- Reviewing modelled residential sectors, residential fuel combustion is a top sector contributing to annual mean NO_2 levels only in Ontario (9%).

Table 3-11 Sector contribution to modelled base case annual average (population-weighted) $PM_{2.5}$ and NO_2 in 2015 – national, provincial, and territorial.

(Three highest sectors nationally and by province or territory shown highlighted: red indicates top-ranked, dark orange is second-ranked, light orange is third-ranked)

		ALL On-road	Off-road & mobile	Air	Marine	Rail	Ore & mineral	Oil & gas[d]	Electricity gen	Manufacturing	Fuel combust	Firewood burn
		% of modelled base case $PM_{2.5}$[a, b, c]										
		TRANSPORTATION					**INDUSTRY**				**RESIDENTIAL**	
	CANADA	7	5	<	<	<	7	2	1	2	1	21
WEST	BRITISH COLUMBIA	10	5	<	2	<	2	<	<	4	1	22
	ALBERTA	8	4	<	<	2	2	17	9	5	1	6
	SASKATCHEWAN	6	5	<	<	2	5	14	12	4	<	3
	MANITOBA	10	4	<	<	2	7	4	4	2	1	7
CENTRAL	ONTARIO	7	6	<	<	<	9	1	<	2	2	11
	QUEBEC	6	3	<	<	<	8	<	<	1	<	40
ATLANTIC	NEW BRUNSWICK	3	1	<	<	<	16	3	3	3	<	22
	NOVA SCOTIA	2	<	<	1	<	8	1	9	2	<	22
	PRINCE EDWARD ISLAND	4	2	<	2	<	8	2	7	3	<	23
	NEWFOUNDLAND AND LABRADOR	1	1	<	1	<	5	2	8	<	<	15
NORTH	YUKON TERRITORY	<	<	<	<	<	<	<	<	<	<	5
	NORTHWEST TERRITORIES	2	2	<	<	<	3	14	8	3	<	2
	NUNAVUT	<	<	<	<	<	3	3	1	<	<	<
		% of modelled base case NO_2[a, b, c]										
		TRANSPORTATION					**INDUSTRY**				**RESIDENTIAL**	
	CANADA	38	12	2	3	4	3	5	1	2	6	<
WEST	BRITISH COLUMBIA	47	9	2	7	3	3	<	<	2	3	<
	ALBERTA	25	6	<	<	7	<	34	5	3	3	<
	SASKATCHEWAN	24	11	<	<	9	2	17	6	2	2	<
	MANITOBA	51	7	1	<	9	<	<	<	<	4	<
CENTRAL	ONTARIO	35	15	3	<	3	3	<	1	2	9	<
	QUEBEC	45	10	2	6	4	3	1	<	3	2	1
ATLANTIC	NEW BRUNSWICK	27	4	<	11	12	4	8	4	5	2	<
	NOVA SCOTIA	30	5	1	15	6	<	<	12	1	4	<
	PRINCE EDWARD ISLAND	36	7	<	10	2	<	<	11	2	5	<
	NEWFOUNDLAND AND LABRADOR	22	14	<	20	<	2	10	12	<	3	3
NORTH	YUKON TERRITORY	25	<	<	<	<	<	<	<	<	<	<
	NORTHWEST TERRITORIES	7	<	<	1	<	48	10	7	<	<	<
	NUNAVUT	<	<	<	12	<	33	<	33	<	<	<

[a] Relative estimate of sector's contribution to 2015 annual mean population-weighted concentration ($PM_{2.5}$, NO_2: annual average of daily mean, population-weighted); calculated as sector contribution to annual mean concentration divided by base case annual mean concentration for national, provinces, and territories.

[b] Contributions less than 1% denoted by <.

[c] Top three highest sectors contributing to national/provincial/territory air pollutant concentration are highlighted within each row (top-ranked in red, second-ranked in dark orange, third-ranked in light orange).

[d] Oil and gas industry sector contribution to pollutant concentrations not modelled separately but is estimated as sum of individual comprising sector model runs (upstream oil and gas, downstream oil and gas).

Sector contributions to ambient SO_2 concentrations

Sector contributions to 2015 modelled base case SO_2 concentrations (i.e., annual average of daily mean, population-weighted) at the national, provincial, and territorial scales are shown in Table 3-12. Nationally, and at the province/territory scale, contributions to annual mean SO_2 levels are dominated by industry sectors (ore and mineral, oil and gas, manufacturing). These three industry sectors contribute most to annual mean SO_2 levels in most provinces and territories. Provincial and territorial trends are summarized below:

- The ore and mineral industry sector contributes substantially to annual mean SO_2 levels in multiple provinces, including in Nunavut (100%), Quebec (52%), Ontario (48%), and New Brunswick (41%).
- Electric power generation is within the top three sectors contributing to annual mean SO_2 levels in all the Atlantic provinces (13% - 75%), in the Northwest Territories (33%) and in most West provinces (Alberta, 33%; Saskatchewan, 44%; Manitoba, 17%).
- Air transportation is the third-ranked modelled sector contributing to annual mean SO_2 levels in British Columbia (5%). In all other provinces and territories, transportation sectors show lower impacts on ambient SO_2 levels (3% or less). Marine transportation sector contributions to annual mean SO_2 levels were highest in British Columbia (2%) and Quebec (1%) but otherwise low (<1%), consistent with low-sulphur content fuel regulations enacted in 2015 for large vessels navigating Canadian waters.[16]
- Modelled residential sectors showed minimal contributions to annual mean SO_2 levels at the province and territory scale (2% or less).

Sector contributions to ambient O_3 and summer O_3 concentrations

Sector contributions to 2015 modelled base case annual O_3 (i.e., annual average of daily maximum, population-weighted) and summer O_3 (i.e., May-September average of daily maximum, population-weighted) at the national, and provincial and territorial scales are shown in Table 3-13. At the national scale, the modelled sectors showed minimal contributions to annual mean O_3 levels. By comparison, summer O_3 levels in some provinces and territories are impacted by up to 4% by the on-road transportation and off-road vehicles and mobile equipment sectors and by up to 10% by the oil and gas industry sector. Sectors showing greater contributions to mean summer O_3 levels are summarized below:

- The oil and gas industry was the top-ranked modelled sector contributing to mean summer O_3 levels in the Western provinces of Alberta (10%) and Saskatchewan (4%), and in the Northwest Territories (2%); oil and gas industry was also within the top-three sectors contributing to mean summer O_3 levels in Manitoba (2%).
- Transportation sectors were also found to contribute to mean summer O_3 levels. Highest contributions were found for on-road transportation (1 - 4%) and off-road vehicles and mobile equipment (1 - 3%) across all West and Central provinces and most of the Atlantic provinces (1 - 4%).

[16] The Canadian "Regulations Amending the Sulphur in Diesel Fuel Regulations (SOR/2002–254)" were enacted 1st January 2015 and reduced the maximum permissible fuel sulphur content to 0.1% (i.e., from prior levels of 3.5% pre-2012 and 1% mid-2012-2015) for all large vessels operating within a North American Emissions Control Area (NA ECA).

Marine transportation contributed to mean summer O_3 levels in all of the Atlantic provinces (1% - 3%) and in British Columbia on the Pacific coast (1%).

Table 3-12 Sector contribution to modelled base case annual average (population-weighted) SO_2 in 2015 – national, provincial, and territorial.

(Three highest sectors nationally and by province/territory shown highlighted: red indicates top-ranked, dark orange is second-ranked, light orange is third-ranked)

		TRANSPORTATION					INDUSTRY				RESIDENTIAL	
		% of modelled base case SO_2[a, b, c]										
		ALL On-road	Off-road & mobile	Air	Marine	Rail	Ore & mineral	Oil & gas[d]	Electricity gen	Manufacturing	Fuel combust	Firewood burn
	CANADA	2	<	1	<	<	**39**	**14**	6	**11**	1	<
WEST	BRITISH COLUMBIA	3	<	**5**	2	<	4	**11**	<	**11**	2	2
	ALBERTA	<	<	<	<	<	<	**51**	**33**	**9**	<	<
	SASKATCHEWAN	<	<	<	<	<	2	**39**	**44**	**3**	<	<
	MANITOBA	3	<	<	<	<	**19**	11	**17**	**35**	<	<
CENTRAL	ONTARIO	2	<	2	<	<	**48**	**6**	<	**10**	<	<
	QUEBEC	1	<	<	1	<	**52**	**9**	<	**14**	2	1
ATLANTIC	NEW BRUNSWICK	<	<	<	<	<	**41**	12	**13**	**13**	<	<
	NOVA SCOTIA	<	<	<	<	<	**9**	<	**75**	**1**	<	<
	PRINCE EDWARD ISLAND	<	<	<	<	<	**16**	<	**67**	<	<	<
	NEWFOUNDLAND AND LABRADOR	<	<	<	<	<	**3**	**51**	**31**	<	<	<
NORTH	YUKON TERRITORY	<	<	<	<	<	<	<	<	<	<	<
	NORTHWEST TERRITORIES[e]	<	<	<	<	<	**29**	**58**	**33**	<	<	<
	NUNAVUT[f]	<	<	<	<	<	**100**	<	<	<	<	<

[a] Relative estimate of sector's contribution to 2015 annual mean population-weighted concentration (SO_2: annual average of daily mean, population-weighted); calculated as sector contribution to annual mean concentration divided by base case annual mean concentration for national, provinces, and territories.

[b] Contributions less than 1% denoted by <.

[c] Top three highest sectors contributing to national/provincial/territory air pollutant concentration are highlighted within each row (top-ranked in red, second-ranked in dark orange, third-ranked in light orange).

[d] Oil and gas industry sector contribution to pollutant concentrations not modelled separately but is estimated as sum of individual comprising sector model runs (upstream oil and gas, downstream oil and gas).

[e] Combined contribution of modelled sectors may sum to greater than 100% due to zero out approach and non-linear atmospheric chemistry processes (Meng et al, 2019).

[f] Nunavut data reflects high impact of SO_2 emissions from proximal non-ferrous smelting and refining facility (facility since closed).

Table 3-13 Sector contribution to modelled base case annual and summer average (population-weighted) O_3 in 2015 – national, provincial, and territorial.

		ALL On-road	Off-road & mobile	Air	Marine	Rail	Ore & mineral	Oil & gas[c]	Electricity gen	Manufacturing	Fuel combust	Firewood burn
		% of modelled base case O_3 [a, b]										
		TRANSPORTATION					**INDUSTRY**				**RESIDENTIAL**	
	CANADA	<	<	<	<	<	<	<	<	<	<	<
WEST	BRITISH COLUMBIA	<	<	<	<	<	<	<	<	<	<	<
	ALBERTA	<	<	<	<	<	<	**3**	<	<	<	<
	SASKATCHEWAN	**1**	**1**	<	<	<	<	**2**	<	<	<	<
	MANITOBA	<	<	<	<	<	<	<	<	<	<	<
CENTRAL	ONTARIO	<	<	<	<	<	<	<	<	<	<	<
	QUEBEC	<	<	<	<	<	<	<	<	<	<	<
ATLANTIC	NEW BRUNSWICK	**1**	<	<	<	<	<	<	<	<	<	<
	NOVA SCOTIA	<	<	<	**2**	<	<	<	<	<	<	<
	PRINCE EDWARD ISLAND	**1**	<	<	**1**	<	<	<	<	<	<	<
	NEWFOUNDLAND AND LABRADOR	<	<	<	**1**	<	<	<	<	<	<	<
NORTH	YUKON TERRITORY	<	<	<	<	<	<	<	<	<	<	<
	NORTHWEST TERRITORIES	<	<	<	<	<	<	<	<	<	<	<
	NUNAVUT	<	<	<	<	<	<	<	<	<	<	<
		% of modelled base case summer O_3 [a, b]										
		TRANSPORTATION					**INDUSTRY**				**RESIDENTIAL**	
	CANADA	**2**	**2**	<	<	<	<	**2**	<	<	<	<
WEST	BRITISH COLUMBIA	**1**	**2**	<	**1**	<	<	<	<	1	<	<
	ALBERTA	**4**	**2**	<	<	1	<	**10**	1	<	<	<
	SASKATCHEWAN	**3**	**3**	<	<	<	<	**4**	2	<	<	<
	MANITOBA	**2**	**2**	<	<	<	<	**2**	<	<	<	<
CENTRAL	ONTARIO	**2**	**2**	<	<	<	<	<	<	<	<	<
	QUEBEC	**4**	**2**	<	<	<	<	<	<	<	<	<
ATLANTIC	NEW BRUNSWICK	**2**	**1**	<	**1**	<	<	<	<	<	<	<
	NOVA SCOTIA	**2**	<	<	**3**	<	<	<	**1**	<	<	<
	PRINCE EDWARD ISLAND	**2**	1	<	**2**	<	<	<	**1**	<	<	<
	NEWFOUNDLAND AND LABRADOR	<	<	<	**2**	<	<	<	<	<	<	<
NORTH	YUKON TERRITORY	<	<	<	<	<	<	<	<	<	<	<
	NORTHWEST TERRITORIES	<	<	<	<	<	<	**2**	<	<	<	<
	NUNAVUT	<	<	<	<	<	<	<	<	<	<	<

[a] Relative estimate of sector's contribution to 2015 mean population-weighted concentration (O_3: annual average of daily maximum, population-weighted; summer O_3: May-September average of daily maximum, population-weighted); calculated as sector contribution to annual or summer mean concentration divided by base case annual or summer mean concentration for national, provinces, and territories.

[b] Contributions less than 1% denoted by <.

[c] Oil and gas industry sector contribution to pollutant concentrations not modelled separately but is estimated as the sum of individual comprising sector model runs (upstream oil and gas, downstream oil and gas).

3.2.3.2 Profile of sector air quality impacts (key pollutants, geographic variation)

A general profile of air quality impact can be summarized for each sector by noting the pollutants that are most impacted and the regions where impacts are the greatest.

Transportation and mobile equipment sector emissions are generally dominated by NO_2 and primary $PM_{2.5}$ along with aerosol precursors (e.g., NO_x, VOCs) and thus greatly influence population-weighted annual mean concentrations for NO_2 and $PM_{2.5}$ in most regions of the country. The greatest transportation sector contributions to these two pollutants are generally due to on-road transportation, with HDVs (i.e., typically diesel-powered trucks) generally impacting NO_2 and $PM_{2.5}$ ambient air concentrations more than LDVs (i.e., passenger cars and trucks, typically gasoline-fueled). The off-road vehicles and mobile equipment sector also has substantial contributions to annual mean NO_2 and $PM_{2.5}$ air concentrations in a number of provinces. The marine transportation sector can influence annual mean NO_2 and $PM_{2.5}$ levels in coastal regions – in some Atlantic provinces the impact of marine transportation is comparable in magnitude to the impact of on-road LDVs.

Industry sector emissions also influence annual mean levels of $PM_{2.5}$ and NO_2 and also often represent dominant contributions to annual mean SO_2 levels (i.e., much higher impact on SO_2 than transportation sectors or residential sectors). The relative impact of the particular industry sectors shows a high degree of geographic variation, aligned with the location of the industry facilities, and some industry sectors impact comparably few provinces. As an example, the upstream oil and gas industry is a top contributor to annual mean air pollutant concentrations in the western provinces of Alberta and Saskatchewan, but not necessarily elsewhere. Conversely, some industries are common top contributors to annual mean air pollutant concentrations in many provinces and territories, such as the ore and mineral industry (Ontario, Quebec, New Brunswick, Nunavut) and coal-fired electric power generation (Alberta, Saskatchewan, Nova Scotia, Prince Edward Island, New Brunswick).

For the modelled residential combustion sectors, residential firewood burning is the dominant contributing source to annual mean $PM_{2.5}$ levels in many provinces, including Quebec, British Columbia, and the Atlantic provinces.

3.3 Sector contributions to air pollution-related health impacts

3.3.1 Pollutants driving premature mortality

At the national scale, the individual sector contributions to air pollution-related premature mortality are presented by pollutant (i.e., $PM_{2.5}$, NO_2, O_3, and summer O_3) in Table 3-14, along with the corresponding total socio-economic valuation (i.e., sum of mortality and morbidity endpoints, all pollutants). At the national scale, a total of approximately 6,500 air pollution-related deaths were attributed to the modelled transportation, industry, and residential sectors. The total socioeconomic valuation attributed to the modelled sectors is approximately $51 B (2015 CAD).

Provincial and territorial tables of sector contributions to air pollution-related mortality and total valuation (i.e., mortality and morbidity) are presented in *Appendix A.1*. [17]

The specific pollutants driving premature mortality estimates vary by sector, reflecting differences in each sector's pollutant emissions (i.e., emissions activity profile). For the transportation and mobile equipment sectors, more than half of total premature deaths (i.e., sum of all modelled pollutants; see Table 3-14) are associated with sector contributions to ambient $PM_{2.5}$ concentrations (e.g., approximately 67% for all on-road transportation), followed by sector contributions to NO_2 and summer O_3.

Across the industry sectors, while absolute and relative premature deaths from individual pollutants vary, ambient $PM_{2.5}$ concentrations remain the main contributor to health impacts, representing 54% to 98% of total sector deaths. Mean summer O_3 concentrations also contribute a substantial fraction of premature deaths, reaching 20% for upstream oil and gas, 8% for electric power generation, and 6% to 13% for manufacturing sectors.

For the modelled residential sectors, deaths associated with emissions from home firewood burning are almost entirely attributed to $PM_{2.5}$ exposure, consistent with this sector's high emissions of primary $PM_{2.5}$ and $PM_{2.5}$ precursors such as VOCs. For residential fuel combustion, $PM_{2.5}$ is again the dominant pollutant contributing to premature deaths but deaths are also attributed to NO_2.

Sector-specific total all-cause premature mortality estimates for the total of all pollutants ($PM_{2.5}$, NO_2, O_3, summer O_3) are graphically summarized in Figure 3-1.

[17] Additional health impact model results (i.e., sector morbidity cases by pollutant at national level) are included in the accompanying *Supplementary Material* document.

Table 3-14 All-cause premature mortality and valuation by sector and pollutant, national (2015).

	MORTALITY BY POLLUTANT[a, b, c]				ALL-POLLUTANT MORTALITY[e] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] mortality and morbidity median (2.5% - 97.5% CI)
	$PM_{2.5}$	NO_2	O_3	Summer O_3[d]		
TRANSPORTATION & MOBILE EQUIPMENT SECTORS						
ALL On-road	**800**	**330**	**-7**	**92**	**1,200 (500 – 1,900)**	**$ 9,500 ($ 2,500 – $ 19,000)**
On-road LDV	300	99	-8	24	410 (170 – 660)	$ 3,200 ($ 900 – $ 6,500)
On-road HDV	490	220	-22	42	730 (280 – 1,200)	$ 5,700 ($ 1,200 – $ 12,000)
Off-road & mobile equipment	**540**	**100**	**47**	**71**	**760 (370 – 1,100)**	**$ 5,900 ($ 2,200 – $ 11,000)**
Air + Marine + Rail	**170**	**80**	**25**	**41**	**320 (130 – 510)**	**$ 2,500 ($ 800 – $ 5,000)**
Air transportation	21	16	-7	-3	28 (2 – 55)	$ 220 ($ 46 – $ 560)
Marine transportation	76	28	23	26	150 (74 – 230)	$ 1,200 ($ 420 – $ 2,300)
Rail transportation	77	37	8	17	140 (60 – 220)	$ 1,100 ($ 330 – $ 2,100)
INDUSTRY SECTORS						
Ore and mineral industry	**890**	**23**	**-2**	**7**	**910 (450 – 1,400)**	**$ 7,200 ($ 2,600 – $ 14,000)**
Cement manufacturing	110	12	-9	-3	110 (32 – 190)	$ 870 ($ 60 – $ 1,900)
Non-ferrous refining and smelting	210	0	1	1	210 (110 – 310)	$ 1,600 ($ 650 – $ 3,100)
Oil and gas industry[g]	**220**	**38**	**40**	**53**	**350 (170 – 520)**	**$ 2,700 ($ 980 – $ 5,100)**
Upstream oil and gas	140	31	40	51	260 (130 – 390)	$ 2,000 ($ 750 – $ 3,800)
Downstream oil and gas	78	7	0	2	90 (40 – 130)	$ 690 ($ 230 – $ 1,300)
Electric power generation	**120**	**11**	**7**	**12**	**150 (75 – 230)**	**$ 1,200 ($ 440 – $ 2,300)**
Coal-fired electric power gen	110	5	5	9	130 (65 – 190)	$ 1,000 ($ 380 – $ 1,900)
Manufacturing	**240**	**19**	**20**	**23**	**300 (150 – 450)**	**$ 2,400 ($ 900 – $ 4,500)**
Chemicals	66	6	1	4	76 (37 – 110)	$ 600 ($ 220 – $ 1,100)
Pulp and paper	68	4	9	9	89 (45 – 130)	$ 700 ($ 270 – $ 1,300)
RESIDENTIAL SECTORS						
Residential fuel combustion	**150**	**46**	**-15**	**0**	**180 (70 – 290)**	**$ 1,400 ($ 350 – $ 2,900)**
Home firewood burning	**2,300**	**4**	**2**	**3**	**2,300 (1,200 – 3,300)**	**$ 18,000 ($ 7,000 – $ 33,000)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality for O_3 and summer O_3 correspond to a negative difference for modelled ambient air pollutant concentration for base case (all emissions sectors) less sector scenario (sector emissions set to zero). Annual O_3 metric is more likely to be negative as it overlaps with periods of reduced sunlight and temperature, and reduced O_3 production. Negative O_3 health impacts occur in areas with a lot of NO_x emissions and must be considered within the broader context of emissions reductions, as they are not expected to persist with large-scale reductions in emissions, such as those applied nationally.

[d] May – September months.

[e] Median, 2.5th percentile confidence interval (CI), and 97.5th percentile CI (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile confidence interval (CI), and 97.5th percentile CI (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector mortality and valuation data estimated as the sum of individual comprising sector model runs (upstream oil and gas, downstream oil and gas).

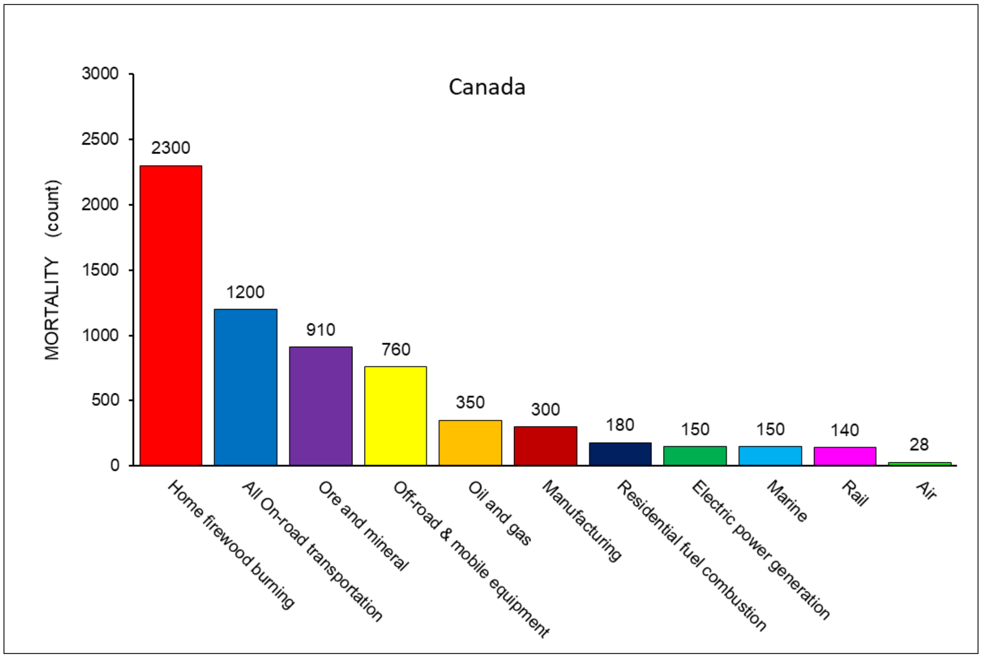

Figure 3-1 Sector-specific all-cause air pollution-related premature mortality ($PM_{2.5}$, NO_2, O_3, summer O_3) in Canada (2015).

3.3.2 Ranking sector health impacts at national, provincial, and territorial scales

The individual sector contributions to total air pollution-related deaths (all modelled pollutants) are shown in Table 3-15. Comparison is made across major sectors, and the three top-ranking sectors contributing to air pollution-related deaths are highlighted for each region (i.e., national, province, territory).

Nationally, the sectors with air pollutant emissions contributing the most to Canadian premature deaths in 2015 were home firewood burning (2,300 deaths), on-road transportation (1,200 deaths), and ore and mineral industry (910 deaths).

Home firewood burning was the top-ranked sector in nearly all provinces except in the western provinces of Alberta, Saskatchewan, and Manitoba. Non-fatal health outcomes attributed to home firewood burning included: 1,300 cardiac and respiratory-related hospital admissions and emergency room visits; 9,300 child and 2,100 adult chronic bronchitis cases; 2.9 million (M) restricted activity days; and 5.9 M symptom days (including acute respiratory and asthma symptom days).

On-road transportation was the second-ranked sector by air pollution-related deaths in most provinces and top-ranked in Manitoba (Table 3-15). In Ontario, the number of deaths attributed to on-road transportation were comparable in magnitude to those from home firewood burning. At the national scale, the majority of deaths attributed to on-road transportation were attributed to on-road HDVs (730 deaths) compared to LDVs (410 deaths) (Table 3-14). Non-fatal health outcomes attributed to on-road transportation included: 780 cardiac and respiratory-related hospital admissions and emergency visits; 3,600 and 800 child and adult chronic bronchitis cases, respectively; 1.3 M restricted activity days; and 3 M symptom days (including acute respiratory and asthma symptom days).

The ore and mineral industry sector was within the top three ranked sectors contributing to air pollution-related premature mortality in a majority of provinces. Within this sector, the cement manufacturing and non-ferrous refining and smelting subsectors together contributed to 320 air pollution-related premature deaths at the national scale (Table 3-14), accounting for close to half the air pollution-related premature death attributed to the ore and mineral industry overall. Non-fatal health outcomes attributed to the ore and mineral industry included: 500 cardiac and respiratory-related hospital admissions and emergency visits; 3,800 and 840 child and adult chronic bronchitis cases, respectively; 1.2 M restricted activity days; and 2.4 M symptom days (including acute respiratory and asthma symptom days).

At the national scale, the total monetized value of the health burden (i.e., sum of fatal and non-fatal health outcomes) for these three top-ranking sectors was: home firewood burning, $18 B; on-road transportation, $9.5 B; and ore and mineral industry, $7.2 B (CAD 2015). The majority of the estimated health burden costs were attributed to premature mortality.

Other sectors were more regional in their air quality health impacts, ranking highly in only one or few provinces.[18] The oil and gas industry sector was within the top three sectors contributing air pollution-related premature mortality only in Alberta and Saskatchewan, and was the top-ranked sector in these provinces. Within the oil and gas industry sector, the majority of national scale air pollution-related premature death (Table 3-14) is attributed to the upstream oil and gas sector (e.g., drilling, extraction; 260 deaths) compared with the downstream oil and gas sector (e.g., refining; 90 deaths).

Also regional in its health impacts was the electric power generation sector (150 deaths nationally), which was within the top three sectors only in the Western provinces of Alberta and Saskatchewan and several Atlantic provinces (Nova Scotia, Prince Edward Island, Newfoundland and Labrador). Air pollution-related premature mortality attributed to the electric power generation sector, is largely due to air quality impacts of coal-fired electric power generation (130 deaths nationally; Table 3-14), consistent with coal-fired facilities generally having much higher emissions of $PM_{2.5}$, NO_x, and SO_x than facilities using other forms of fossil fuel (e.g., natural gas, oil).

The off-road vehicles and mobile equipment sector was within the top three ranked sectors only in the Western provinces of British Columbia and Manitoba. Marine transportation (150 deaths nationally) was ranked within the top three sectors contributing to premature mortality only in the Atlantic provinces of Nova Scotia and Newfoundland and Labrador. Reviewing other transportation sectors, rail transportation (140 deaths nationally) contributed similar premature mortality as marine transportation, while comparably fewer premature deaths were attributed to air transportation (28 deaths).

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[18] Rankings are comparative within each discussed geographic scale (e.g., national, provincial, territorial). A sector ranked within the top three within one province may not be in the top three in another province, even where absolute mortality counts may be higher. As example, marine transportation is within top three ranked sectors in Nova Scotia (9 deaths) but not in British Columbia, notwithstanding higher absolute mortality counts in British Columbia (46 deaths), since other sectors in British Columbia contributed much higher mortality (home firewood burning, 2,300 deaths; all on-road transportation, 1,200 deaths; ore and mineral industry, 910 deaths).

Table 3-15 All-cause air pollution-related premature mortality ($PM_{2.5}$, NO_2, O_3, summer O_3) by sector and geographic region (2015).

(Three highest sectors nationally and by province/territory shown highlighted: red indicates top-ranked, dark orange is second-ranked, light orange is third-ranked)

MORTALITY[a, b, c] (count, all pollutants)		**ALL On-road**	**Off-road & mobile**	**Air**	**Marine**	**Rail**	**Ore and mineral**	**Oil and gas**[d]	**Electric power gen**	**Manufacturing**	**Fuel combustion**	**Home firewood burn**	**Total for Canada / Province / Territory**[e]
REGION[f]		**TRANSPORTATION & MOBILE EQUIPMENT**					**INDUSTRY**				**RESIDENTIAL**		
	CANADA[e]	**1,200**	760	28	150	140	**910**	350	150	300	180	**2,300**	**6,500**
WEST	British Columbia	**160**	**83**	3	46	7	13	12	1	59	12	**250**	**650**
	Alberta	**82**	42	<	2	24	16	**180**	**61**	34	10	30	**480**
	Saskatchewan	**14**	14	<	<	5	6	**25**	**17**	6	1	3	**93**
	Manitoba	**38**	**17**	<	<	8	**18**	13	10	6	4	17	**130**
CEN TRA	Ontario	**500**	390	14	29	53	**480**	74	30	110	130	**550**	**2,400**
	Quebec	**400**	200	8	58	40	**360**	36	16	76	26	**1,400**	**2,600**
ATLANTIC	New Brunswick	**6**	3	<	4	2	**13**	3	3	4	<	**14**	**52**
	Nova Scotia	7	3	<	**9**	1	8	2	**11**	3	<	**15**	**59**
	Prince Edward Island	**2**	<	<	1	<	1	<	**2**	<	<	**3**	**11**
	Newfoundland and Labrador	2	<	<	**3**	<	2	1	**3**	<	<	**3**	**15**
NORTH	Yukon Territory	<	<	<	<	<	<	<	<	<	<	<	<
	Northwest Territories	<	<	<	<	<	<	<	<	<	<	<	<
	Nunavut	<	<	<	<	<	<	<	<	<	<	<	<

[a] Sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Mortality count less than 1 denoted as <.

[d] Oil and gas industry sector mortality and valuation data estimated as the sum of individual comprising sector model runs (upstream oil and gas, downstream oil and gas).

[e] Total of modelled sectors; values may not correspond due to rounding.

[f] Top three sectors by mortality count in each geographic region (Canada, province, territory) shown highlighted (top-ranked in red, second-ranked in dark orange, third-ranked in light orange).

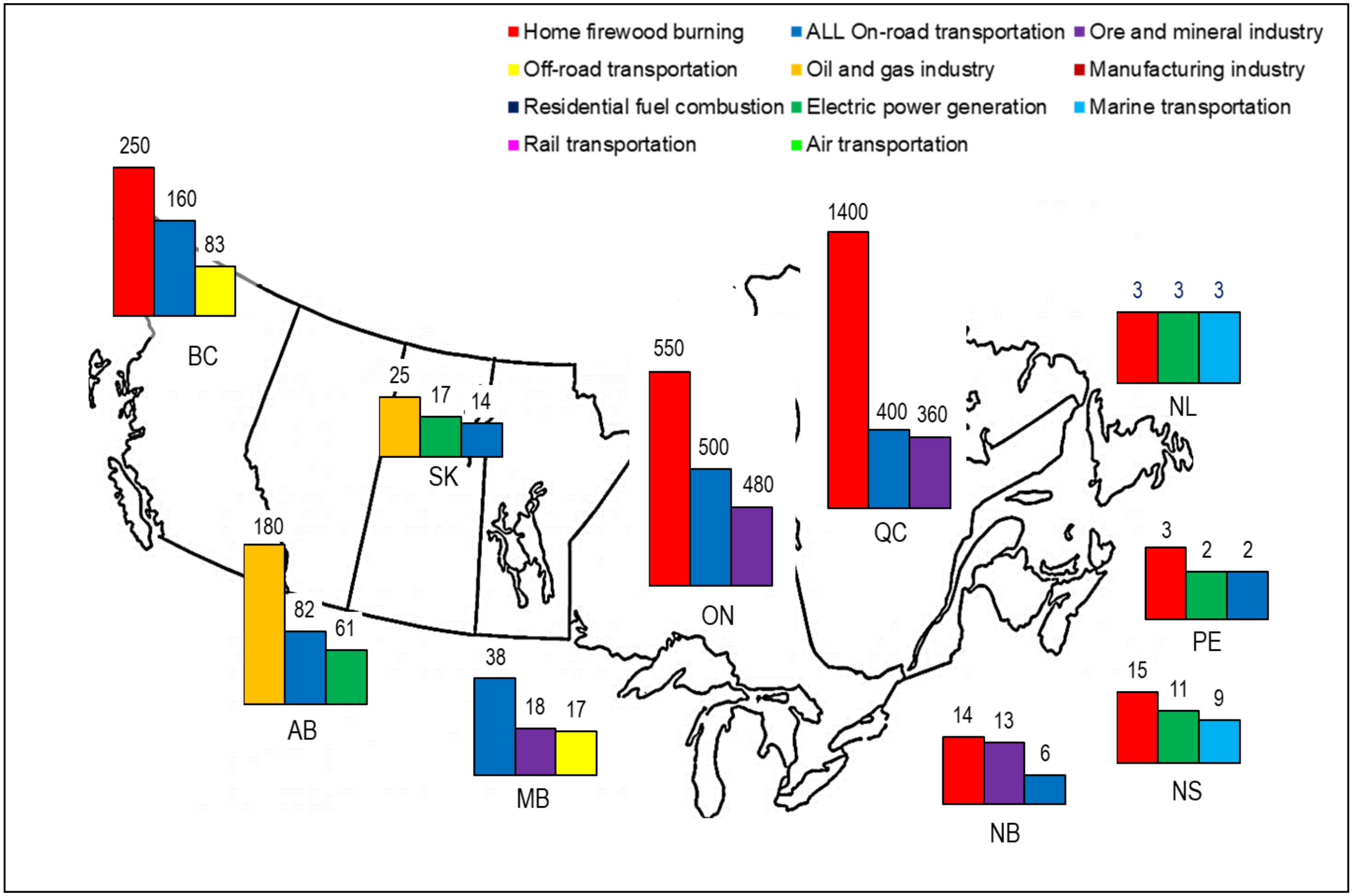

Figure 3-2 All-cause premature mortality counts ($PM_{2.5}$, NO_2, O_3, summer O_3) by top three sectors in each province (2015).

3.3.3 Ranking sector health impacts at air zone scale

3.3.3.1 Air zones and air pollution-related premature mortality of major sectors

The individual major sector contributions to air pollution-related premature mortality are presented for West and Central region air zones in Table 3-16 and for Atlantic region air zones in Table 3-17. Sector deaths summed to less than 1 in all North region air zones (i.e., air zones within Yukon, Northwest Territories, and Nunavut) and thus are not tabulated. Table 3-16 and Table 3-17 also identify the three top-ranking sectors contributing to air pollution-related deaths in each air zone.

Some general trends can be observed from the air zone scale health impact results. First, higher counts of air pollution-related premature deaths occur in highly populated and generally urbanized air zones; conversely, rural and sparsely populated air zones had lower population-weighted estimates of premature deaths due to air pollution (i.e., fewer than 5 cases). Second, top-ranking sectors varied both regionally and within each province, reflecting variations in air zone characteristics (i.e., population density, degree of urbanization, presence of local industry, etc.). Notwithstanding the above, key sectors of interest include on-road transportation (i.e., top-three ranking in nearly all air zones) and home firewood burning (i.e., top-three ranking in majority of air zones, with the notable exception of Saskatchewan and Alberta).

Industry sectors' contributions to air pollution-related deaths exhibit the most strongly regional trends at the air zone scale, reflecting the concentration of nearby industry facilities. For example, the oil and gas industry sector ranks within the top three sectors for mortality in all Alberta and Saskatchewan air zones. The electric power generation sector (specifically, coal-fired facilities) also contributes to premature mortality in Alberta and Saskatchewan and in nearly all Atlantic province air zones. The ore and mineral industry sector ranks within the top three sectors by mortality in nearly all Ontario, Quebec, New Brunswick and Nova Scotia air zones as well as in Manitoba's single air zone.

Detailed sector-specific mortality estimates are presented below for all air zones with 5 or more total premature deaths, arranged by province (Sections 3.3.3.2 – 3.3.3.11). Sector mortality estimates for North region air zones (i.e., Yukon, Northwest Territories, Nunavut) are not discussed here due to low sector deaths (<1 per air zone). Additional sector-specific health impact data (i.e., premature mortality by pollutant; total economic valuations for all mortality and morbidity endpoints) are presented for all air zones with 5 or more total premature deaths in *Appendix A.2* (Sections A.2.1 - A.2.10).

Maps showing air zone names and boundaries are provided in *Appendix A.2* (Section A.2.11).

Table 3-16 All-cause air pollution-related premature mortality by sector and air zone (all pollutants, 2015) – West, Central regions.
(Three highest sectors in each air zone shown highlighted:
red indicates top-ranked, dark orange is second-ranked, light orange is third-ranked)

Region / Province[f]		Air Zone[g]	Pop.[h]	TRANSPORTATION & MOBILE EQUIPMENT: ALL On-road	TRANSPORTATION & MOBILE EQUIPMENT: Off-road & mobile	TRANSPORTATION & MOBILE EQUIPMENT: Air	TRANSPORTATION & MOBILE EQUIPMENT: Marine	TRANSPORTATION & MOBILE EQUIPMENT: Rail	INDUSTRY: Ore and mineral	INDUSTRY: Oil and gas[d]	INDUSTRY: Electricity gen	INDUSTRY: Manufacturing	RESIDENTIAL: Fuel Combustion	RESIDENTIAL: Firewood burn	Total in Air Zone[e]
WEST	BC	CENTRAL INTERIOR	0.2 M	2	1	<	<	<	<	1	<	2	<	2	9
		COASTAL	0.1 M	<	<	<	1	<	<	<	<	<	<	<	<
		GEORGIA STRAIT	0.8 M	23	6	<	17	1	1	<	<	13	1	43	110
		LOWER FRASER VALLEY	2.8 M	120	71	3	26	4	9	7	<	39	10	170	460
		NORTHEAST	< 0.1 M	<	<	<	<	<	<	1	<	<	<	<	<
		NORTHWEST	< 0.1 M	<	<	<	<	<	<	<	<	<	<	<	<
		SOUTHERN INTERIOR	0.7 M	20	4	<	1	2	2	3	1	5	1	28	68
	AB	LOWER ATHABASCA	0.1 M	<	<	<	<	<	<	3	1	<	<	<	5
		NORTH SASKATCHEWAN	1.6 M	32	20	<	1	10	6	83	33	19	4	15	220
		PEACE	0.2 M	1	1	<	<	1	<	7	1	1	<	1	13
		RED DEER	0.7 M	16	7	<	<	4	3	32	10	5	2	4	84
		SOUTH SASKATCHEWAN	1.4 M	31	12	<	1	8	7	49	14	8	4	9	140
		UPPER ATHABASCA	0.1 M	1	1	<	<	1	<	5	2	1	<	1	12
	SK	BOREAL	< 0.1 M	<	<	<	<	<	<	<	<	<	<	<	<
		GRASSLANDS	< 0.1 M	1	1	<	<	<	<	2	2	<	<	<	8
		GREAT PLAINS	0.5 M	7	6	<	<	2	3	9	7	3	<	1	38
		NORTHEAST	0.1 M	2	2	<	<	1	1	3	2	1	<	1	11
		SOUTHEAST	0.1 M	1	1	<	<	1	1	2	2	<	<	<	9
		WESTERN YELLOWHEAD	0.3 M	4	3	<	<	1	1	8	4	2	<	1	24
	MB	MANITOBA	1.3 M	38	17	1	<	8	18	13	10	6	4	17	130
CENTRAL	ON	HAMILTON	0.5 M	27	16	1	2	3	56	5	2	7	6	36	160
		NORTHERN ONTARIO	0.6 M	4	3	<	1	2	8	2	2	2	<	4	26
		SARNIA	< 0.1 M	1	<	<	<	<	1	<	<	<	<	1	<
		SAULT STE. MARIE	<0.1 M	<	<	<	<	<	<	<	<	<	<	<	<
		SOUTHERN ONTARIO	12 M	470	370	14	27	47	400	66	27	100	120	510	2,200
		SUDBURY	0.2 M	3	1	<	<	1	8	1	<	1	<	3	19
	QC	EAST	0.2 M	3	1	<	2	1	4	1	1	1	<	6	20
		NORTH	0.4 M	1	1	<	1	<	5	<	<	1	<	3	12
		SOUTH	7.6 M	400	200	8	55	38	350	35	15	74	26	1,40	2,600

MORTALITY[a, b, c] (count, all pollutants)

[a] Sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3).
[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures.
[c] Mortality count less than 1 denoted as <.
[d] Oil and gas industry sector mortality and valuation data estimated as sum of individual comprising sector model runs (upstream oil and gas, downstream oil and gas).
[e] Air zone total values may not correspond exactly due to rounding.
[f] BC: British Columbia; AB: Alberta; SA: Saskatchewan; MB: Manitoba; ON: Ontario; QC: Québec.
[g] Top three sectors by mortality count in each air zone highlighted (top-ranked red, second-ranked dark orange, third-ranked light orange). For air zones with tied mortality counts, top three ranking is expanded to include all tied sectors, as appropriate.
[h] Approximate population, rounded to nearest 0.1 million.

Table 3-17 All-cause air pollution-related premature mortality by sector and air zone (all pollutants, 2015) – Atlantic region.

(three highest sectors in each air zone shown highlighted:

red indicates top-ranked, dark orange is second-ranked, light orange is third-ranked)

		MORTALITY[a, b, c] *(count, all pollutants)*		TRANSPORTATION & MOBILE EQUIPMENT					INDUSTRY				RESIDENTIAL		
Region / Province[f, g]		**Air Zone**[h]	**Pop.**[i]	**ALL On-road**	**Off-road & mobile**	**Air**	**Marine**	**Rail**	**Ore and mineral**	**Oil and gas**[d]	**Electricity gen**	**Manufacturing**	**Fuel Combustion**	**Firewood burn**	**Total in Air Zone**[e]
ATLANTIC	**NB**	CENTRAL REGION	0.5 M	4	2	<	2	1	6	2	2	2	<	9	31
		NORTH REGION	0.1 M	1	<	<	1	<	2	<	1	<	<	2	7
		SOUTH REGION	0.2 M	1	1	<	1	<	5	1	1	1	<	3	14
	NS	CENTRAL	0.5 M	3	1	<	4	<	3	1	4	1	<	6	23
		EASTERN	0.1 M	1	<	<	2	<	1	<	3	<	<	3	12
		NORTHERN	0.2 M	2	1	<	1	<	2	1	3	1	<	3	13
		WESTERN	0.2 M	1	1	<	2	<	2	1	1	1	<	3	12
	PEI	PRINCE EDWARD ISLAND	0.2 M	2	1	<	1	<	1	<	2	1	<	3	10
	NL	LABRADOR	< 0.1 M	<	<	<	<	<	<	<	<	<	<	<	<
		NEWFOUNDLAND	0.5 M	1	1	<	3	<	2	1	3	<	<	3	15

[a] Sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures.

[c] Mortality count less than 1 denoted as <.

[d] Oil and gas industry sector mortality and valuation data estimated as sum of individual comprising sector model runs (upstream oil and gas, downstream oil and gas).

[e] Air zone total values may not correspond exactly due to rounding.

[f] NB: New Brunswick; NS: Nova Scotia; PEI: Prince Edward Island; NL: Newfoundland and Labrador.

[g] North region (i.e., Yukon, Northwest Territories, Nunavut) air zones not shown since all sector deaths <1.

[h] Top three sectors by mortality count in each air zone highlighted (top-ranked red, second-ranked dark orange, third-ranked light orange). For air zones with tied mortality counts, top three ranking is expanded to include all tied sectors, as appropriate.

[i] Approximate population, rounded to nearest 0.1 million.

3.3.3.2 British Columbia

Several British Columbia air zones had estimates of 5 or more premature deaths attributed to air pollution across the modelled sectors: Lower Fraser Valley, Georgia Strait, Southern Interior, and Central Interior. Detailed sector-specific health impact data are tabulated for these British Columbia air zones in *Appendix A.2* (Section A.2.1). The remaining British Columbia air zones (Coastal, Northeast, Northwest) are largely rural with comparably fewer sources and lower and dispersed populations (< 0.2M inhabitants).

The most highly populated air zone of Lower Fraser Valley had the highest number of air pollution-related premature deaths across the modelled sectors (approximately 460 deaths). In this air zone, the top three modeled sectors contributing to air pollution-related mortality are home firewood burning (170 deaths), all on-road transportation (120 deaths), and off-road vehicles and mobile equipment (71 deaths). Home firewood burning is top-ranked or within the top three sectors with high-mortality in four of seven air zones. Marine transportation also contributed to air pollution-related deaths in air zones with Pacific coastline and related waterways (Lower Fraser Valley, 26 deaths; Georgia Strait, 17 deaths, third-ranked sector; Coastal, 1 death, top-ranked sector).

The management of air quality within British Columbia air zones may be informed by the following key findings summarizing the dominant pollutants and the top-ranked modelled sectors contributing to air pollution-related health impacts within each air zone (air zones arranged by decreasing total premature mortality):

- **Lower Fraser Valley:** This is the most populous air zone in the province (2015 pop. ~2.8M) and a total of 460 air pollution-related premature deaths were estimated across the modelled sectors. By pollutant, premature deaths are attributed primarily to sector contributions to ambient annual mean $PM_{2.5}$ levels (420 deaths) with additional deaths due to sector contributions to annual mean NO_2 levels (65 deaths). By sector, home firewood burning (170 deaths) and on-road transportation (120 deaths) emissions contribute the most to air pollution-related deaths, followed by off-road vehicles and mobile equipment (71 deaths). Marine sector impacts to air quality also contribute to comparably high mortality in this coastal air zone (26 deaths).
- **Georgia Strait:** This is the second most populous air zone in the province (2015 pop. ~0.8M) and 110 air pollution-related premature deaths are estimated across the modelled sectors. These are attributed primarily to sector contributions to annual mean $PM_{2.5}$ levels (73 deaths) and annual/summer mean O_3 levels (21 deaths). By sector, home firewood burning (43 deaths), on-road transportation (23 deaths), and marine transportation (17 deaths) contribute the most premature mortality.
- **Southern Interior:** This is also a highly populated air zone (2015 pop. ~0.7M) and 68 air pollution-related premature deaths are estimated across the modelled sectors. By pollutant, the majority of premature deaths are due to sector contributions to annual mean $PM_{2.5}$ levels (43 deaths) and annual/summer mean O_3 levels (20 deaths). By sector, premature deaths are largely due to emissions from home firewood burning (28 deaths) and on-road transportation (20 deaths), followed by the manufacturing industry (5 deaths).
- **Central Interior:** In this lower population air zone (2015 pop. ~0.2M) the modelled sectors together contribute an estimated 9 air pollution-related premature deaths, primarily due to sector contributions to annual mean $PM_{2.5}$ levels (4 deaths). Sector emissions contributing most to air

pollution-related premature mortality in this air zone are those from home firewood burning (2 deaths), on-road transportation (2 deaths), and manufacturing industry (2 deaths).

3.3.3.3 Alberta

All Alberta air zones had estimates of 5 or more premature deaths due to air pollution across the modelled sectors: North Saskatchewan, South Saskatchewan, Red Deer, Peace, Upper Athabasca, and Lower Athabasca. Detailed sector-specific health impact data are tabulated for these Alberta air zones in *Appendix A.2* (Section A.2.2).

In Alberta, the highest air pollution-related deaths are in the more densely populated air zones of North Saskatchewan (approximately 220 deaths across modeled sectors), South Saskatchewan (approximately 140 deaths), and Red Deer (approximately 84 deaths). Across all Alberta air zones, the majority of air pollution-related premature mortality is attributed to the oil and gas industry sector. On-road transportation and electric power generation are also in the top three sectors in most Alberta air zones. Intensive oil and gas industry emissions are located in the northern air zones of Lower Athabasca and Peace (e.g., oil sands projects, Fort McMurray) but showed low overall air pollution-related deaths due to their low population densities.

The management of air quality within Alberta air zones may be informed by the following key findings summarizing the dominant pollutants and the top-ranked modelled sectors contributing to air pollution-related health impacts within each air zone (air zones arranged by decreasing total premature mortality):

- **North Saskatchewan:** This is Alberta's most populous air zone (2015 pop. ~1.6M) with a total of approximately 220 air pollution-related premature deaths estimated across the modeled sectors. By pollutant, premature deaths are attributed primarily to sector contributions to ambient annual mean $PM_{2.5}$ levels (150 deaths) with additional mortality attributed to sector contributions to annual/summer mean O_3 levels (41 deaths) and annual mean NO_2 levels (34 deaths). By sector, oil and gas industry impacts on air quality contribute the most premature mortality (83 deaths), followed by coal-fired electric power generation (33 deaths), and on-road transportation (32 deaths). Premature deaths are also estimated for other sectors, including off-road vehicles and mobile equipment (20 deaths), manufacturing (19 deaths, with 14 deaths from the chemicals industry), and home firewood burning (15 deaths).
- **South Saskatchewan:** This is Alberta's second-most populous air zone (2015 pop. ~1.4M) with 140 air pollution-related premature deaths estimated across modelled sectors. By pollutant, premature deaths are attributed to sector contributions to annual mean $PM_{2.5}$ levels (87 deaths), annual/summer mean O_3 levels (35 deaths), and annual mean NO_2 levels (20 deaths). By sector, the oil and gas industry contributes the most to premature deaths (49 deaths). Additional premature deaths are also attributed to on-road transportation (31 deaths) and coal-fired electric power generation (14 deaths).
- **Red Deer:** This is also a highly populated air zone in the province (2015 pop. ~0.7M) and 84 air pollution-related premature deaths were estimated across the modelled sectors, due primarily to sector contributions to annual mean $PM_{2.5}$ levels (51 deaths), annual/summer mean O_3 levels (18 deaths) and annual mean NO_2 levels (12 deaths). As seen in other Alberta air zones, oil and gas industry sector impacts on air quality contribute the highest premature deaths (32 deaths).

Additional air pollution-related premature deaths are attributed to emissions from on-road transportation 16 deaths) and coal-fired electric power generation (10 deaths).

- **Peace:** In this comparably lower population air zone (2015 pop. ~0.2M), the modelled sectors together contribute an estimated 13 air pollution-related premature deaths, attributed primarily to the upstream oil and gas industry (7 deaths).
- **Upper Athabasca:** The modelled sectors together contribute approximately 12 air pollution-related premature deaths in this low population air zone (2015 pop. ~0.1M). Air pollution-related premature deaths are largely attributed to the upstream oil and gas industry (5 deaths).
- **Lower Athabasca:** Approximately 5 air pollution-related premature deaths are estimated across the modelled sectors in this low population air zone (2015 pop. ~0.1M). Air pollution-related premature deaths are largely attributed to emissions from the upstream oil and gas industry (3 deaths) and coal-fired electric power generation (1 death).

3.3.3.4 Saskatchewan

Most Saskatchewan air zones had estimates of 5 or more air pollution-related premature deaths across the modelled sectors: Great Plains, Western Yellowhead, Northeast, Southeast, and Grasslands. Detailed sector-specific health impact data are tabulated for these air zones in *Appendix A.2* (Section A.2.3). The remaining Saskatchewan air zone (Boreal) is largely rural with a dispersed population (< 0.05M inhabitants), resulting in low estimates of premature mortality due to air pollution.

In Saskatchewan, the highest air pollution-related deaths are in the comparably more populated air zone of Great Plains (approximately 38 deaths across modeled sectors). Similar to sector trends in neighbouring Alberta, the top three sectors contributing to air pollution-related mortality across multiple air zones were oil and gas industry, electric power generation (i.e., coal-fired), and on-road transportation. In the majority of air zones, air pollution-related premature mortality attributed to off-road vehicles and mobile equipment emissions was comparable to deaths from on-road transportation emissions.

The management of air quality within Saskatchewan air zones may be informed by the following key findings summarizing the dominant pollutants and the top-ranked modelled sectors contributing to air pollution-related health impacts within each air zone (air zones arranged by decreasing total premature mortality):

- **Great Plains:** This is Saskatchewan's most populous air zone (2015 pop. ~0.5M) and the modelled sectors together contribute an estimated 38 air pollution-related premature deaths. By pollutant, the majority of premature deaths are attributed to sector contributions to ambient annual mean $PM_{2.5}$ levels (23 deaths) and annual/summer mean O_3 levels (8 deaths). Top-ranked sectors contributing to air pollution-related premature mortality are upstream oil and gas (8 deaths), coal-fired electric power generation (7 deaths), on-road transportation (7 deaths), and off-road vehicles and mobile equipment (6 deaths).
- **Western Yellowhead:** This is Saskatchewan's second-most populous air zone (2015 pop. ~0.3M) and a total of 24 air pollution-related premature deaths are estimated across the modelled sectors. By pollutant, the majority of these deaths are attributed to sector contributions to annual mean $PM_{2.5}$ levels (14 deaths) and annual/summer mean O_3 levels (7 deaths). Top-ranked sectors are upstream oil and gas (7 deaths), coal-fired electric power generation (4 deaths), on-road transportation (4 deaths), and off-road vehicles and mobile equipment (3 deaths).

- **Northeast:** This is a comparably low population Saskatchewan air zone (2015 pop. ~0.15M) with 11 air pollution-related premature deaths estimated across the modelled sectors, primarily attributed to sector contributions to annual mean $PM_{2.5}$ levels (8 deaths). Key sectors with emissions contributing air pollution-related mortality are upstream oil and gas industry (3 deaths), coal-fired electric power generation (2 deaths), on-road transportation (2 deaths), and off-road vehicles and mobile equipment activity (2 deaths).
- **Southeast:** This is also a comparably low population air zone (2015 pop. ~0.1M) and 9 air pollution-related deaths are estimated across the modelled sectors, primarily attributed to sector contributions to annual mean $PM_{2.5}$ levels (5 deaths). Key sectors contributing air pollution-related premature deaths are upstream oil and gas (2 deaths) and coal-fired electric power generation (2 deaths), with additional deaths attributed to transportation sectors and other industry sectors.
- **Grasslands:** The modelled sectors together contribute approximately 8 air pollution-related deaths in this low population air zone (2015 pop. ~0.1M). These are attributed to air quality impact of emissions from coal-fired electric power generation (2 deaths) and upstream oil and gas (2 deaths) with the remaining deaths attributed to air pollution from on-road transportation and off-road vehicles and mobile equipment.

3.3.3.5 Manitoba

The province of Manitoba (2015 pop. ~1.3M) is only a single air zone and a total of 130 air pollution-related premature deaths are estimated across the modelled sectors. Detailed sector-specific health impact data are tabulated for the Manitoba air zone in *Appendix A.2* (Section A.2.4).

By pollutant, the majority of air pollution-related premature deaths are attributed to sector contributions to annual mean ambient $PM_{2.5}$ concentrations (100 deaths). Across modelled sectors, all on-road transportation contributed the most air pollution-related premature mortality (38 deaths), followed by ore and mineral industry (18 deaths), off-road vehicles and mobile equipment (17 deaths), and home firewood burning (17 deaths). Additional premature mortality is attributed to other industry (i.e., 13 deaths from upstream oil and gas sector; 10 deaths from coal-fired electric power generation).

3.3.3.6 Ontario

Most Ontario air zones had estimates of 5 or more premature deaths due to air pollution across the modelled sectors: Southern Ontario, Hamilton, Northern Ontario, and Sudbury. Detailed sector-specific health impact data are tabulated for these air zones in *Appendix A.2* (Section A.2.5). The remaining Ontario air zones (Sarnia and Sault Ste. Marie) are largely rural with dispersed population or smaller population centers (<0.1M inhabitants) and thus had lower population-weighted estimates of air pollution-related premature mortality.

In Ontario, the highest air pollution-related premature deaths were estimated for the highly populated air zone of Southern Ontario (approximately 2,200 deaths across modeled sectors). In this air zone, the top three sectors contributing to air pollution-related premature mortality are home firewood burning, on-road transportation, and ore and mineral industry. These same three sectors generally dominate air pollution-related mortality in all other Ontario air zones, even where total mortality counts are much lower.

The management of air quality within Ontario air zones may be informed by the following key findings summarizing the dominant pollutants and the top-ranked modelled sectors contributing to air pollution-related health impacts within each air zone (air zones arranged by decreasing total premature mortality):

- **Southern Ontario:** This is Ontario's most populous air zone (2015 pop. ~12.4M) and the modelled sectors together contribute an estimated 2,200 air pollution-related premature deaths. By pollutant, the majority of deaths are attributed to sector contributions to annual mean $PM_{2.5}$ levels (1,800 deaths) and annual mean NO_2 levels (260 deaths). By sector class, the majority of air pollution-related deaths are attributed to transportation sectors (>900 deaths), followed by industry (>600 deaths) and residential combustion sectors (>600 deaths). Top-ranking individual sectors contributing to air pollution-related premature mortality are home firewood burning (510 deaths), on-road transportation (470 deaths), the ore and mineral industry (400 deaths), and off-road vehicles and mobile equipment (370).
- **Hamilton:** This air zone covers a small geographic area but is densely populated (2015 pop. ~0.5M) and a total of 160 air pollution-related premature deaths are estimated across the modelled sectors. By pollutant, the majority of these deaths are attributed to sector contributions to annual mean $PM_{2.5}$ levels (140 deaths). Sectors contributing to the majority of air pollution-related premature mortality are the ore and mineral industry (56 deaths), home firewood burning (36 deaths), and on-road transportation (27 deaths).
- **Northern Ontario:** This air zone has a dispersed population (2015 pop. ~0.6M) over a large geographic extent and 26 air pollution-related premature deaths were estimated across the modelled sectors. By pollutant, these are largely attributed to sector contributions to annual mean $PM_{2.5}$ levels (16 deaths) and annual/summer mean O_3 levels (6 deaths). By sector, the greatest number of air pollution-related premature deaths are attributed to the ore and mineral industry (8 deaths), largely from non-ferrous refining and smelting emissions (6 deaths). Additional air pollution-related premature deaths are attributed to on-road transportation (4 deaths) and home firewood burning (4 deaths).
- **Sudbury:** This is a comparably low population air zone (2015 pop. ~0.2M) with 19 air pollution-related premature deaths across modelled sectors. The majority of deaths are associated with sector contributions to annual mean $PM_{2.5}$ levels (15 deaths). Premature deaths are largely attributed to the ore and mineral industry (8 deaths), specifically non-ferrous refining and smelting (7 deaths), followed by on-road transportation (3 deaths) and home firewood burning (3 deaths).

3.3.3.7 Quebec

All Quebec air zones (South, East, North) had estimates of 5 or more air pollution-related premature deaths across the modelled sectors. Detailed sector-specific health impact data are tabulated for Quebec air zones in *Appendix A.2* (Section A.2.6).

Highest modelled sector deaths are in the highly populated South air zone (approximately 2,600 deaths across modeled sectors). In this air zone, the top three sectors contributing to premature mortality are similar to those dominating air pollution-related mortality in Ontario: home firewood burning (1,400 deaths), on-road transportation (400 deaths), and ore and mineral industry (350 deaths).

The management of air quality within Quebec air zones may be informed by the following key findings summarizing the dominant pollutants and the top-ranked modelled sectors contributing to air pollution-related health impacts within each air zone (air zones arranged by decreasing total premature mortality):

- **South:** This is Quebec's most populous air zone (2015 pop. ~7.6M) and a total of 2,600 air pollution-related premature deaths are estimated across the modelled sectors. By pollutant, the majority of premature deaths are attributed to sector contributions to annual mean $PM_{2.5}$ levels (2,300 deaths) and annual mean NO_2 levels (200 deaths). By a large margin, the majority of air pollution-related premature deaths are attributed to home firewood burning (1,400 deaths), followed by mobile sources including 400 deaths for on-road transportation, 200 deaths for off-road vehicles and mobile equipment, and 100 deaths for marine, rail and air transportation combined. Industrial sector air emissions also contribute to higher premature mortality in this air zone, primarily from the ore and mineral industry (350 deaths).
- **East:** This is a comparably low population (2015 pop. ~0.25M) and largely rural air zone with 21 air pollution-related premature deaths estimated across the modelled sectors. By pollutant, the majority of the estimated premature deaths are due to sector contributions to annual mean $PM_{2.5}$ levels (15 deaths). Top-ranking sectors contributing air pollution-related premature mortality are home firewood burning (6 deaths), ore and mineral industry (4 deaths), and on-road transportation (3 deaths).
- **North:** This is also a comparably low population (2015 pop. ~0.4M) and largely rural air zone with 12 air pollution-related premature deaths estimated across the modelled sectors. By pollutant, the majority of estimated premature deaths are attributed to sector contributions to annual mean $PM_{2.5}$ levels (7 deaths). The sectors contributing majority of the estimated air pollution-related mortality in this air zone are the ore and mineral industry (5 deaths) and home firewood burning (3 deaths).

3.3.3.8 New Brunswick

All New Brunswick air zones (Central Region, South Region, North Region) had estimates of 5 or more premature deaths due to air pollution across the modelled sectors. Detailed sector-specific health impact data are tabulated for New Brunswick air zones in *Appendix A.2* (Section A.2.7).

Air pollution-related premature deaths in New Brunswick were lower compared to more highly populated provinces and also show comparably less variability across the province's three air zones (7 – 30 deaths across modeled sectors). Sectors contributing high air pollution-related premature mortality in New Brunswick air zones are home firewood burning, ore and mineral industry, and on-road transportation. Other modelled sectors noted as contributing 1 – 2 deaths per air zone are marine transportation and electric power generation.

The management of air quality within New Brunswick air zones may be informed by the following key findings summarizing the dominant pollutants and the top-ranked modelled sectors contributing to air pollution-related health impacts within each air zone (air zones arranged by decreasing total premature mortality):

- **Central Region:** This is New Brunswick's most populous air zone (2015 pop. ~0.5M) and a total of 31 air pollution-related premature deaths are estimated across the modelled sectors. By pollutant, the majority of these deaths are attributed to sector contributions to annual mean $PM_{2.5}$ levels (21 deaths) followed by contributions to O_3 (6 deaths). The majority of air pollution-related premature deaths are attributed to home firewood burning (9 deaths), followed by the ore and mineral industry (6 deaths) and on-road transportation (4 deaths). Marine transportation sector impacts to air quality also contribute comparably high premature mortality in this air zone (2 deaths).

- **South Region:** This is a low population air zone (2015 pop. ~0.2M) and the modelled sectors together contribute to an estimate of 14 air pollution-related premature deaths, largely due to their contribution to annual mean $PM_{2.5}$ levels (11 deaths). Modelled sectors contributing comparably more to air pollution-related premature mortality are the ore and mineral industry (5 deaths) and home firewood burning (3 deaths).
- **North Region:** This is also a low population and more rural air zone (2015 pop. ~0.1M) and the modelled sectors together contribute to an estimate of 7 air pollution-related premature deaths, largely due to sector impacts on annual mean $PM_{2.5}$ levels. Sectors contributing comparably more air pollution-related premature mortality are home firewood burning (2 deaths) and the ore and mineral industry (2 deaths).

3.3.3.9 Nova Scotia

All Nova Scotia air zones (Central, Northern, Western, Eastern) had estimates of 5 or more premature deaths due to air pollution across the modelled sectors. Detailed sector-specific health impact data are tabulated for Nova Scotia air zones in *Appendix A.2* (Section A.2.8).

The highest air pollution-related premature deaths are in the Central air zone (approximately 22 deaths across modeled sectors). The three sectors dominating air pollution-related premature mortality in most Nova Scotia air zones are home firewood burning, electric power generation, and marine transportation. The comparably high premature mortality related to emissions from marine transportation is consistent with intense ship traffic at busy Atlantic ports.

The management of air quality within Nova Scotia air zones may be informed by the following key findings summarizing the dominant pollutants and the top-ranked modelled sectors contributing to air pollution-related health impacts within each air zone (air zones arranged by decreasing total premature mortality):

- **Central:** This is Nova Scotia's most populous air zone (2015 pop. ~0.5M) and a total of 23 air pollution-related premature deaths are estimated across the modelled sectors. By pollutant, the majority of these deaths are attributed to sector contributions to annual mean $PM_{2.5}$ levels (14 deaths) and annual/summer mean O_3 levels (7 deaths). Top-ranking modelled sectors contributing air pollution-related premature deaths are home firewood burning (6 deaths) and electric power generation (4 deaths, largely coal-fired facilities). Marine transportation sector impacts on air quality also contribute comparably higher premature mortality in this air zone (4 deaths). Additional air pollution-related premature deaths are attributed to on-road transportation (3 deaths) and the ore and mineral industry (3 deaths).
- **Northern:** The modelled sectors contribute 13 air pollution-related deaths in this comparably lower population (2015 pop. ~0.2M) air zone, attributed largely to sector contributions to annual mean $PM_{2.5}$ levels (8 deaths) and annual/summer mean O_3 levels (4 deaths). Modelled sectors contributing comparably more to air pollution-related premature mortality are home firewood burning (3 deaths) and electric power generation (3 deaths, largely coal-fired emissions).
- **Western:** A total of 12 air pollution-related deaths were estimated across the modelled sectors in this lower population (2015 pop. ~0.2M) air zone, primarily attributed to sector contributions to annual mean $PM_{2.5}$ levels (6 deaths) and annual/summer mean O_3 levels (4 deaths). Sectors

contributing comparably more to air pollution-related premature mortality are home firewood burning (3 deaths), the ore and mineral industry (2 deaths), and marine transportation (2 deaths).

- **Eastern:** This is Nova Scotia's lowest population air zone (2015 pop. ~0.1M) and the modelled sectors contribute to 12 air pollution-related premature deaths, primarily attributed to $PM_{2.5}$ levels. By sector, higher air pollution-related premature mortality is attributed to electric power generation (3 deaths, largely from coal-fired facility emissions), home firewood burning (3 deaths), and marine transportation (2 deaths).

3.3.3.10 Prince Edward Island

The small province of Prince Edward Island (2015 pop. ~0.15M) is a single air zone and a total of 10 air pollution-related premature deaths are estimated across the modelled sectors. Detailed sector-specific health impact data are tabulated for the Prince Edward Island air zone in *Appendix A.2* (Section A.2.9).

By pollutant, the majority of air pollution-related premature deaths are attributed to sector contributions to annual mean $PM_{2.5}$ levels (6 deaths).

By sector, the majority of air pollution-related premature deaths are attributed to home firewood burning (3 deaths), on-road transportation (2 deaths), and electric power generation (2 deaths).

3.3.3.11 Newfoundland and Labrador

The province of Newfoundland and Labrador is naturally divided into two air zones, Newfoundland (2015 pop. ~0.5M) and Labrador (2015 pop. <0.05M).

The majority of air pollution-related premature deaths were estimated in the air zone of Newfoundland (approximately 15 deaths across modelled sectors), whereas impacts are low in the sparsely populated Labrador air zone. Detailed sector-specific health impact data are tabulated for the Newfoundland air zone in *Appendix A.2* (Section A.2.10).

By pollutant, premature deaths are attributed primarily to sector contributions to annual mean $PM_{2.5}$ levels (7 deaths) and annual/summer mean O3 levels (4 deaths).

Three dominant sectors each contribute approximately equally (3 deaths) to air pollution-related premature mortality: home firewood burning, marine transportation, and electric power generation (i.e., largely from coal-fired power generation).

4 Discussion

4.1 Pollutants driving mortality and regional variation

Generally, across all sectors modelled in this assessment, the majority of premature deaths are attributed to sector impacts on ambient annual mean $PM_{2.5}$ concentrations followed by impacts on annual mean NO_2, and annual/summer mean O_3. However, the pollutants driving premature deaths showed regional variation, aligning with regional contrasts in modelled emissions and air quality impacts. Tabulated provincial and territorial health impacts can be found in *Appendix A.1*.

In Central region provinces, most air pollution-related premature deaths were attributed to sector impacts on $PM_{2.5}$ air quality, followed by impacts on NO_2 air quality. $PM_{2.5}$-related deaths were often approximately ten times higher than NO_2-related deaths, particularly in Quebec, where they were approximately twelve times higher. In the Western provinces of Alberta and Saskatchewan, while $PM_{2.5}$-associated deaths remain higher than those from other modelled pollutants, NO_2-related deaths contributed a greater percentage of total mortality count than in Central region provinces and comparably less mortality is attributed to annual/summer mean O_3.[19] In Atlantic region provinces, most air pollution-related deaths were similarly attributed to sector impacts on annual mean $PM_{2.5}$ levels, but sector impacts on annual/summer mean O_3 levels contributed the second highest premature deaths. These health impact results are consistent with health risks from $PM_{2.5}$ being higher than for other pollutants; however, deaths attributable to NO_2 and O_3 exposure may be higher in regions where there are large or many emission sources contributing to formation of these pollutants.

By sector, pollutants driving the air pollution-related premature mortality estimates generally reflect sector emissions activity pollutant profiles. Premature deaths associated with modelled residential combustion sectors (home firewood burning, residential fuel combustion) were essentially entirely attributed to sector contributions to ambient annual mean $PM_{2.5}$ concentrations. For premature deaths associated with transportation and mobile equipment sector emissions (e.g., on-road, off-road and mobile equipment, marine, rail, air), most were again attributed to sector contributions to ambient annual mean $PM_{2.5}$ levels, but a substantial portion was also attributed to sector contributions to annual mean NO_2 levels. For premature deaths associated with industry sectors, contributions to annual mean $PM_{2.5}$ levels remained key but greater variation was seen: sector contributions to annual mean NO_2 and annual/summer mean O_3 corresponded to premature deaths for upstream oil and gas, electric power generation, and pulp and paper manufacturing.

4.2 National context for modelled sector mortality estimates

Health Canada (2021) estimated health impacts attributable to above-background air pollution in Canada, including air pollution from human sources in North America, to be 15,300 premature deaths per year, based on population data for 2016 and air pollution concentrations from 2014 to 2017 (i.e., $PM_{2.5}$, NO_2, O_3) with a

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[19] Negative mortality for O_3 and summer-O_3 correspond to a negative difference for modelled ambient air pollutant concentration for base case (all emissions sectors) less sector scenario (sector emissions set to zero). Annual O_3 metric is more likely to be negative as it overlaps with periods of reduced sunlight and temperature, and reduced O_3 production. Negative O_3 health impacts occur in areas with a lot of NO_x emissions and must be considered within the broader context of emissions reductions, as they are not expected to persist with large-scale reductions in emissions, such as those applied nationally.

total economic cost of all health impacts attributable to air pollution being $120 B (CAD 2016). That report used an air quality and health impact modelling framework[20] broadly consistent with methods in the current assessment, supporting general comparisons of health impact estimates and providing broader context to the sector-based health impact estimates.

In the current sector-based analysis, the three nationally top-ranked sectors contributing to premature mortality were found to be home firewood burning (2,300 deaths), on-road transportation (1,200 deaths), and ore and mineral industry (910 deaths). Thus, based on a general comparison of premature death estimates from the two analyses, the results suggest that home firewood burning, on-road transportation, and ore and mineral industry activity contribute approximately 15%, 8%, and 6%, respectively, of total air pollution-related health impacts in Canada. Taken together at the national scale, these three sectors comprise approximately 30% of total estimated premature deaths attributable to air pollution in Canada.

4.3 Comparison with prior sector assessments

Individual sector results within this multi-sector health impact assessment compare well with previous Health Canada sector-based assessments. Available and relevant prior health impact assessments selected for comparison are those completed for human health risk assessments for gasoline exhaust emissions (Health Canada, 2017) and diesel exhaust emissions (Health Canada, 2016). These two assessments (Health Canada, 2017, 2016) examined health impacts attributed to combustion exhaust emissions from all gasoline- and diesel-fueled on-road transportation and off-road vehicles and mobile equipment activity. As per these analyses, 97% of on-road LDVs used gasoline compared with 3% using diesel; for on-road HDVs, 68% used diesel compared with 32% using gasoline; and, for off-road engines, 87% used gasoline compared to 13% using diesel.

The prior gasoline and diesel assessments (Health Canada, 2017, 2016) used a similar modelling framework[21] and presented results for the 2015 calendar year, making them readily comparable to the results in the present report for the common model scenarios (i.e., all on-road transportation (LDV+HDV), on-road LDV, on-road HDV, all off-road vehicles and mobile equipment).

The gasoline-fueled transportation assessment (Health Canada, 2017) estimated that exposure to air pollution (i.e., annual mean $PM_{2.5}$, NO_2, and annual/summer mean O_3) from on-road gasoline vehicles contributed a total of approximately 650 premature deaths across the same suite of modelled pollutants; the majority of the premature mortality was attributed to chronic exposure to annual mean $PM_{2.5}$ levels (480

[20] Emissions inventory modelling followed by air quality modelling followed by health impact evaluation. Health Canada (2021) methods were most similar to current analysis for emissions inventory modelling and allocation and for health impact modelling steps. Air quality modelling methods differed more greatly with Health Canada (2021) using hybrid exposure surfaces for $PM_{2.5}$, NO_2, and O_3 from monitoring data, chemical transport models, land use regression models and satellite data.

[21] Emissions inventory modelling followed by air quality modelling followed by health impact evaluation. The prior health impact assessments of gasoline exhaust emissions (Health Canada, 2017) and diesel exhaust emissions (Health Canada, 2016) used analogous but not identical emissions inventory models (i.e., MOBILE6.2c used for LDV fleet emissions, MOVES2010a for HDV fleet emissions versus current report applied MOVES for both LDV and HDV fleets), an identical spatial allocation model (i.e., SMOKE) and identical health impact assessment model (i.e., AQBAT) albeit with minor differences in CRF data. Air quality modelling used an earlier chemical transport model that preceded GEM-MACH (i.e., A Unified Regional Air-quality Modelling System; AURAMS) with lower spatial resolution (AURAMS; 45 km x 45 km grid size with 22.5 km ×x 22.5 km grid for horizontal resolution) than the newer GEM-MACH model used in this report (10 km x 10 km grid size).

deaths) followed by acute exposure to NO_2 levels (140 deaths). The diesel-fueled transportation assessment (Health Canada, 2016) estimated that exposure to exhaust emissions air pollution from on-road diesel vehicles contributed a total of approximately 320 premature deaths across a similar suite of modelled pollutants primarily due to sector contributions to ambient annual mean $PM_{2.5}$ levels (250 deaths) and NO_2 levels (150 deaths).[22] Summing across the two prior assessments, the estimated total premature mortality from on-road transportation emissions (gasoline and diesel vehicles combined) is approximately 970 deaths, attributed primarily to sector contributions to ambient annual mean $PM_{2.5}$ levels (730 deaths) followed by sector contributions to NO_2 (290 deaths). The current assessment estimated approximately 1,200 premature deaths for the analogous all on-road transportation sector (i.e., all on-road vehicles, gasoline-fueled and diesel-fueled), including 800 premature deaths from sector contributions to annual mean $PM_{2.5}$ levels and 340 premature deaths from contributions to NO_2 levels. The mortality estimates in the current assessment compare well with prior Health Canada assessments for the important on-road transportation sector (i.e., same order of magnitude, differing by approximately 20%), notwithstanding methodological differences (see footnote 21).

The current mortality estimates for the off-road vehicles and mobile equipment sector can also be compared against the prior assessments (Health Canada, 2017, 2016). Off-road gasoline vehicle emissions were previously estimated (Health Canada, 2017) to contribute approximately 240 premature deaths (sum of annual mean $PM_{2.5}$, annual mean NO_2, annual mean O_3, summer mean O_3), with the majority attributed to annual mean $PM_{2.5}$ levels (~140 deaths) followed by annual mean NO_2 levels (~20 deaths). Off-road diesel vehicle emissions were previously estimated (Health Canada, 2016) to contribute to approximately 390 premature deaths with the majority again attributed to chronic exposure to annual mean $PM_{2.5}$ levels (~210 deaths) followed by acute exposure to annual mean NO_2 levels (~80 deaths). Summing across the two prior assessments, the estimated total premature mortality from off-road vehicles and mobile equipment emissions (i.e., all off-road vehicles, gasoline and diesel-fueled) is approximately 630 deaths, primarily including 350 premature deaths from sector contributions to annual mean $PM_{2.5}$ levels and 100 premature deaths from contributions to annual mean NO_2 levels. The current assessment estimated approximately 760 deaths for the analogous all off-road vehicles and mobile equipment sector (i.e., all off-road vehicles and mobile equipment, gasoline-fueled and diesel-fueled), attributed primarily to sector contributions to annual mean $PM_{2.5}$ levels (~540 deaths) and annual mean NO_2 levels (~100 deaths). Again, these mortality estimates compare well with the prior Health Canada assessments. Results are in the same order of magnitude and the difference in precise model results (~20% difference) is reasonable considering the previously noted modelling differences (see footnote 21).

As expected, regional trends found in the current report also compared well with the prior single-sector assessments (Health Canada, 2017, 2016): in both sets of results, higher premature mortality was estimated for highly populated and urbanized areas including Metro Vancouver, Greater Toronto and Hamilton Area, and Greater Montreal, consistent with the findings for the air zones enclosing these areas in the current multi-sector assessment.

A relevant prior health impact assessment examined wildfire $PM_{2.5}$ in Canada using two air quality models (GEM-MACH and FireWork) and AQBAT (Matz et al., 2020) for multiple individual years (i.e., 2013, 2014, 2015, 2017, 2018). The analysis indicated that wildfire-$PM_{2.5}$ contributed to approximately 600-2,700 premature deaths annually (combined acute and chronic exposure), with the large variation between years reflecting severity of wildfire season and population exposures in a given year. The prior wildfire analysis

[22] The sum for on-road diesel vehicles accounts for avoided deaths from reduction in exposure to O_3.

provides an interesting comparison: for some regions, home firewood burning emissions may contribute a similar number of annual deaths (2,300) as wildfire emissions during a year with a severe wildfire season in exposed populated areas (2,700 modelled for 2017; Matz et al., 2020). This is consistent with findings in recent health impact analyses that modelled both home firewood burning and wildfires (Meng et al., 2019; McDuffie et al., 2021).

A recent multi-sector assessment of air quality was completed by Meng et al. (2019) and provides a useful comparison data set for the results in the current assessment. While the authors did not complete a health impact analysis, they comprehensively modelled all Canadian and American inventoried sector emissions for impact on national scale $PM_{2.5}$ exposures (i.e., population-weighted $PM_{2.5}$ levels) and reported sector-specific results for Canada and the United States (US). There are several methodological differences between the current health impact assessment and the approach of Meng et al. (2019), including different modelling year (2013 vs. 2015), a different air quality model (GEOS-Chem vs. GEM-MACH), and different emissions inventory dataset (APEI 2018 in Meng vs. APEI 2017). Additionally, while the authors' sector definitions are generally broadly comparable to the present analysis, some differed more greatly (e.g., on-road transportation sector in Meng et al. (2019) includes road dust emissions; the present analysis did not include road dust but did include some non-exhaust emissions, specifically tire and brake wear emissions). Notwithstanding these differences, their estimate of the Canadian average population-weighted reference $PM_{2.5}$ concentration was 5.5 µg/m^3 for calendar year 2013 (Meng et al., 2019), which is in very good agreement with the 5.3 µg/m^3 annual population-weighted average for calendar year 2015 modelled in this assessment. The authors also found that, for most modelled sectors, the majority of population-weighted $PM_{2.5}$ originated from Canadian sources (i.e., versus transboundary emissions from USA sources). The exception was for electric power generation, where the majority of air quality impacts were attributed to transboundary $PM_{2.5}$ from the many coal-fired power plants operating in the USA in the simulation year.

The results from Meng et al. (2019) indicated that wildfire emissions contributed 17% of the national average population-weighted $PM_{2.5}$ levels, followed by (in decreasing order): transportation emissions (15% total, 9% from Canadian emissions and 6% from US emissions), residential combustion (15% total: 10% from Canadian emissions and 5% from US emissions), industry (14% total: 10% from Canadian emissions and 4% from US emissions), agriculture (10% total: 4% from Canadian emissions and 6% from US emissions), and power generation (7% total: 1% from Canadian emissions and 6% from US emissions). Thus, the three top-ranking sectors with Canadian emissions impacting $PM_{2.5}$ exposures were found to be: residential combustion, transportation, and industry (i.e., excluding wildfires and agriculture sectors, which were not modeled in the current assessment). These results are in agreement with air quality findings in the current multi-sector health impact assessment and thereby also reflect the top three sectors found to contribute to premature mortality.

Quantitative comparison of the air pollutant contributions from Canadian emission sources in Meng et al. (2019) with the current assessment results show that sectoral contributions to annual mean $PM_{2.5}$ concentrations generally compare well between the studies. For on-road transportation and off-road vehicles and mobile equipment, this assessment estimated sector emissions to contribute approximately 12% (0.62 µg/m^3) of national population-weighted $PM_{2.5}$ levels. This is in close agreement with the results estimated by Meng et al. (i.e., 9% or 0.50 µg/m^3 attributable to Canadian on-road transportation and off-road vehicles and mobile equipment activity, including road dust; Meng et al., 2019). For industry emissions, this assessment estimated that the combined emissions from ore and mineral, oil and gas, electric power generation, and manufacturing industries (i.e., the sectors representing the majority of industry $PM_{2.5}$ emissions) contributed approximately 12% of national population-weighted $PM_{2.5}$ levels (0.66 µg/m^3). This is in close agreement with the results estimated by Meng et al. attributing 10% or 0.37 µg/m^3 of ambient $PM_{2.5}$ levels to Canadian industry facility emissions. Results for the electric power generation sector were also in close agreement, with this assessment and Meng et al. (2019) both predicting approximately 1% of national population-weighted $PM_{2.5}$ levels from this source. Results also agreed reasonably closely for residential combustion, comprising home firewood burning and other combustion (i.e., approximately 22% of national population-weighted $PM_{2.5}$ levels versus approximately 15% or 0.8 µg/m^3 in Meng et al., 2019; reflecting between-study differences in year of emissions inventory data used and comparably greater inherent dataset uncertainty for this sector).

McDuffie et al. (2021) completed an international multi-sector health impact assessment, reporting sector- and fuel-specific contributions to population-weighted ambient $PM_{2.5}$ concentrations and $PM_{2.5}$-attributed premature mortality for a total of 204 countries, including Canada. Methods were broadly comparable to those in the current study (i.e., modelling train of emissions inventory to air quality modelling to health impact modelling using health endpoint-specific concentration-response functions, with similar "zero out" method to target individual sector emissions and their contributions to ambient $PM_{2.5}$ concentrations). Health impacts, including premature deaths, were estimated with endpoint-specific concentration-response (CRF) functions. However, compared to the multi-sector assessment in this report, the assessment of McDuffie et al. (2021) had several specific methodological and data differences arising from the study's international scope, including: different emissions inventory data (Community Emissions Data System), a different atmospheric chemistry transport model (GEOS-CHEM), a different modelling year (2017), selection of different CRF values, and some differences in sector categorization (e.g., upstream and downstream oil and gas activity were included within "energy non-coal" sector). In addition, to account for non-linearity in atmospheric chemistry and in the application of the CRFs, McDuffie et al. (2021) used model simulation results to calculate fractional contributions from each source that summed to 100%. These fractions were then applied to high resolution (1 km x 1 km) satellite-derived $PM_{2.5}$ exposure estimates and total estimated $PM_{2.5}$-attributable deaths to derive the absolute contributions of each sector to both $PM_{2.5}$ mass and the associated deaths. Notwithstanding the methodological differences, their independent set of air quality impact and health estimates from McDuffie et al. (2021) for the road transportation and residential biofuel combustion sectors can be usefully compared to results in the current assessment for the closely analogous Canadian sectors of all on-road transportation and home firewood burning (i.e., road transportation and residential biofuel combustion respectively, in McDuffie et al., 2021).

Air quality modelling estimates of individual sector contributions in McDuffie et al. (2021) were consistent with this analysis, notwithstanding the different modelling years and multiple methodological differences. For the analogs to the all on-road transportation sector and the home firewood burning sector, McDuffie et al. (2021) estimated a 7.6% (0.54 µg/m^3) and a 14% (1.02 µg/m^3) contribution to the national population-weighted annual mean ambient $PM_{2.5}$ concentration (2017), respectively. By comparison, the multi-sector analysis in this report estimated that the all on-road transportation sector contributed 7% (0.37 µg/m^3) and that home firewood burning contributed 21% (0.97 µg/m^3) to the national population-weighted annual mean ambient $PM_{2.5}$ concentration (2015).

Health impact modelling results (i.e., sector contributions to $PM_{2.5}$-associated premature mortality) differed more greatly between the two analyses on an absolute basis but were consistent with each other on a relative basis. Mortality estimates in McDuffie et al. (2021) were lower than those in the current report (e.g., all on-road transportation, 280 deaths versus 800 in current analysis; home firewood burning, 516 deaths versus 2,300 in current analysis). These differences in mortality estimates likely reflect differences in CRF values or baseline mortality data used in each case, along with prior-noted methodological differences in the health impact modelling (i.e., McDuffie et al., 2021 used fractional source contributions and theoretical minimum risk exposure levels which differ from ambient air pollution contributions). However, for modelled sectors common to both sector-based assessments, the three top-ranking sectors found to contribute premature $PM_{2.5}$-related mortality in Canada by McDuffie et al. (2021) were residential biofuel combustion, industry non-coal, and road transportation. This compares well with the relative ranking found in the current multi-sector assessment for the approximately analogous sectors: home firewood burning, followed by sum of ore and mineral and manufacturing sectors (i.e., comprise much of McDuffie et al., 2021 industry non-coal sector), followed by all on-road transportation.

4.4 Methodological considerations

This health impact assessment made use of a formal modelling framework throughout the emissions inventory, air quality impact modelling, and health and socioeconomic impact modelling. Efforts were also made to ensure the best available data used as input to each of the models, (e.g., industry sector facility-reported emissions, transportation sector fleet characterization and emission profiles and activity, residential combustion sector emissions estimates, meteorological data, concentration-response functions) and that appropriate assumptions were made throughout.

Despite these efforts, limitations and uncertainties are inherent in each of the modelling steps and cumulatively influence the emission, air quality, and health impact assessment results. While uncertainty cannot be readily quantified for this analysis, a qualitative summary of uncertainty for each stage of the health impact assessment (emissions inventory, air quality modelling, health impact modelling) is presented below. For each modelling step, the range of listed uncertainties is summarized by their overall potential influence on the reported health impact estimates. These qualitative uncertainty estimates provide the likely direction of influence and, where possible, the likely range-of-magnitude of influence. Since a key strength of this health impact assessment is methodological support for comparisons across sectors and multiple spatial scales, any possible differences in uncertainty across sectors or geographic regions are also noted.

This approach is broadly based on the WHO uncertainty framework (WHO, 2008) and the US EPA qualitative assessment of uncertainty approach outlined in the assessment of the PM National Ambient Air Quality Standard (US EPA, 2012).

4.4.1 Emissions inventory modelling

The emissions inventory modelling is the first stage of the modelling framework (see Section 2.1). It involved preparing an annual sector- and pollutant-specific emissions inventory and then spatially allocating all source emissions releases to a national grid surface (i.e., via US EPA SMOKE model). Emission inventories are dynamic, with new versions regularly developed to support activities ranging from decision making to policy development to air quality modelling analyses with an appropriate level of accuracy, spatial resolution and temporal representativeness (Zhang et al. 2018). For all sectors excepting home firewood burning, ECCC used the APEI from the year 2015; for home firewood burning, an older 2010 inventory was used as it was considered by ECCC to best represent emissions.

Uncertainties may accumulate from uncertainty in the methods used to derive the emissions data. For example, for the modelled transportation sectors (e.g., on-road, off-road vehicles and mobile equipment, air, marine, rail), the APEI database applied modelled data (i.e., source-specific activity data and emissions factors) and uncertainties may relate to fleet composition data, vehicle activity data, and chosen emissions factors. For the industry sectors, the APEI database used facility-reported data (i.e., pollutant release data as required for reporting to the National Pollutant Release Inventory) which may have uncertainties in reported activity data and representativeness of emissions factors for the industrial processes at a specific facility. Emissions data for the residential combustion sectors may have a greater degree of uncertainty due to the disparate nature of these emissions sources and uncertainty in the general applicability of emission factors to different fuel types and combustion conditions.

In addition to uncertainties in the magnitude of emissions, additional uncertainty may be introduced during the temporal and spatial allocation of the emissions database to the national gridded surface (i.e., via US EPA SMOKE model). This gridding process applies spatial surrogates (e.g., roadways or population) to the national emissions which are necessarily simplified, and thus may have uncertainties in the accuracy in which they represent the spatial distribution of actual emissions.

As previously noted, the uncertainty associated with the home firewood burning sector is likely greater than for other modelled sectors (either overestimate or underestimate) owing to inherent challenges of developing an adequately representative emissions dataset for representative spatial and temporal allocation. There are many combustion-related factors that may influence the emissions profile (i.e., presence and quantity of chemical compounds) for home firewood burning; examples include the types of fuel wood, the type of combustion appliance, wood moisture content, and combustion makeup air. Further, obtaining accurate activity data for this intermittent and multi-purpose activity is challenging (e.g., wood burning use is highly variable and can be used as a primary heat source, supplemental heat source, or for aesthetics).

Overall, accumulated uncertainty in the emissions inventory data or its spatial allocation could either overestimate or underestimate pollutant emissions to air from individual sectors. The direction and magnitude for uncertainty bias in the emissions inventory estimates and their subsequent influence on overall uncertainty in the health impact results cannot be estimated.

The emissions inventory data was also reviewed over the 2015 through 2020 period (ECCC, 2022) and is tabulated in the Supplemental Material (available upon request). This showed level trends at the national scale for the majority of the sectors modelled. This indicates that sector air quality and health impacts and comparative sector rankings presented in this report are also likely to have remained level over this period at the national and provincial scale and for the majority of the air zones.

4.4.2 Air quality impact modelling

The air quality modelling is the second stage of the modelling framework (see Section 2.1). It applied ECCC's *Global Environmental Multiscale model – Modelling Air quality and CHemistry* (GEM-MACH), which combines the Canada-wide spatially allocated emissions surface data with meteorological data and specific algorithms to simulate atmospheric diffusion, transport and chemical transformation of gaseous and particle pollutants and thereby predict atmospheric concentrations over a continental grid surface.

Uncertainties may accumulate from choice of geographic scale and grid resolution, atmospheric chemistry reactions and transport behaviours, and choice of temporal averaging times for modeled pollutants. There is also inherent uncertainty in the "zero-out" modelling approach used in this assessment to estimate air quality impacts for individual modeled sectors and non-linear atmospheric chemistry reactions (Meng et al., 2019). Additional uncertainty is inherent in interpolation between grid cell scale and larger-area census district scale.

Performance of the GEM-MACH model has been evaluated previously and found to be generally comparable or better than other CTMs (Makar et al. 2014a, 2014b; Whaley et al. 2018). For additional confidence in reported results, the specific combination of emissions inventory, spatial surrogates and GEM-MACH version used in the current analysis were evaluated using a model performance analysis. This analysis compared modelled results from the 2015 base case (i.e., all sector emissions included) air concentration surfaces for NO_2, O_3, and $PM_{2.5}$ against actual ambient pollutant concentrations measured at central site monitoring stations across Canada in 2017 (i.e., 2017 was selected to match the meteorological data) and found good agreement between modelled and observed ambient concentrations for all three pollutants driving the health impacts estimated in this report (NO_2, O_3 and $PM_{2.5}$).

4.4.3 Health impact modelling

The health impact and socio-economic valuation modelling is the final stage of the modelling framework (see Section 2.1). It applied HC's *Air Quality Benefits Assessment Tool* (AQBAT), which in this analysis combined the sector-specific contributions to population-weighted mean pollutant concentrations obtained from the air quality modelling with pollutant-specific concentration-response functions (CRFs) for multiple mortality and morbidity endpoints. The health impact modelling yielded estimates of population health impacts along with corresponding socio-economic valuations at the national and regional scales reported by this assessment (i.e., province, territory, air zone). The current analysis included multiple pollutants associated with adverse health impacts: annual mean $PM_{2.5}$, annual mean NO_2, and annual/summer mean O_3.

Uncertainties in the health impact modelling may accumulate from the choice of CRFs and from limitations in geographical resolution in exposure estimates in the epidemiological studies on which the CRFs are based. However, there is high confidence in the CRFs selected for this Canadian assessment, and Monte Carlo estimation was also used to reflect potential range in CRFs. However, owing to data limitations and knowledge gaps, not all associative health effects demonstrated for exposure to $PM_{2.5}$, NO_2 and ground-level O_3 can currently be quantified and there are other air contaminants that contribute to air pollution health impacts which are beyond the scope of this work. Thus, the quantitative estimates of population health impacts provided in this report are assumed to underestimate the full impact of exposure to air pollution in Canada.

The AQBAT model results in this analysis are considered valid representations of regional population-level impacts (i.e., results generated for census divisions and then averaged for larger geographic domains such as air zones, provinces/territories, and national). However, the regional population-level impacts quantified in this analysis cannot constitute an assessment of local risks for communities in direct proximity to emissions sources, such as locations near high-traffic roadways and those near industrial facilities.

5 Conclusions

This analysis estimated population health impacts and socio-economic valuations associated with exposure to air pollutant emissions from multiple Canadian sectors and across multiple spatial geographic scales (i.e., national, provincial, territorial, air zone). A total of 21 major Canadian transportation and mobile equipment, industry, and residential source sectors were assessed.

At the national scale, the modelled sectors found to contribute the most to Canadian premature deaths in 2015 were home firewood burning (2,300 deaths), on-road transportation (1,200 deaths), and ore and mineral industry (910 deaths). The monetized value attributed to the total health impacts (i.e., sum of fatal and non-fatal outcomes) from these three sectors reach $18 B for home firewood burning, $9.5 B for on-road transportation, and $7.2 B for the ore and mineral industry (CAD 2015).

As context, Health Canada (2021) estimated health impacts attributable to above-background air pollution in Canada, including air pollution ($PM_{2.5}$, NO_2, O_3) from human sources in North America, to be 15,300 premature deaths per year, based on population data for 2016 and average air pollution concentrations from 2014 to 2017. Although these two reports use different approaches for estimating air pollution exposure, a comparison of results provides broader context to the sector-specific health burden reported here. The present sector-based analysis is focused on 21 Canadian sector health impacts and found these to together contribute approximately 6,900 premature deaths annually in 2015. This represents approximately 45% of the overall 15,300 total premature deaths previously attributed to air pollution (Health Canada, 2021). From the present analysis, the nationally top-ranked sectors of home firewood burning, on-road transportation, and ore and mineral industry activity are estimated to contribute approximately 15%, 8%, and 6%, respectively, of total annual air pollution-related health impacts in Canada. Taken together, these three sectors alone are estimated to contribute approximately 30% of total estimated premature deaths attributable to air pollution in Canada in 2015. Other sectors and sources not assessed in the present analysis (e.g., agriculture, incineration and waste, dust) along with wildfire emissions and transboundary air pollution are expected to further contribute to total Canadian air pollution-related deaths.

Nationally, across all modelled sectors and pollutants, the majority of air pollution-related premature deaths were associated with ambient annual mean $PM_{2.5}$ concentrations (5,900 deaths), followed by annual mean NO_2 (670 deaths), summer mean O_3 (270 deaths) and annual mean O_3 (100 deaths). The pollutants driving mortality estimates varied by sector, generally reflecting the emissions activity profile of each sector. For the residential combustion sectors (home firewood burning, residential fuel combustion), deaths were mostly attributed to sector contributions to annual mean $PM_{2.5}$ (i.e., releases of primary $PM_{2.5}$ and precursors to secondary $PM_{2.5}$ formation). For transportation and mobile equipment sectors (on-road, off-road vehicles and mobile equipment, marine, rail, air), most were again attributed to sector contributions to ambient annual mean $PM_{2.5}$ levels along with sector contributions to annual mean NO_2 levels. For industry sectors (upstream oil and gas, electric power generation, and pulp and paper manufacturing), the majority of premature mortality was attributed to sector contributions to annual mean $PM_{2.5}$ but premature mortality was also attributed to sector contributions to annual mean NO_2 and annual/summer mean O_3.

At the provincial and territorial scale, higher air pollution-related premature deaths were estimated for the highly populated Central provinces of Quebec and Ontario, followed by the Western region provinces. A comparably smaller number of deaths was estimated in Atlantic region provinces and none were estimated for the Northern territories.

The top-three assessed sectors contributing to air pollution-related premature mortality at the national scale (i.e., home firewood burning, on-road transportation, ore and mineral industry) showed high impacts in most provinces. Other sectors were strongly regional in their health impacts, ranking highly (within top three) in only one or few provinces. These more regional sectors included: oil and gas industry sector in Alberta and Saskatchewan; coal-fired electric power generation in Alberta, Saskatchewan and several Atlantic provinces; off-road vehicles and mobile equipment in British Columbia and Manitoba; marine transportation in Nova Scotia and Newfoundland and Labrador.

The sectors that dominate air pollution-related health impacts at the national or provincial/territorial scale may differ at the smaller air zone scale, reflecting variations in air zone characteristics (e.g., population density, degree of urbanization, local industry) as well as potential influence of transported emissions released from sector sources in neighbouring air zones. Generally, on-road transportation and home firewood burning dominated air pollution-related mortality in most air zones (notable exception of less impact from home firewood burning in Saskatchewan and Alberta air zones), while mortality from industry sectors exhibited strongly regional trends, reflecting the presence and concentration of industry facilities within each air zone: oil and gas industry contributed high premature deaths in all Alberta and Saskatchewan air zones; coal-fired electric power generation contributed high mortality in Alberta, Saskatchewan, and most Atlantic province air zones; ore and mineral industry contributed high mortality in nearly all Manitoba, Ontario, Quebec, New Brunswick and Nova Scotia air zones.

Individual sector results within this multi-sector health impact assessment compare well with Health Canada's prior sector-based assessments completed for gasoline exhaust emissions (Health Canada, 2017) and diesel vehicle exhaust emissions (Health Canada, 2016). Comparison against a prior assessment of health impacts for wildfire-generated $PM_{2.5}$ in Canada (Matz et al., 2020) indicates that, for some regions, home firewood burning emissions may contribute a similar number of deaths as wildfire emissions during a severe wildfire season. Estimates of air quality and health impact for top-ranking sectors (e.g., home firewood burning, on-road transportation, etc.) were also consistent with prior multi-sector assessments in the scientific literature (Meng et al., 2019; McDuffie et al., 2021), notwithstanding modelling and data differences. Review of 2015 through recently released 2020 emissions inventory data showed level trends at the national scale for the majority of the sectors modelled. This indicates that sector air quality and health impacts and comparative sector rankings presented in this report are also likely to have remained level over this period at the national and provincial scale and for the majority of air zones.

While efforts were made to use the best available air quality and health modelling tools and data for Canada in the current health assessment, there were limitations and uncertainties. Uncertainty originated from various sources, including: the availability and quality of Canadian emissions inventory data; algorithms representing atmospheric transport and transformation; and health data to support the selection and use of relevant CRFs and baseline incidences for the Canadian population. Moreover, the air pollution-associated health impacts presented in this report are based solely on exposure to ambient concentrations of $PM_{2.5}$, NO_2 and ozone, assessed because there is robust epidemiological evidence of their adverse health impacts and the spatial distribution of their ambient concentrations across Canada can be accurately estimated. However, owing to data limitations and knowledge gaps, not all health effects associated with exposure to $PM_{2.5}$, NO_2 and ozone can currently be quantified in AQBAT. Further, there are other air contaminants that contribute to air pollution health impacts which are beyond the scope of this work. Thus, the quantitative estimates of population health impacts provided in this report are assumed to underestimate the full impact of exposure to air pollution in Canada. Moreover, the current analysis provided a regional evaluation of health burden, rather than an assessment of local risks for communities in direct proximity to emissions sources, such as locations near high-traffic roadways and those near industrial facilities.

This health impact assessment has clearly identified top-ranking sectors affecting national, provincial/territorial, and air zone air quality and health impact burden. As such, the current analysis contributes to our understanding of the health risks associated with exposure to transportation and mobile equipment, industry, and residential emissions in Canada. It is intended that this information on population health burden will inform provincial, territorial and regional stakeholders, including air zone managers, and support further development of efficient and effective air quality management strategies.

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A. Appendix

This Appendix is organized as follows:

- **A.1:** Pollutant-specific health impact estimates (mortality, economic evaluation) for modelled sectors, by province or territory.
- **A.2:** Pollutant-specific health impact estimates (mortality, economic valuation) for modelled sectors, by air zone.

A *Supplementary Material* document is available upon request alongside this report. The *Supplementary Material* includes detailed individual sector emissions data, emissions spatial allocation maps, additional results for air quality modelling (i.e., maps of sector contributions to ambient concentrations), additional health impacts (i.e., morbidity cases by pollutant at national level), and additional information on modelling methodology.

A.1 Health impacts of sector emissions – mortality by province or territory

Table A-1. British Columbia – all-cause premature mortality and valuation by sector and pollutant (2015).

BRITISH COLUMBIA	MORTALITY BY POLLUTANT[a, b, c, i] PM$_{2.5}$	NO$_2$	O$_3$[d]	ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On-road	**110**	**48**	**7**	**160 (59 - 270)**	**$1.3 B ($0.25 B - $2.7 B)**
On-road LDV	42	15	4	61 (26 - 96)	$480 M ($140 M - $950 M)
On-road HDV	64	30	-12	83 (13 - 150)	$0.65 B ($-0.084 B - $1.6 B)
Off-road vehicles & mobile equipment	**59**	**10**	**14**	**83 (41 - 120)**	**$0.65 B ($0.24 B - $1.2 B)**
Air + Marine + Rail	**33**	**12**	**10**	**56 (22 - 90)**	**$430 M ($99 M - $890 M)**
Air	4	2	-3	3 (-1 - 8)	$28 M ($-25 M - $89 M)
Marine	25	8	13	46 (22 - 69)	$360 M ($130 M - $680 M)
Rail	4	3	0	7 (1 - 12)	$51 M ($-3.8 M - $120 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**27**	**3**	**-18**	**13 (-12 - 38)**	**$110 M ($-170 M - $420 M)**
Cement manufacture	7	3	-19	-9 (-24 - 7)	$-63 M ($-250 M - $110 M)
Non-ferrous refining and smelting	0	0	0	0 (0 - 1)	$2.6 M ($-4.4 M - $10 M)
Oil and gas industry[g]	**8**	**0**	**4**	**12 (6 - 18)**	**$94 M ($36 M - $180 M)**
Upstream oil and gas	3	0	3	7 (4 - 10)	$53 M ($20 M - $99 M)
Downstream oil and gas	5	0	0	5 (3 - 8)	$41 M ($16 M - $76 M)
Electric power generation	**1**	**0**	**0**	**1 (0 - 1)**	**$4.9 M ($-2.3 M - $14 M)**
Coal-fired electric power generation	1	0	0	1 (0 - 1)	$4.9 M ($1.3 M - $9.8 M)
Manufacturing	**48**	**2**	**9**	**59 (30 - 87)**	**$460 M ($180 M - $870 M)**
Chemicals industry	0	0	0	0 (0 - 0)	$1.2 M ($0.40 M - $2.3 M)
Pulp and paper industry	27	1	5	33 (17 - 50)	$260 M ($100 M - $490 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**11**	**3**	**-3**	**12 (3 - 21)**	**$96 M ($4.1 M - $210 M)**
Home firewood burning	**250**	**0**	**1**	**250 (130 - 370)**	**$2.0 B ($0.79 B - $3.7 B)**
TOTAL OF MODELLED SECTORS[h]	**540**	**80**	**24**	**650 (280 - 1000)**	**$5.1 B ($1.4 B - $10 B)**

[a] Chronic exposure mortality (PM$_{2.5}$), acute exposure mortality (NO$_2$, O$_3$), and chronic exposure respiratory mortality (summer O$_3$).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O$_3$ health impacts may occur in areas with high NO$_x$ emissions.

[d] Sum of annual O$_3$ (acute exposure mortality) and summer O$_3$ (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO$_2$, O$_3$), chronic exposure mortality (PM$_{2.5}$), and chronic exposure respiratory mortality (summer O$_3$). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

Table A-2. Alberta – all-cause premature mortality and valuation by sector and pollutant (2015).

ALBERTA	MORTALITY BY POLLUTANT[a, b, c, i] PM2.5	NO2	O3[d]	ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On-road	**43**	**20**	**18**	**82 (37 - 130)**	**$0.64 B ($0.22 B - $1.2 B)**
On-road LDV	11	3	4	19 (9 - 28)	$150 M ($53 M - $280 M)
On-road HDV	32	16	12	59 (27 - 92)	$460 M ($160 M - $900 M)
Off-road vehicles & mobile equipment	**23**	**5**	**14**	**42 (21 - 63)**	**$330 M ($120 M - $620 M)**
Air + Marine + Rail	**12**	**7**	**8**	**26 (12 - 40)**	**$200 M ($71 M - $390 M)**
Air	0	0	0	1 (0 - 1)	$5.2 M ($1.6 M - $10 M)
Marine	0	0	2	2 (1 - 3)	$15 M ($5.5 M - $28 M)
Rail	11	6	6	24 (11 - 37)	$180 M ($64 M - $350 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**13**	**1**	**2**	**16 (8 - 24)**	**$130 M ($51 M - $240 M)**
Cement manufacture	2	0	1	3 (2 - 5)	$27 M ($10 M - $50 M)
Non-ferrous refining and smelting	0	0	0	0 (0 - 0)	$1.8 M ($0.62 M - $3.4 M)
Oil and gas industry[g]	**93**	**29**	**58**	**180 (86 - 270)**	**$1.4 B ($0.51 B - $2.7 B)**
Upstream oil and gas	89	28	58	170 (84 - 260)	$1.4 B ($0.50 B - $2.6 B)
Downstream oil and gas	4	1	0	5 (2 - 8)	$40 M ($13 M - $79 M)
Electric power generation	**51**	**4**	**5**	**61 (30 - 91)**	**$480 M ($180 M - $920 M)**
Coal-fired electric power generation	50	4	5	58 (29 - 88)	$460 M ($170 M - $870 M)
Manufacturing	**27**	**3**	**4**	**34 (17 - 50)**	**$270 M ($100 M - $510 M)**
Chemicals industry	18	2	1	21 (10 - 32)	$170 M ($64 M - $320 M)
Pulp and paper industry	3	0	1	4 (2 - 7)	$35 M ($14 M - $66 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**8**	**3**	**0**	**10 (4 - 16)**	**$79 M ($24 M - $160 M)**
Home firewood burning	**30**	**0**	**0**	**30 (16 - 44)**	**$240 M ($98 M - $440 M)**
TOTAL OF MODELLED SECTORS[h]	**300**	**71**	**110**	**480 (230 - 730)**	**$3.8 B ($1.4 B - $7.2 B)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.

[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

Table A-3. Saskatchewan – all-cause premature mortality and valuation by sector and pollutant (2015).

SASKATCHEWAN	MORTALITY BY POLLUTANT[a, b, c, i]			ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
	$PM_{2.5}$	NO_2	O_3[d]		
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On-road	**7**	**2**	**6**	**14 (7 - 22)**	**$110 M ($40 M - $210 M)**
On-road LDV	2	0	1	4 (2 - 6)	$29 M ($10 M - $55 M)
On-road HDV	5	1	4	10 (5 - 16)	$80 M ($29 M - $150 M)
Off-road vehicles & mobile equipment	**5**	**1**	**7**	**14 (7 - 20)**	**$100 M ($38 M - $200 M)**
Air + Marine + Rail	**2**	**1**	**3**	**6 (3 - 8)**	**$42 M ($15 M - $81 M)**
Air	0	0	0	0 (0 - 0)	$460 K ($150 K - $920 K)
Marine	0	0	1	1 (0 - 1)	$4.1 M ($1.5 M - $7.7 M)
Rail	2	1	2	5 (2 - 8)	$38 M ($14 M - $73 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**5**	**0**	**1**	**6 (3 - 9)**	**$46 M ($18 M - $86 M)**
Cement manufacture	0	0	0	0 (0 - 0)	$1.2 M ($0.43 M - $2.3 M)
Non-ferrous refining and smelting	2	0	0	2 (1 - 3)	$15 M ($5.9 M - $28 M)
Oil and gas industry[g]	**15**	**1**	**9**	**25 (13 - 38)**	**$190 M ($72 M - $370 M)**
Upstream oil and gas	14	1	8	24 (12 - 35)	$180 M ($68 M - $340 M)
Downstream oil and gas	1	0	0	2 (1 - 2)	$12 M ($4.6 M - $23 M)
Electric power generation	**14**	**0**	**3**	**17 (9 - 26)**	**$130 M ($51 M - $250 M)**
Coal-fired electric power generation	13	0	3	17 (9 - 25)	$130 M ($49 M - $240 M)
Manufacturing	**5**	**0**	**1**	**6 (3 - 9)**	**$45 M ($17 M - $85 M)**
Chemicals industry	3	0	0	4 (2 - 6)	$30 M ($12 M - $57 M)
Pulp and paper industry	1	0	0	1 (0 - 1)	$7.0 M ($2.7 M - $13 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**1**	**0**	**0**	**1 (0 - 1)**	**$6.3 M ($2.0 M - $12 M)**
Home firewood burning	**3**	**0**	**0**	**3 (2 - 5)**	**$26 M ($10 M - $49 M)**
TOTAL OF MODELLED SECTORS[h]	**57**	**6**	**29**	**92 (46 - 140)**	**$0.71 B ($0.26 B - $1.3 B)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.

[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

Table A-4. Manitoba – all-cause premature mortality and valuation by sector and pollutant (2015).

	MORTALITY BY POLLUTANT[a, b, c, i]			ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
MANITOBA	**$PM_{2.5}$**	**NO_2**	**O_3[d]**		
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On-road	**24**	**14**	**1**	**38 (15 - 61)**	**$290 M ($74 M - $600 M)**
On-road LDV	7	4	0	10 (4 - 17)	$81 M ($16 M - $170 M)
On-road HDV	16	9	0	25 (10 - 40)	$190 M ($47 M - $390 M)
Off-road vehicles & mobile equipment	**10**	**2**	**5**	**17 (9 - 26)**	**$130 M ($49 M - $250 M)**
Air + Marine + Rail	**5**	**3**	**2**	**10 (4 - 15)**	**$73 M ($24 M - $140 M)**
Air	1	0	0	1 (0 - 1)	$6.9 M ($1.9 M - $14 M)
Marine	0	0	0	0 (0 - 1)	$3.2 M ($1.2 M - $6.0 M)
Rail	5	2	1	8 (4 - 13)	$63 M ($21 M - $120 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**17**	**0**	**1**	**18 (9 - 26)**	**$140 M ($55 M - $260 M)**
Cement manufacture	0	0	0	0 (0 - 0)	$0.83 M ($0.31 M - $1.6
Non-ferrous refining and smelting	4	0	0	4 (2 - 6)	$30 M ($12 M - $56 M)
Oil and gas industry[g]	**9**	**0**	**3**	**13 (7 - 19)**	**$100 M ($39 M - $190 M)**
Upstream oil and gas	9	0	3	13 (7 - 19)	$98 M ($38 M - $180 M)
Downstream oil and gas	0	0	0	0 (0 - 0)	$2.0 M ($0.73 M - $3.7 M)
Electric power generation	**9**	**0**	**1**	**10 (5 - 15)**	**$80 M ($31 M - $150 M)**
Coal-fired electric power generation	9	0	1	10 (5 - 15)	$78 M ($30 M - $150 M)
Manufacturing	**5**	**0**	**1**	**6 (3 - 9)**	**$45 M ($18 M - $86 M)**
Chemicals industry	2	0	0	3 (1 - 4)	$21 M ($8.2 M - $40 M)
Pulp and paper industry	0	0	0	0 (0 - 0)	$2.4 M ($0.91 M - $4.6 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**3**	**1**	**0**	**4 (2 - 7)**	**$32 M ($7.7 M - $67 M)**
Home firewood burning	**17**	**0**	**0**	**17 (9 - 25)**	**$130 M ($52 M - $250 M)**
TOTAL OF MODELLED SECTORS[h]	**99**	**20**	**13**	**130 (63 - 200)**	**$1.0 B ($0.35 B - $2.0 B)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.

[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

Table A-5. Ontario – all-cause premature mortality and valuation by sector and pollutant (2015).

ONTARIO	MORTALITY BY POLLUTANT[a, b, c, i]			ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
	$PM_{2.5}$	NO_2	O_3[d]		
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On-road	**350**	**130**	**15**	**500 (200 - 790)**	**$3.9 B ($1.0 B - $7.9 B)**
On-road LDV	160	45	0	200 (83 - 320)	$1.6 B ($0.43 B - $3.2 B)
On-road HDV	190	83	-1	270 (100 - 450)	$2.1 B ($0.45 B - $4.4 B)
Off-road vehicles & mobile equipment	**290**	**58**	**42**	**390 (190 - 590)**	**$3.0 B ($1.1 B - $5.8 B)**
Air + Marine + Rail	**63**	**27**	**7**	**96 (38 - 150)**	**$0.75 B ($0.18 B - $1.5 B)**
Air	11	10	-6	14 (0 - 29)	$110 M ($-33 M - $300 M)
Marine	19	3	7	29 (15 - 44)	$230 M ($87 M - $430 M)
Rail	33	14	6	53 (23 - 82)	$410 M ($130 M - $800 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**460**	**11**	**5**	**480 (240 - 710)**	**$3.8 B ($1.4 B - $7.1 B)**
Cement manufacture	57	5	2	63 (29 - 98)	$500 M ($160 M - $970 M)
Non-ferrous refining and smelting	120	0	1	120 (63 - 180)	$0.96 B ($0.39 B - $1.8 B)
Oil and gas industry[g]	**59**	**3**	**13**	**74 (38 - 110)**	**$0.58 B ($0.23 B - $1.1 B)**
Upstream oil and gas	17	1	10	28 (15 - 42)	$220 M ($85 M - $410 M)
Downstream oil and gas	42	2	2	46 (23 - 69)	$360 M ($140 M - $680 M)
Electric power generation	**25**	**5**	**1**	**30 (14 - 47)**	**$240 M ($72 M - $480 M)**
Coal-fired electric power generation	17	0	1	18 (9 - 26)	$140 M ($54 M - $260 M)
Manufacturing	**90**	**7**	**17**	**110 (58 - 170)**	**$0.90 B ($0.35 B - $1.7 B)**
Chemicals industry	30	2	2	34 (17 - 51)	$270 M ($99 M - $510 M)
Pulp and paper industry	15	1	3	20 (10 - 30)	$160 M ($60 M - $300 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**100**	**32**	**-11**	**130 (50 - 200)**	**$0.99 B ($0.25 B - $2.0 B)**
Home firewood burning	**550**	**1**	**2**	**550 (300 - 820)**	**$4.4 B ($1.8 B - $8.2 B)**
TOTAL OF MODELLED SECTORS[h]	**2000**	**280**	**91**	**2400 (1100 - 3600)**	**$19 B ($6.4 B - $36 B)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.

[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

Table A-6. Quebec – all-cause premature mortality and valuation by sector and pollutant (2015).

QUEBEC	MORTALITY BY POLLUTANT[a, b, c, i] PM2.5	NO2	O3[d]	ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On-road	**260**	**120**	**28**	**410 (170 - 640)**	**\$3.1 B (\$0.86 B - \$6.3 B)**
On-road LDV	78	30	5	110 (46 - 180)	\$0.88 B (\$0.24 B - \$1.8 B)
On-road HDV	180	80	10	270 (110 - 430)	\$2.1 B (\$0.55 B - \$4.2 B)
Off-road vehicles & mobile equipment	**150**	**26**	**32**	**210 (100 - 310)**	**\$1.6 B (\$0.59 B - \$3.1 B)**
Air + Marine + Rail	**56**	**30**	**20**	**110 (47 - 160)**	**\$0.81 B (\$0.26 B - \$1.6 B)**
Air	5	4	-1	8 (2 - 14)	\$64 M (\$7.1 M - \$140 M)
Marine	29	15	13	58 (26 - 88)	\$440 M (\$150 M - \$860 M)
Rail	21	10	8	40 (18 - 61)	\$300 M (\$100 M - \$590 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**340**	**8**	**11**	**360 (190 - 530)**	**\$2.8 B (\$1.1 B - \$5.3 B)**
Cement manufacture	43	4	3	50 (24 - 76)	\$390 M (\$140 M - \$750 M)
Non-ferrous refining and smelting	69	0	0	70 (36 - 100)	\$0.55 B (\$0.22 B - \$1.0 B)
Oil and gas industry[g]	**28**	**4**	**4**	**36 (16 - 56)**	**\$280 M (\$78 M - \$560 M)**
Upstream oil and gas	5	0	6	11 (6 - 17)	\$87 M (\$33 M - \$160 M)
Downstream oil and gas	23	4	-2	25 (10 - 40)	\$190 M (\$46 M - \$390 M)
Electric power generation	**12**	**1**	**4**	**16 (8 - 24)**	**\$120 M (\$47 M - \$240 M)**
Coal-fired electric power generation	8	0	1	9 (5 - 13)	\$71 M (\$27 M - \$130 M)
Manufacturing	**59**	**7**	**10**	**76 (37 - 110)**	**\$0.59 B (\$0.22 B - \$1.1 B)**
Chemicals industry	12	1	1	14 (7 - 21)	\$110 M (\$39 M - \$210 M)
Pulp and paper industry	18	2	6	25 (13 - 38)	\$200 M (\$74 M - \$370 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**20**	**6**	**-1**	**26 (11 - 41)**	**\$200 M (\$58 M - \$410 M)**
Home firewood burning	**1400**	**3**	**2**	**1400 (740 - 2000)**	**\$11 B (\$4.3 B - \$20 B)**
TOTAL OF MODELLED SECTORS[h]	**2300**	**200**	**110**	**2600 (1300 - 3900)**	**\$20 B (\$7.6 B - \$39 B)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.

[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

Table A-7. New Brunswick – all-cause premature mortality and valuation by sector and pollutant (2015).

NEW BRUNSWICK	MORTALITY BY POLLUTANT[a, b, c, i]			ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
	$PM_{2.5}$	**NO_2**	**O_3[d]**		
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On-road	**2**	**1**	**4**	**6 (3 - 10)**	**$49 M ($18 M - $94 M)**
On-road LDV	1	0	1	2 (1 - 3)	$14 M ($5.1 M - $27 M)
On-road HDV	1	0	3	4 (2 - 7)	$34 M ($12 M - $65 M)
Off-road vehicles & mobile equipment	**1**	**0**	**2**	**3 (1 - 4)**	**$20 M ($7.3 M - $38 M)**
Air + Marine + Rail	**1**	**1**	**4**	**5 (3 - 8)**	**$41 M ($15 M - $78 M)**
Air	0	0	0	0 (0 - 0)	$0.69 M ($0.25 M - $1.3 M)
Marine	1	0	3	4 (2 - 6)	$28 M ($10 M - $53 M)
Rail	0	0	1	2 (1 - 2)	$12 M ($4.2 M - $23 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**12**	**0**	**1**	**13 (7 - 19)**	**$100 M ($40 M - $190 M)**
Cement manufacture	0	0	0	1 (0 - 1)	$5.4 M ($2.1 M - $10 M)
Non-ferrous refining and smelting	4	0	0	4 (2 - 6)	$32 M ($13 M - $60 M)
Oil and gas industry[g]	**2**	**0**	**1**	**3 (1 - 5)**	**$24 M ($8.0 M - $46 M)**
Upstream oil and gas	0	0	1	1 (0 - 1)	$6.5 M ($2.4 M - $12 M)
Downstream oil and gas	2	0	0	2 (1 - 3)	$17 M ($5.6 M - $34 M)
Electric power generation	**2**	**0**	**1**	**3 (2 - 5)**	**$25 M ($9.3 M - $47 M)**
Coal-fired electric power generation	2	0	1	3 (1 - 4)	$20 M ($7.5 M - $37 M)
Manufacturing	**2**	**0**	**1**	**4 (2 - 5)**	**$28 M ($10 M - $53 M)**
Chemicals industry	0	0	0	0 (0 - 0)	$2.1 M ($0.80 M - $3.9 M)
Pulp and paper industry	1	0	1	2 (1 - 3)	$17 M ($6.6 M - $33 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**0**	**0**	**0**	**0 (0 - 0)**	**$2.5 M ($0.94 M - $4.8 M)**
Home firewood burning	**14**	**0**	**0**	**14 (8 - 21)**	**$110 M ($44 M - $210 M)**
TOTAL OF MODELLED SECTORS[h]	**37**	**2**	**13**	**52 (27 - 77)**	**$400 M ($150 M - $760 M)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.

[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

Table A-8. Nova Scotia – all-cause premature mortality and valuation by sector and pollutant (2015).

NOVA SCOTIA	MORTALITY BY POLLUTANT[a, b, c, i] PM$_{2.5}$	NO$_2$	O$_3$[d]	ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On-road	**2**	**1**	**5**	**7 (4 - 11)**	**$55 M ($19 M - $110 M)**
On-road LDV	1	0	1	2 (1 - 3)	$16 M ($5.7 M - $31 M)
On-road HDV	1	1	3	5 (3 - 8)	$39 M ($14 M - $75 M)
Off-road vehicles & mobile equipment	**1**	**0**	**2**	**3 (1 - 4)**	**$21 M ($7.5 M - $40 M)**
Air + Marine + Rail	**1**	**1**	**8**	**10 (5 - 15)**	**$77 M ($27 M - $150 M)**
Air	0	0	0	0 (0 - 0)	$0.77 M ($0.26 M - $1.5
Marine	1	0	7	9 (5 - 13)	$66 M ($24 M - $130 M)
Rail	0	0	1	1 (1 - 2)	$9.8 M ($3.4 M - $19 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**7**	**0**	**1**	**8 (4 - 12)**	**$63 M ($24 M - $120 M)**
Cement manufacture	0	0	0	1 (0 - 1)	$5.4 M ($2.0 M - $10 M)
Non-ferrous refining and smelting	3	0	0	3 (2 - 5)	$27 M ($11 M - $51 M)
Oil and gas industry[g]	**1**	**0**	**1**	**2 (1 - 3)**	**$18 M ($6.5 M - $33 M)**
Upstream oil and gas	0	0	1	1 (1 - 2)	$8.2 M ($3.0 M - $16 M)
Downstream oil and gas	1	0	0	1 (1 - 2)	$9.3 M ($3.5 M - $18 M)
Electric power generation	**8**	**0**	**3**	**11 (6 - 16)**	**$85 M ($32 M - $160 M)**
Coal-fired electric power generation	7	0	2	9 (5 - 13)	$69 M ($26 M - $130 M)
Manufacturing	**2**	**0**	**1**	**3 (2 - 4)**	**$23 M ($8.6 M - $43 M)**
Chemicals industry	0	0	0	0 (0 - 0)	$2.1 M ($0.80 M - $4.0 M)
Pulp and paper industry	1	0	0	2 (1 - 3)	$14 M ($5.5 M - $27 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**0**	**0**	**0**	**0 (0 - 1)**	**$3.2 M ($1.1 M - $6.3 M)**
Home firewood burning	**15**	**0**	**0**	**15 (8 - 23)**	**$120 M ($47 M - $230 M)**
TOTAL OF MODELLED SECTORS[h]	**38**	**2**	**20**	**60 (31 - 90)**	**$460 M ($170 M - $880 M)**

[a] Chronic exposure mortality (PM$_{2.5}$), acute exposure mortality (NO$_2$, O$_3$), and chronic exposure respiratory mortality (summer O$_3$).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O$_3$ health impacts may occur in areas with high NO$_x$ emissions.

[d] Sum of annual O$_3$ (acute exposure mortality) and summer O$_3$ (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO$_2$, O$_3$), chronic exposure mortality (PM$_{2.5}$), and chronic exposure respiratory mortality (summer O$_3$). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

Table A-9. Prince Edward Island – all-cause premature mortality and valuation by sector and pollutant (2015).

PRINCE EDWARD ISLAND	MORTALITY BY POLLUTANT[a, b, c, i]			ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
	$PM_{2.5}$	**NO_2**	**O_3[d]**		
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On-road	**1**	**0**	**1**	**2 (1 - 2)**	**$12 M ($4.1 M - $22 M)**
On-road LDV	0	0	0	0 (0 - 1)	$3.0 M ($1.0 M - $5.7 M)
On-road HDV	0	0	1	1 (1 - 2)	$8.0 M ($2.9 M - $15 M)
Off-road vehicles & mobile equipment	**0**	**0**	**0**	**1 (0 - 1)**	**$4.8 M ($1.7 M - $9.1 M)**
Air + Marine + Rail	**0**	**0**	**1**	**1 (1 - 2)**	**$11 M ($4.0 M - $21 M)**
Air	0	0	0	0 (0 - 0)	$0.57 M ($0.23 M - $1.1
Marine	0	0	1	1 (1 - 2)	$8.6 M ($3.1 M - $16 M)
Rail	0	0	0	0 (0 - 0)	$1.8 M ($0.65 M - $3.5 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**1**	**0**	**0**	**1 (1 - 2)**	**$11 M ($4.2 M - $20 M)**
Cement manufacture	0	0	0	0 (0 - 0)	$0.79 M ($0.30 M - $1.5
Non-ferrous refining and smelting	1	0	0	1 (0 - 1)	$4.4 M ($1.7 M - $8.2 M)
Oil and gas industry[g]	**0**	**0**	**0**	**0 (0 - 1)**	**$3.3 M ($1.2 M - $6.1 M)**
Upstream oil and gas	0	0	0	0 (0 - 0)	$1.3 M ($0.49 M - $2.5 M)
Downstream oil and gas	0	0	0	0 (0 - 0)	$1.9 M ($0.73 M - $3.6 M)
Electric power generation	**1**	**0**	**1**	**2 (1 - 2)**	**$13 M ($4.8 M - $24 M)**
Coal-fired electric power generation	1	0	0	1 (1 - 2)	$10 M ($3.8 M - $19 M)
Manufacturing	**0**	**0**	**0**	**1 (0 - 1)**	**$4.1 M ($1.5 M - $7.7 M)**
Chemicals industry	0	0	0	0 (0 - 0)	$520 K ($210 K - $970 K)
Pulp and paper industry	0	0	0	0 (0 - 1)	$2.7 M ($1.1 M - $5.2 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**0**	**0**	**0**	**0 (0 - 0)**	**$0.74 M ($0.27 M - $1.4**
Home firewood burning	**3**	**0**	**0**	**3 (1 - 4)**	**$20 M ($7.9 M - $37 M)**
TOTAL OF MODELLED SECTORS[h]	**7**	**0**	**3**	**10 (5 - 15)**	**$79 M ($30 M - $150 M)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.

[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

Table A-10. Newfoundland and Labrador – all-cause premature mortality and valuation by sector and pollutant (2015).

NEWFOUNDLAND & LABRADOR	MORTALITY BY POLLUTANT[a, b, c, i]			ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
	$PM_{2.5}$	NO_2	O_3[d]		
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On-road	**0**	**0**	**1**	**2 (1 - 2)**	**$11 M ($4.0 M - $22 M)**
On-road LDV	0	0	0	0 (0 - 0)	$2.4 M ($0.83 M - $4.5 M)
On-road HDV	0	0	1	1 (0 - 1)	$7.2 M ($2.5 M - $14 M)
Off-road vehicles & mobile equipment	**0**	**0**	**1**	**1 (0 - 1)**	**$7.3 M ($2.6 M - $14 M)**
Air + Marine + Rail	**0**	**0**	**3**	**3 (2 - 5)**	**$26 M ($9.4 M - $49 M)**
Air	0	0	0	0 (0 - 0)	$96 K ($37 K - $180 K)
Marine	0	0	3	3 (2 - 5)	$24 M ($8.7 M - $46 M)
Rail	0	0	0	0 (0 - 0)	$1.8 M ($0.66 M - $3.4 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**1**	**0**	**0**	**2 (1 - 2)**	**$12 M ($4.8 M - $23 M)**
Cement manufacture	0	0	0	0 (0 - 0)	$0.73 M ($0.28 M - $1.4 M)
Non-ferrous refining and smelting	1	0	0	1 (0 - 1)	$4.5 M ($1.8 M - $8.4 M)
Oil and gas industry[g]	**1**	**0**	**0**	**1 (1 - 2)**	**$8.0 M ($3.0 M - $15 M)**
Upstream oil and gas	0	0	0	0 (0 - 0)	$2.5 M ($0.88 M - $4.7 M)
Downstream oil and gas	1	0	0	1 (0 - 1)	$5.5 M ($2.1 M - $10 M)
Electric power generation	**2**	**0**	**1**	**3 (1 - 4)**	**$21 M ($8.1 M - $41 M)**
Coal-fired electric power generation	1	0	0	2 (1 - 3)	$15 M ($5.7 M - $28 M)
Manufacturing	**0**	**0**	**0**	**0 (0 - 0)**	**$2.0 M ($0.75 M - $3.9 M)**
Chemicals industry	0	0	0	0 (0 - 0)	$95 K ($37 K - $170 K)
Pulp and paper industry	0	0	0	0 (0 - 0)	$1.2 M ($0.45 M - $2.3 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**0**	**0**	**0**	**0 (0 - 0)**	**$330 K ($110 K - $650 K)**
Home firewood burning	**3**	**0**	**0**	**3 (2 - 5)**	**$26 M ($10 M - $49 M)**
TOTAL OF MODELLED SECTORS[h]	**8**	**1**	**6**	**15 (8 - 22)**	**$110 M ($43 M - $220 M)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.

[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

Table A-11. Yukon – all-cause premature mortality and valuation by sector and pollutant (2015).

YUKON	MORTALITY BY POLLUTANT[a, b, c, i] PM2.5	NO2	O3[d]	ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On-road	**0**	**0**	**0**	**0 (0 - 0)**	**$85 K ($30 K - $160 K)**
On-road LDV	0	0	0	0 (0 - 0)	$19 K ($7.2 K - $34 K)
On-road HDV	0	0	0	0 (0 - 0)	$79 K ($28 K - $150 K)
Off-road vehicles & mobile equipment	**0**	**0**	**0**	**0 (0 - 0)**	**$43 K ($16 K - $81 K)**
Air + Marine + Rail	**0**	**0**	**0**	**0 (0 - 0)**	**$150 K ($53 K - $280 K)**
Air	0	0	0	0 (0 - 0)	$5.8 K ($1.7 K - $12 K)
Marine	0	0	0	0 (0 - 0)	$120 K ($43 K - $220 K)
Rail	0	0	0	0 (0 - 0)	$24 K ($8.9 K - $46 K)
INDUSTRIAL SECTORS					
Ore and mineral industry	**0**	**0**	**0**	**0 (0 - 0)**	**$43 K ($16 K - $81 K)**
Cement manufacture	0	0	0	0 (0 - 0)	$5.8 K ($1.6 K - $12 K)
Non-ferrous refining and smelting	0	0	0	0 (0 - 0)	0 (0 - 0)
Oil and gas industry[g]	**0**	**0**	**0**	**0 (0 - 0)**	**$190 K ($68 K - $360 K)**
Upstream oil and gas	0	0	0	0 (0 - 0)	$190 K ($68 K - $360 K)
Downstream oil and gas	0	0	0	0 (0 - 0)	0 (0 - 0)
Electric power generation	**0**	**0**	**0**	**0 (0 - 0)**	**$30 K ($11 K - $58 K)**
Coal-fired electric power generation	0	0	0	0 (0 - 0)	$5.8 K ($1.7 K - $12 K)
Manufacturing	**0**	**0**	**0**	**0 (0 - 0)**	**$24 K ($8.9 K - $47 K)**
Chemicals industry	0	0	0	0 (0 - 0)	$5.8 K ($1.6 K - $12 K)
Pulp and paper industry	0	0	0	0 (0 - 0)	$5.8 K ($1.7 K - $12 K)
RESIDENTIAL SECTORS					
Residential fuel combustion	**0**	**0**	**0**	**0 (0 - 0)**	**$5.8 K ($1.7 K - $12 K)**
Home firewood burning	**0**	**0**	**0**	**0 (0 - 0)**	**$160 K ($63 K - $290 K)**
TOTAL OF MODELLED SECTORS[h]	**0**	**0**	**0**	**0 (0 - 0)**	**$0.72 M ($0.27 M - $1.4**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.

[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

Table A-12. Northwest Territories – all-cause premature mortality and valuation by sector and pollutant (2015).

NORTHWEST TERRITORIES	MORTALITY BY POLLUTANT[a, b, c, i]			ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
	$PM_{2.5}$	NO_2	O_3[d]		
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On-road	**0**	**0**	**0**	**0 (0 - 0)**	**$220 K ($79 K - $420 K)**
On-road LDV	0	0	0	0 (0 - 0)	$29 K ($10 K - $56 K)
On-road HDV	0	0	0	0 (0 - 0)	$180 K ($66 K - $340 K)
Off-road vehicles & mobile equipment	**0**	**0**	**0**	**0 (0 - 0)**	**$200 K ($74 K - $380 K)**
Air + Marine + Rail	**0**	**0**	**0**	**0 (0 - 0)**	**$180 K ($64 K - $340 K)**
Air	0	0	0	0 (0 - 0)	$0 ($0 - $0)
Marine	0	0	0	0 (0 - 0)	$98 K ($35 K - $190 K)
Rail	0	0	0	0 (0 - 0)	$81 K ($29 K - $160 K)
INDUSTRIAL SECTORS					
Ore and mineral industry	**0**	**0**	**0**	**0 (0 - 0)**	**$240 K ($90 K - $460 K)**
Cement manufacture	0	0	0	0 (0 - 0)	0 (0 - 0)
Non-ferrous refining and smelting	0	0	0	0 (0 - 0)	$69 K ($29 K - $130 K)
Oil and gas industry[g]	**0**	**0**	**0**	**0 (0 - 0)**	**$1.2 M ($0.44 M - $2.3 M)**
Upstream oil and gas	0	0	0	0 (0 - 0)	$1.2 M ($0.42 M - $2.2 M)
Downstream oil and gas	0	0	0	0 (0 - 0)	$47 K ($20 K - $84 K)
Electric power generation	**0**	**0**	**0**	**0 (0 - 0)**	**$350 K ($140 K - $660 K)**
Coal-fired electric power generation	0	0	0	0 (0 - 0)	$280 K ($110 K - $510 K)
Manufacturing	**0**	**0**	**0**	**0 (0 - 0)**	**$140 K ($54 K - $270 K)**
Chemicals industry	0	0	0	0 (0 - 0)	$25 K ($11 K - $44 K)
Pulp and paper industry	0	0	0	0 (0 - 0)	$59 K ($24 K - $110 K)
RESIDENTIAL SECTORS					
Residential fuel combustion	**0**	**0**	**0**	**0 (0 - 0)**	**$1.3 K ($0.38 K - $2.6 K)**
Home firewood burning	**0**	**0**	**0**	**0 (0 - 0)**	**$45 K ($19 K - $82 K)**
TOTAL OF MODELLED SECTORS[h]	**0**	**0**	**0**	**0 (0 - 0)**	**$2.6 M ($0.96 M - $4.9 M)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.

[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

Table A-13. Nunavut – all-cause premature mortality and valuation by sector and pollutant (2015).

NUNAVUT	MORTALITY BY POLLUTANT[a, b, c, i]			ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
	$PM_{2.5}$	NO_2	O_3[d]		
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On-road	**0**	**0**	**0**	**0 (0 - 0)**	**$37 K ($13 K - $72 K)**
On-road LDV	0	0	0	0 (0 - 0)	$6.0 K ($1.7 K - $12 K)
On-road HDV	0	0	0	0 (0 - 0)	$26 K ($8.9 K - $52 K)
Off-road vehicles & mobile equipment	**0**	**0**	**0**	**0 (0 - 0)**	**$34 K ($12 K - $67 K)**
Air + Marine + Rail	**0**	**0**	**0**	**0 (0 - 0)**	**$84 K ($29 K - $160 K)**
Air	0	0	0	0 (0 - 0)	$440 ($150 - $870)
Marine	0	0	0	0 (0 - 0)	$69 K ($24 K - $130 K)
Rail	0	0	0	0 (0 - 0)	$14 K ($4.8 K - $28 K)
INDUSTRIAL SECTORS					
Ore and mineral industry	**0**	**0**	**0**	**0 (0 - 0)**	**$100 K ($37 K - $190 K)**
Cement manufacture	0	0	0	0 (0 - 0)	$440 ($140 - $850)
Non-ferrous refining and smelting	0	0	0	0 (0 - 0)	$25 K ($11 K - $46 K)
Oil and gas industry[g]	**0**	**0**	**0**	**0 (0 - 0)**	**$140 K ($50 K - $260 K)**
Upstream oil and gas	0	0	0	0 (0 - 0)	$140 K ($50 K - $260 K)
Downstream oil and gas	0	0	0	0 (0 - 0)	$440 ($140 - $870)
Electric power generation	**0**	**0**	**0**	**0 (0 - 0)**	**$68 K ($24 K - $130 K)**
Coal-fired electric power generation	0	0	0	0 (0 - 0)	$25 K ($9.5 K - $46 K)
Manufacturing	**0**	**0**	**0**	**0 (0 - 0)**	**$9.7 K ($3.1 K - $20 K)**
Chemicals industry	0	0	0	0 (0 - 0)	$440 ($140 - $870)
Pulp and paper industry	0	0	0	0 (0 - 0)	$2.3 K ($0.68 K - $4.6 K)
RESIDENTIAL SECTORS					
Residential fuel combustion	**0**	**0**	**0**	**0 (0 - 0)**	**$440 ($150 - $870)**
Home firewood burning	**0**	**0**	**0**	**0 (0 - 0)**	**0 (0 - 0)**
TOTAL OF MODELLED SECTORS[h]	**0**	**0**	**0**	**(0 - 0)**	**$470 K ($170 K - $900 K)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.

[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

A.2 Health impacts of sector emissions – mortality by air zone

A.2.1 British Columbia air zones

Table A-14. BC Lower Fraser Valley air zone – all-cause premature mortality and valuation by sector and pollutant (2015).

Air Zone BC - LOWER FRASER VALLEY (pop. 2.8 M)	MORTALITY BY POLLUTANT[a, b, c, i]			ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
	$PM_{2.5}$	NO_2	O_3[d]		
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On-road	**90**	**41**	**-13**	**120 (38 - 200)**	**$0.93 B ($0.080 B – $2.1 B)**
On-road LDV	37	13	-2	49 (20 - 77)	$380 M ($89 M – $810 M)
On-road HDV	53	25	-25	53 (-2 - 110)	$0.42 B ($-20 B – $1.2 B)
Off-road vehicles & mobile equipment	**54**	**9**	**9**	**71 (35 - 110)**	**$0.56 B ($0.19 B – $1.1 B)**
Air + Marine + Rail	**28**	**8**	**-4**	**32 (10 - 54)**	**$260 M ($18 M – $580 M)**
Air	4	2	-3	3 (-2 - 7)	$23 M ($-30 M – $84 M)
Marine	21	4	1	26 (12 - 40)	$210 M ($63 M – $420 M)
Rail	3	2	-2	4 (< - 7)	$28 M ($-15 M – $80 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**25**	**3**	**-19**	**9 (-14 - 33)**	**$83 M ($-210 M – $400 M)**
Cement manufacture	7	3	-20	-10 (-25 - 5)	$-69 M ($-270 M – $110 M)
Non-ferrous refining and smelting	<	<	<	<	$26 K ($9.5 K – $50 K)
Oil and gas industry[g]	**6**	**<**	**<**	**7 (3 - 10)**	**$57 M ($18 M – $110 M)**
Upstream oil and gas	2	<	<	2 (1 - 3)	$17 M ($5.9 M – $34 M)
Downstream oil and gas	4	<	<	5 (2 - 7)	$40 M ($12 M – $79 M)
Electric power generation	**<**	**<**	**<**	**<**	**$-1.8 M ($-4.8 M – $0.75 M)**
Coal-fired electric power generation	<	<	<	<	$27 K ($9.5 K – $53 K)
Manufacturing	**31**	**1**	**6**	**39 (20 - 57)**	**$310 M ($100 M – $610 M)**
Chemicals industry	<	<	<	<	$0.51 M ($0.13 M – $1.1 M)
Pulp and paper industry	15	<	3	18 (9 - 27)	$140 M ($48 M – $280 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**10**	**3**	**-3**	**10 (2 - 18)**	**$79 M ($-6.3 M – $190 M)**
Home firewood burning	**173**	**<**	**1**	**170 (93 - 260)**	**$1.4 B ($0.47 B – $2.7 B)**
TOTAL OF MODELLED SECTORS[h]	**420**	**65**	**-23**	**460 (190 - 730)**	**$3.7 B ($0.66 B - $7.8 B)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).
[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.
[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.
[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).
[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.
[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.
[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).
[h] Estimate from sum of all sector model runs (not modelled separately).
[i] < denotes mortality count less than 1.

Table A-15. BC Georgia Strait air zone – all-cause premature mortality and valuation by sector and pollutant (2015).

Air Zone BC - GEORGIA STRAIT (pop. 0.8 M)	MORTALITY BY POLLUTANT[a, b, c, i]			ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
	$PM_{2.5}$	NO_2	O_3[d]		
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On-road	**11**	**5**	**7**	**23 (11 - 36)**	**$180 M ($58 M – $350 M)**
On-road LDV	3	1	2	7 (3 - 10)	$52 M ($17 M – $100 M)
On-road HDV	7	4	3	14 (6 - 22)	$110 M ($31 M – $210 M)
Off-road vehicles & mobile equipment	**3**	**1**	**2**	**6 (3 - 9)**	**$45 M ($15 M – $88 M)**
Air + Marine + Rail	**4**	**4**	**10**	**18 (8 - 27)**	**$130 M ($42 M – $270 M)**
Air	<	<	<	<	$1.9 M ($0.58 M – $3.9 M)
Marine	4	4	10	17 (8 - 26)	$130 M ($40 M – $250 M)
Rail	<	<	<	1 (< - 1)	$5.6 M ($1.7 M – $11 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**1**	**<**	**<**	**1 (< - 1)**	**$7.6 M ($2.5 M – $15 M)**
Cement manufacture	<	<	<	<	$1.7 M ($0.16 M – $3.9 M)
Non-ferrous refining and smelting	<	<	<	< (-1 - <)	$-3.6 M ($-6.9 M – $-1.3 M)
Oil and gas industry[g]	**<**	**<**	**<**	**1 (< - 1)**	**$4.2 M ($1.4 M – $8.1 M)**
Upstream oil and gas	<	<	<	<	$2.6 M ($0.90 M – $4.9 M)
Downstream oil and gas	<	<	<	<	$1.6 M ($0.54 M – $3.2 M)
Electric power generation	**<**	**<**	**<**	**<**	**$320 K ($23 K – $710 K)**
Coal-fired electric power generation	<	<	<	<	$-350 K ($-670 K – $-120 K)
Manufacturing	**11**	**<**	**2**	**13 (7 - 19)**	**$100 M ($35 M – $210 M)**
Chemicals industry	<	<	<	<	$36 K ($14 K – $66 K)
Pulp and paper industry	10	<	2	11 (6 - 17)	$91 M ($30 M – $180 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**1**	**<**	**<**	**1 (< - 2)**	**$7.0 M ($1.1 M – $15 M)**
Home firewood burning	**42**	**<**	**<**	**43 (23 - 63)**	**$330 M ($110 M – $650 M)**
TOTAL OF MODELLED SECTORS[h]	**73**	**10**	**21**	**110 (53 - 160)**	**$0.81 B ($0.27 B - $1.6B)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.

[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

Table A-16. BC Southern Interior air zone – all-cause premature mortality and valuation by sector and pollutant (2015).

Air Zone BC - SOUTHERN INTERIOR (pop. 0.7 M)	MORTALITY BY POLLUTANT[a, b, c, i]			ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
	$PM_{2.5}$	NO_2	O_3[d]		
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On-road	**6**	**2**	**12**	**20 (10 - 31)**	**$150 M ($52 M – $300 M)**
On-road LDV	2	1	2	5 (2 - 7)	$37 M ($13 M – $73 M)
On-road HDV	4	2	8	15 (7 - 22)	$110 M ($37 M – $220 M)
Off-road vehicles & mobile equipment	**2**	**<**	**2**	**4 (2 - 7)**	**$34 M ($12 M – $67 M)**
Air + Marine + Rail	**1**	**<**	**2**	**4 (2 - 5)**	**$27 M ($9.1 M – $52 M)**
Air	<	<	<	< (< - 1)	$3.7 M ($1.3 M – $7.2 M)
Marine	<	<	1	1 (1 - 2)	$9.7 M ($3.4 M – $19 M)
Rail	1	<	1	2 (1 - 3)	$13 M ($4.5 M – $26 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**1**	**<**	**<**	**2 (1 - 3)**	**$17 M ($5.6 M – $33 M)**
Cement manufacture	<	<	<	1 (< - 1)	$4.4 M ($1.5 M – $8.6 M)
Non-ferrous refining and smelting	1	<	<	1 (< - 1)	$6.6 M ($2.2 M – $13 M)
Oil and gas industry[g]	**1**	**<**	**2**	**3 (1 - 4)**	**$20 M ($7.0 M – $39 M)**
Upstream oil and gas	1	<	2	2 (1 - 3)	$18 M ($6.2 M – $35 M)
Downstream oil and gas	<	<	<	<	$2.2 M ($0.77 M – $4.3 M)
Electric power generation	**<**	**<**	**<**	**1 (< - 1)**	**$4.4 M ($1.5 M – $8.6 M)**
Coal-fired electric power generation	<	<	<	1 (< - 1)	$4.2 M ($1.4 M – $8.2 M)
Manufacturing	**3**	**<**	**2**	**5 (2 - 7)**	**$37 M ($13 M – $73 M)**
Chemicals industry	<	<	<	<	$150 K ($55 K – $280 K)
Pulp and paper industry	2	<	<	2 (1 - 3)	$17 M ($6.0 M – $33 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**1**	**<**	**<**	**1 (1 - 2)**	**$8.5 M ($2.9 M – $17 M)**
Home firewood burning	**28**	**<**	**<**	**28 (15 - 42)**	**$220 M ($76 M – $430 M)**
TOTAL OF MODELLED SECTORS[h]	**43**	**2**	**20**	**68 (35 - 100)**	**$0.52 B ($0.18 B - $1.0 B)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.

[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

Table A-17. BC Central Interior air zone – all-cause premature mortality and valuation by sector and pollutant (2015).

Air Zone BC - CENTRAL INTERIOR (pop. 0.2 M)	MORTALITY BY POLLUTANT[a, b, c, i]			ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
	$PM_{2.5}$	NO_2	O_3[d]		
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On-road	**<**	**<**	**1**	**2 (1 - 2)**	**\$12 M (\$4.1 M – \$24 M)**
On-road LDV	<	<	<	< (< - 1)	\$3.1 M (\$1.1 M – \$6.0 M)
On-road HDV	<	<	<	1 (1 - 2)	\$9.1 M (\$3.1 M – \$18 M)
Off-road vehicles & mobile equipment	**<**	**<**	**<**	**1 (< - 1)**	**\$4.6 M (\$1.6 M – \$8.9 M)**
Air + Marine + Rail	**<**	**<**	**<**	**1 (1 - 2)**	**\$7.8 M (\$2.6 M – \$15 M)**
Air	<	<	<	<	\$0.58 M (\$0.21 M – \$1.1 M)
Marine	<	<	<	< (< - 1)	\$3.5 M (\$1.2 M – \$6.8 M)
Rail	<	<	<	< (< - 1)	\$3.7 M (\$1.2 M – \$7.3 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**<**	**<**	**<**	**<**	**\$2.4 M (\$0.80 M – \$4.7 M)**
Cement manufacture	<	<	<	<	\$0.86 M (\$0.29 M – \$1.7 M)
Non-ferrous refining and smelting	<	<	<	<	\$280 (\$-53 – \$680)
Oil and gas industry[g]	**<**	**<**	**<**	**1 (1 - 2)**	**\$8.5 M (\$2.8 M – \$17 M)**
Upstream oil and gas	<	<	<	1 (1 - 2)	\$7.9 M (\$2.7 M – \$15 M)
Downstream oil and gas	<	<	<	<	\$0.55 M (\$0.17 M – \$1.1 M)
Electric power generation	**<**	**<**	**<**	**<**	**\$1.4 M (\$0.45 M – \$2.7 M)**
Coal-fired electric power generation	<	<	<	<	\$0.61 M (\$0.20 M – \$1.2 M)
Manufacturing	**2**	**<**	**<**	**2 (1 - 3)**	**\$17 M (\$5.6 M – \$33 M)**
Chemicals industry	<	<	<	<	\$460 K (\$150 K – \$910 K)
Pulp and paper industry	1	<	<	1 (1 - 2)	\$11 M (\$3.7 M – \$22 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**<**	**<**	**<**	**<**	**\$0.61 M (\$0.21 M – \$1.2 M)**
Home firewood burning	**2**	**<**	**<**	**2 (1 - 3)**	**\$13 M (\$4.6 M – \$26 M)**
TOTAL OF MODELLED SECTORS[h]	**4**	**<**	**1**	**9 (4 - 13)**	**\$67 M (\$23 M - \$130 M)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.

[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

A.2.2 Alberta air zones

Table A-18. AB North Saskatchewan air zone – all-cause premature mortality and valuation by sector and pollutant (2015).

Air Zone AB - NORTH SASKATCHEWAN (pop. 1.6 M)	MORTALITY BY POLLUTANT[a, b, c, i] $PM_{2.5}$	 NO_2	 O_3 [d]	ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On-road	**20**	**9**	**4**	**32 (14 - 51)**	**$250 M ($74 M – $520 M)**
On-road LDV	5	2	1	8 (4 - 12)	$63 M ($20 M – $130 M)
On-road HDV	14	7	1	23 (10 - 37)	$180 M ($48 M – $380 M)
Off-road vehicles & mobile equipment	**12**	**3**	**5**	**20 (10 - 30)**	**$160 M ($51 M – $310 M)**
Air + Marine + Rail	**5**	**3**	**2**	**11 (5 - 17)**	**$85 M ($26 M – $170 M)**
Air	<	<	<	<	$1.7 M ($0.46 M – $3.5 M)
Marine	<	<	<	1 (< - 1)	$5.3 M ($1.8 M – $10 M)
Rail	5	3	2	10 (4 - 16)	$78 M ($23 M – $160 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**5**	**<**	**<**	**6 (3 - 9)**	**$48 M ($15 M – $95 M)**
Cement manufacture	<	<	<	<	$2.1 M ($0.58 M – $4.2 M)
Non-ferrous refining and smelting	<	<	<	<	$0.56 M ($-0.42 M – $1.6 M)
Oil and gas industry[g]	**43**	**13**	**27**	**83 (39 - 130)**	**$0.66 B ($0.21 B – $1.3 B)**
Upstream oil and gas	40	12	27	79 (38 - 120)	$0.63 B ($0.20 B – $1.3 B)
Downstream oil and gas	3	1	<	4 (2 - 7)	$32 M ($6.5 M – $68 M)
Electric power generation	**28**	**3**	**2**	**33 (16 - 50)**	**$280 M ($82 M – $560 M)**
Coal-fired electric power generation	27	3	2	32 (16 - 48)	$270 M ($78 M – $550 M)
Manufacturing	**16**	**2**	**1**	**19 (10 - 29)**	**$150 M ($49 M – $310 M)**
Chemicals industry	12	1	<	14 (7 - 22)	$110 M ($35 M – $230 M)
Pulp and paper industry	2	<	<	2 (1 - 3)	$18 M ($5.9 M – $35 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**3**	**1**	**<**	**4 (2 - 6)**	**$30 M ($6.4 M – $65 M)**
Home firewood burning	**15**	**<**	**<**	**15 (8 - 22)**	**$120 M ($41 M – $240 M)**
TOTAL OF MODELLED SECTORS[h]	**150**	**34**	**41**	**220 (110 - 340)**	**$1.8 B ($0.55 B - $3.6 B)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.

[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

Table A-19. AB South Saskatchewan air zone – all-cause premature mortality and valuation by sector and pollutant (2015).

Air Zone **AB - SOUTH SASKATCHEWAN (pop. 1.4 M)**	**MORTALITY BY POLLUTANT**[a, b, c, i]			**ALL-POLLUTANT MORTALITY**[e, i] median (2.5% - 97.5% CI)	**TOTAL VALUATION**[f] **(mortality and morbidity)** median (2.5% - 97.5% CI)
	$PM_{2.5}$	**NO_2**	**O_3** [d]		
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On-road	**15**	**7**	**8**	**31 (14 - 47)**	**$240 M ($76 M – $480 M)**
On-road LDV	4	1	2	6 (3 - 10)	$51 M ($17 M – $100 M)
On-road HDV	11	5	6	22 (10 - 34)	$170 M ($55 M – $350 M)
Off-road vehicles & mobile equipment	**7**	**1**	**4**	**12 (6 - 18)**	**$96 M ($32 M – $190 M)**
Air + Marine + Rail	**3**	**2**	**2**	**9 (4 - 13)**	**$66 M ($20 M – $130 M)**
Air	<	<	<	<	$1.6 M ($0.46 M – $3.3 M)
Marine	<	<	<	1 (< - 1)	$4.5 M ($1.6 M – $8.6 M)
Rail	3	2	2	8 (4 - 12)	$60 M ($18 M – $120 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**5**	**<**	**2**	**7 (3 - 10)**	**$52 M ($17 M – $100 M)**
Cement manufacture	1	<	<	2 (1 - 3)	$16 M ($5.2 M – $31 M)
Non-ferrous refining and smelting	<	<	<	<	$0.43 M ($-0.18 M – $1.1 M)
Oil and gas industry[g]	**27**	**8**	**15**	**49 (23 - 74)**	**$390 M ($120 M – $790 M)**
Upstream oil and gas	26	8	15	48 (23 - 73)	$390 M ($120 M – $780 M)
Downstream oil and gas	1	<	<	1 (< - 1)	$5.5 M ($1.8 M – $11 M)
Electric power generation	**12**	**<**	**2**	**14 (7 - 21)**	**$110 M ($37 M – $220 M)**
Coal-fired electric power generation	12	<	2	14 (7 - 20)	$110 M ($36 M – $220 M)
Manufacturing	**6**	**1**	**2**	**8 (4 - 12)**	**$62 M ($20 M – $120 M)**
Chemicals industry	3	<	<	4 (2 - 6)	$32 M ($10 M – $63 M)
Pulp and paper industry	1	<	<	1 (< - 1)	$7.2 M ($2.5 M – $14 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**3**	**1**	**<**	**4 (2 - 6)**	**$31 M ($8.3 M – $65 M)**
Home firewood burning	**9**	**<**	**<**	**9 (5 - 13)**	**$72 M ($24 M – $140 M)**
TOTAL OF MODELLED SECTORS[h]	**87**	**20**	**35**	**140 (69 - 210)**	**$1.1 B ($0.36 B - $2.3 B)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.

[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

Table A-20. AB Red Deer air zone – all-cause premature mortality and valuation by sector and pollutant (2015).

Air Zone AB - RED DEER (pop. 0.7 M)	MORTALITY BY POLLUTANT[a, b, c, i]			ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
	$PM_{2.5}$	NO_2	O_3[d]		
TRANSPORTATION SECTORS					
ALL On-road	**8**	**4**	**5**	**16 (7 - 24)**	**$120 M ($39 M – $250 M)**
On-road LDV	2	1	1	3 (2 - 5)	$27 M ($8.8 M – $54 M)
On-road HDV	6	3	3	12 (5 - 18)	$90 M ($28 M – $180 M)
Off-road vehicles & mobile equipment	**4**	**1**	**2**	**7 (3 - 10)**	**$53 M ($17 M – $110 M)**
Air + Marine + Rail	**2**	**1**	**1**	**5 (2 - 8)**	**$38 M ($12 M – $77 M)**
Air	<	<	<	<	$1.8 M ($0.58 M – $3.6 M)
Marine	<	<	<	< (< - 1)	$3.2 M ($1.1 M – $6.3 M)
Rail	2	1	1	4 (2 - 7)	$33 M ($10 M – $67 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**2**	**<**	**<**	**3 (2 - 5)**	**$25 M ($8.2 M – $50 M)**
Cement manufacture	1	<	<	1 (1 - 2)	$8.2 M ($2.7 M – $16 M)
Non-ferrous refining and smelting	<	<	<	<	$-13 K ($-260 K – $200 K)
Oil and gas industry[g]	**18**	**6**	**9**	**32 (15 - 49)**	**$260 M ($81 M – $520 M)**
Upstream oil and gas	17	6	9	32 (15 - 50)	$250 M ($79 M – $510 M)
Downstream oil and gas	1	<	<	1 (< - 1)	$5.0 M ($1.6 M – $9.9 M)
Electric power generation	**8**	**<**	**1**	**10 (5 - 16)**	**$82 M ($27 M – $160 M)**
Coal-fired electric power generation	8	<	1	10 (5 - 15)	$79 M ($25 M – $160 M)
Manufacturing	**3**	**<**	**<**	**5 (2 - 7)**	**$37 M ($12 M – $73 M)**
Chemicals industry	2	<	<	2 (1 - 4)	$20 M ($6.3 M – $39 M)
Pulp and paper industry	<	<	<	1 (< - 1)	$5.2 M ($1.8 M – $10 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**2**	**<**	**<**	**2 (1 - 3)**	**$16 M ($4.4 M – $34 M)**
Home firewood burning	**4**	**<**	**<**	**4 (2 - 7)**	**$36 M ($12 M – $71 M)**
TOTAL OF MODELLED SECTORS[h]	**51**	**12**	**18**	**84 (41 - 130)**	**$0.67 B ($0.21 B - $1.3 B)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.

[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

Table A-21. AB Peace air zone – all-cause premature mortality and valuation by sector and pollutant (2015).

Air Zone AB – PEACE (pop. 0.2 M)	MORTALITY BY POLLUTANT[a, b, c, i] $PM_{2.5}$	 NO_2	 O_3[d]	ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On-road	**<**	**<**	**<**	**1 (< - 2)**	**\$7.8 M (\$2.5 M – \$16 M)**
On-road LDV	<	<	<	<	\$1.4 M (\$0.46 M – \$2.8 M)
On-road HDV	<	<	<	1 (< - 1)	\$6.2 M (\$2.0 M – \$12 M)
Off-road vehicles & mobile equipment	**<**	**<**	**<**	**1 (< - 1)**	**\$7.6 M (\$2.5 M – \$15 M)**
Air + Marine + Rail	**<**	**<**	**<**	**1 (< - 1)**	**\$5.7 M (\$1.8 M – \$11 M)**
Air	<	<	<	<	\$10 K (\$3.1 K – \$21 K)
Marine	<	<	<	<	\$0.86 M (\$0.29 M – \$1.7 M)
Rail	<	<	<	1 (< - 1)	\$4.8 M (\$1.5 M – \$9.7 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**<**	**<**	**<**	**<**	**\$340 K (\$110 K – \$670 K)**
Cement manufacture	<	<	<	<	\$64 K (\$21 K – \$130 K)
Non-ferrous refining and smelting	<	<	<	<	\$-56 K (\$-110 K – \$-17 K)
Oil and gas industry[g]	**3**	**1**	**4**	**7 (3 - 11)**	**\$58 M (\$18 M – \$120 M)**
Upstream oil and gas	3	1	4	7 (3 - 11)	\$57 M (\$18 M – \$120 M)
Downstream oil and gas	<	<	<	<	\$110 K (\$25 K – \$220 K)
Electric power generation	**1**	**<**	**<**	**1 (< - 1)**	**\$7.6 M (\$2.5 M – \$15 M)**
Coal-fired electric power generation	1	<	<	1 (< - 1)	\$6.8 M (\$2.2 M – \$13 M)
Manufacturing	**1**	**<**	**<**	**1 (< - 1)**	**\$7.5 M (\$2.4 M – \$15 M)**
Chemicals industry	<	<	<	<	\$0.93 M (\$0.30 M – \$1.8 M)
Pulp and paper industry	<	<	<	< (< - 1)	\$2.7 M (\$0.89 M – \$5.4 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**<**	**<**	**<**	**<**	**\$180 K (\$51 K – \$370 K)**
Home firewood burning	**1**	**<**	**<**	**1 (< - 1)**	**\$5.3 M (\$1.8 M – \$11 M)**
TOTAL OF MODELLED SECTORS[h]	**6**	**1**	**4**	**13 (6 - 19)**	**\$100 M (\$32 M - \$200 M)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.

[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

Table A-22. AB Upper Athabasca air zone – all-cause premature mortality and valuation by sector and pollutant (2015).

Air Zone AB - UPPER ATHABASCA (pop. 0.1 M)	MORTALITY BY POLLUTANT[a, b, c, i] PM$_{2.5}$	NO$_2$	O$_3$[d]	ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On-road	**1**	**<**	**<**	**1 (1 - 2)**	**$10 M ($3.4 M – $21 M)**
On-road LDV	<	<	<	<	$2.1 M ($0.69 M – $4.1 M)
On-road HDV	<	<	<	1 (< - 2)	$7.9 M ($2.5 M – $16 M)
Off-road vehicles & mobile equipment	**<**	**<**	**<**	**1 (1 - 2)**	**$8.3 M ($2.8 M – $16 M)**
Air + Marine + Rail	**<**	**<**	**<**	**1 (< - 1)**	**$5.5 M ($1.7 M – $11 M)**
Air	<	<	<	<	$59 K ($16 K – $120 K)
Marine	<	<	<	<	$0.55 M ($0.18 M – $1.1 M)
Rail	<	<	<	1 (< - 1)	$4.9 M ($1.5 – $9.9 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**<**	**<**	**<**	**<**	**$1.6 M ($0.50 M – $3.2 M)**
Cement manufacture	<	<	<	<	$310 K ($98 K – $620 K)
Non-ferrous refining and smelting	<	<	<	<	$-12 K ($-41 K – $11 K)
Oil and gas industry[g]	**2**	**1**	**2**	**5 (2 - 8)**	**$39 M ($13 M – $78 M)**
Upstream oil and gas	2	1	2	5 (2 - 8)	$38 M ($12 M – $76 M)
Downstream oil and gas	<	<	<	<	$1.2 M ($0.37 M – $2.3 M)
Electric power generation	**1**	**<**	**<**	**2 (1 - 3)**	**$14 M ($4.6 M – $28 M)**
Coal-fired electric power generation	1	<	<	2 (1 - 3)	$14 M ($4.4 M – $27 M)
Manufacturing	**1**	**<**	**<**	**1 (1 - 2)**	**$9.4 M ($3.1 M – $19 M)**
Chemicals industry	1	<	<	1 (< - 1)	$5.1 M ($1.7 M – $10 M)
Pulp and paper industry	<	<	<	<	$2.2 M ($0.74 M – $4.4 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**<**	**<**	**<**	**<**	**$0.64 M ($0.21 M – $1.3 M)**
Home firewood burning	**1**	**<**	**<**	**1 (< - 1)**	**$4.0 M ($1.4 M – $7.8 M)**
TOTAL OF MODELLED SECTORS[h]	**6**	**1**	**2**	**12 (6 - 18)**	**$93 M ($30 M - $190 M)**

[a] Chronic exposure mortality (PM$_{2.5}$), acute exposure mortality (NO$_2$, O$_3$), and chronic exposure respiratory mortality (summer O$_3$).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O$_3$ health impacts may occur in areas with high NO$_x$ emissions.

[d] Sum of annual O$_3$ (acute exposure mortality) and summer O$_3$ (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO$_2$, O$_3$), chronic exposure mortality (PM$_{2.5}$), and chronic exposure respiratory mortality (summer O$_3$). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

Table A-23. AB Lower Athabasca air zone – all-cause premature mortality and valuation by sector and pollutant (2015).

Air Zone AB - LOWER ATHABASCA (pop. 0.1 M)	MORTALITY BY POLLUTANT[a, b, c, i]			ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
	$PM_{2.5}$	NO_2	O_3[d]		
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On-road	**<**	**<**	**<**	**< (< - 1)**	**$3.8 M ($1.2 M – $7.5 M)**
On-road LDV	<	<	<	<	$0.96 M ($0.32 M – $1.9 M)
On-road HDV	<	<	<	< (< - 1)	$3.0 M ($0.97 M – $6.0 M)
Off-road vehicles & mobile equipment	**<**	**<**	**<**	**< (< - 1)**	**$3.8 M ($1.3 M – $7.6 M)**
Air + Marine + Rail	**<**	**<**	**<**	**< (< - 1)**	**$2.5 M ($0.80 M – $5.1 M)**
Air	<	<	<	<	$12 K ($4.1 K – $25 K)
Marine	<	<	<	<	$230 K ($78 K – $440 K)
Rail	<	<	<	<	$2.3 M ($0.72 M – $4.6 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**<**	**<**	**<**	**<**	**$0.72 M ($0.24 M – $1.4 M)**
Cement manufacture	<	<	<	<	$290 K ($100 K – $560 K)
Non-ferrous refining and smelting	<	<	<	<	$250 K ($86 K – $490 K)
Oil and gas industry[g]	**1**	**<**	**2**	**3 (1 - 4)**	**$21 M ($6.8 M – $43 M)**
Upstream oil and gas	1	<	2	3 (1 - 4)	$21 M ($6.6 M – $41 M)
Downstream oil and gas	<	<	<	<	$0.60 M ($0.20 M – $1.2 M)
Electric power generation	**1**	**<**	**<**	**1 (< - 1)**	**$5.6 M ($1.8 M – $11 M)**
Coal-fired electric power generation	1	<	<	1 (< - 1)	$5.5 M ($1.8 M – $11 M)
Manufacturing	**<**	**<**	**<**	**< (< - 1)**	**$3.6 M ($1.2 M – $7.1 M)**
Chemicals industry	<	<	<	<	$2.3 M ($0.77 M – $4.6 M)
Pulp and paper industry	<	<	<	<	$0.85 M ($0.28 M – $1.7 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**<**	**<**	**<**	**<**	**$320 K ($110 K – $640 K)**
Home firewood burning	**<**	**<**	**<**	**<**	**$1.6 M ($0.53 M – $3.1 M)**
TOTAL OF MODELLED SECTORS[h]	**2**	**<**	**2**	**5 (3 - 8)**	**$43 M ($14 M - $86 M)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.

[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

A.2.3 Saskatchewan air zones

Table A-24. SK Great Plains air zone – all-cause premature mortality and valuation by sector and pollutant (2015).

Air Zone SK – GREAT PLAINS (pop. 0.5 M)	MORTALITY BY POLLUTANT[a, b, c, i]			ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
	$PM_{2.5}$	NO_2	O_3 [d]		
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On–road	**3**	**1**	**2**	**7 (3 - 10)**	**$51 M ($17 M – $100 M)**
On–road LDV	1	<	<	2 (1 - 3)	$13 M ($4.3 M – $26 M)
On–road HDV	2	1	2	5 (2 - 7)	$37 M ($12 M – $73 M)
Off-road vehicles & mobile equipment	**2**	**<**	**2**	**6 (3 - 8)**	**$43 M ($15 M – $84 M)**
Air + Marine + Rail	**1**	**<**	**<**	**2 (1 - 3)**	**$17 M ($5.4 M – $34 M)**
Air	<	<	<	<	$89 K ($24 K – $190 K)
Marine	<	<	<	<	$1.5 M ($0.50 M – $2.9 M)
Rail	1	<	<	2 (1 - 3)	$15 M ($4.9 M – $31 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**2**	**<**	**<**	**3 (1 - 4)**	**$22 M ($7.6 M – $44 M)**
Cement manufacture	<	<	<	<	$360 K ($120 K – $700 K)
Non – ferrous refining and smelting	1	<	<	1 (< - 1)	$6.8 M ($2.3 M – $13 M)
Oil and gas industry[g]	**6**	**<**	**2**	**9 (5 - 14)**	**$72 M ($24 M – $140 M)**
Upstream oil and gas	5	<	2	8 (4 - 12)	$65 M ($22 M – $130 M)
Downstream oil and gas	1	<	<	1 (< - 1)	$6.9 M ($2.2 M – $14 M)
Electric power generation	**6**	**<**	**2**	**7 (4 - 11)**	**$58 M ($19 M – $110 M)**
Coal – fired electric power generation	6	<	2	7 (4 - 10)	$56 M ($18 M – $110 M)
Manufacturing	**2**	**<**	**<**	**3 (1 - 4)**	**$20 M ($6.6 M – $39 M)**
Chemicals industry	2	<	<	2 (1 - 3)	$14 M ($4.8 M – $28 M)
Pulp and paper industry	<	<	<	< (< - 1)	$3.0 M ($1.0 M – $5.8 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**<**	**<**	**<**	**< (< - 1)**	**$2.9 M ($0.82 M – $6.0 M)**
Home firewood burning	**1**	**<**	**<**	**1 (1 - 2)**	**$11 M ($3.8 M – $22 M)**
TOTAL OF MODELLED SECTORS[h]	**23**	**1**	**8**	**38 (19 - 57)**	**$300 M ($99 M - $590 M)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.

[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

Table A-25. SK Western Yellowhead air zone – all-cause premature mortality and valuation by sector and pollutant (2015).

Air Zone SK – WESTERN YELLOWHEAD (pop. 0.3 M)	MORTALITY BY POLLUTANT[a, b, c, i] PM2.5	NO2	O3[d]	ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On – road	**2**	**<**	**2**	**4 (2 - 5)**	**\$28 M (\$9.2 M – \$55 M)**
On – road LDV	<	<	<	1 (< - 1)	\$7.2 M (\$2.4 M – \$14 M)
On – road HDV	1	<	1	3 (1 - 4)	\$20 M (\$6.6 M – \$40 M)
Off-road vehicles & mobile equipment	**1**	**<**	**2**	**3 (2 - 5)**	**\$26 M (\$8.9 M – \$51 M)**
Air + Marine + Rail	**1**	**<**	**<**	**1 (1 - 2)**	**\$11 M (\$3.6 M – \$22 M)**
Air	<	<	<	<	\$110 K (\$30 K – \$220 K)
Marine	<	<	<	<	\$1.0 M (\$0.34 M – \$1.9 M)
Rail	1	<	<	1 (1 - 2)	\$10 M (\$3.2 M – \$20 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**1**	**<**	**<**	**1 (1 - 2)**	**\$11 M (\$3.7 M – \$21 M)**
Cement manufacture	<	<	<	<	\$370 K (\$120 K – \$730 K)
Non – ferrous refining and smelting	<	<	<	<	\$2.5 (\$0.87 M – \$4.9 M)
Oil and gas industry[g]	**4**	**1**	**3**	**8 (4 - 12)**	**\$60 M (\$20 M – \$120 M)**
Upstream oil and gas	4	1	3	7 (4 - 11)	\$58 M (\$19 M – \$110 M)
Downstream oil and gas	<	<	<	<	\$2.3 M (\$0.75 M – \$4.5 M)
Electric power generation	**3**	**<**	**<**	**4 (2 - 6)**	**\$32 M (\$11 M – \$63 M)**
Coal – fired electric power generation	3	<	<	4 (2 - 6)	\$30 M (\$10 M – \$60 M)
Manufacturing	**1**	**<**	**<**	**2 (1 - 2)**	**\$12 M (\$4.0 M – \$24 M)**
Chemicals industry	1	<	<	1 (< - 1)	\$7.4 M (\$2.5 M – \$14 M)
Pulp and paper industry	<	<	<	<	\$1.8 M (\$0.62 M – \$3.6 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**<**	**<**	**<**	**<**	**\$1.4 M (\$0.35 M – \$3.0 M)**
Home firewood burning	**1**	**<**	**<**	**1 (< - 1)**	**\$6.3 M (\$2.1 M – \$12 M)**
TOTAL OF MODELLED SECTORS[h]	**14**	**1**	**7**	**24 (12 - 36)**	**\$190 M (\$62 M - \$370 M)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).
[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.
[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.
[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).
[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.
[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.
[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).
[h] Estimate from sum of all sector model runs (not modelled separately).
[i] < denotes mortality count less than 1.

Table A-26. SK Northeast air zone – all-cause premature mortality and valuation by sector and pollutant (2015).

Air Zone SK – NORTHEAST (pop. 0.1 M)	MORTALITY BY POLLUTANT[a, b, c, i]			ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
	$PM_{2.5}$	NO_2	O_3 [d]		
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On – road	**1**	**<**	**<**	**2 (1 - 3)**	**$14 M ($4.8 M – $28 M)**
On – road LDV	<	<	<	1 (< - 1)	$3.8 M ($1.3 M – $7.5 M)
On – road HDV	1	<	<	1 (1 - 2)	$10 M ($3.4 M – $20 M)
Off-road vehicles & mobile equipment	**1**	**<**	**1**	**2 (1 - 3)**	**$14 M ($4.7 M – $27 M)**
Air + Marine + Rail	**<**	**<**	**<**	**1 (< - 1)**	**$5.6 M ($1.8 – $11 M)**
Air	<	<	<	<	$63 K ($17 K – $130 K)
Marine	<	<	<	<	$0.56 M ($0.19 M – $1.1 M)
Rail	<	<	<	1 (< - 1)	$4.9 M ($1.6 M – $9.8 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**1**	**<**	**<**	**1 (< - 1)**	**$6.3 M ($2.2 M – $12 M)**
Cement manufacture	<	<	<	<	$83 K ($23 K – $170 K)
Non – ferrous refining and smelting	<	<	<	< (< - 1)	$2.8 M ($0.97 M – $5.4 M)
Oil and gas industry[g]	**2**	**<**	**1**	**3 (2 - 4)**	**$23 M ($7.8 M – $46 M)**
Upstream oil and gas	2	<	1	3 (1 - 4)	$22 M ($7.4 M – $44 M)
Downstream oil and gas	<	<	<	<	$1.2 M ($0.39 M – $2.3 M)
Electric power generation	**1**	**<**	**<**	**2 (1 - 3)**	**$14 M ($4.7 M – $27 M)**
Coal – fired electric power generation	1	<	<	2 (1 - 3)	$14 M ($4.5 M – $27 M)
Manufacturing	**1**	**<**	**<**	**1 (< - 1)**	**$5.2 M ($1.8 M – $10 M)**
Chemicals industry	<	<	<	< (< - 1)	$2.7 M ($0.93 M – $5.4 M)
Pulp and paper industry	<	<	<	<	$1.1 M ($0.37 M – $2.1 M)
©RESIDENTIAL SECTORS					
Residential fuel combustion	**<**	**<**	**<**	**<**	**$0.98 M ($0.26 M – $2.0 M)**
Home firewood burning	**1**	**<**	**<**	**1 (< - 1)**	**$4.3 M ($1.5 M – $8.5 M)**
TOTAL OF MODELLED SECTORS[h]	**8**	**<**	**2**	**11 (6 - 17)**	**$88 M ($29 M - $170 M)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.

[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

Table A-27. SK Southeast Saskatchewan air zone – all-cause premature mortality and valuation by sector and pollutant (2015).

Air Zone SK – SOUTHEAST (pop. 0.1 M)	MORTALITY BY POLLUTANT[a, b, c, i]			ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
	$PM_{2.5}$	NO_2	O_3 [d]		
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On – road	**1**	**<**	**<**	**1 (1 - 2)**	**$10 M ($3.4 M – $20 M)**
On – road LDV	<	<	<	< (< - 1)	$2.8 M ($0.93 M – $5.5 M)
On – road HDV	<	<	<	1 (< - 1)	$7.4 M ($2.4 M – $15 M)
Off-road vehicles & mobile equipment	**1**	**<**	**<**	**1 (1 - 2)**	**$11 M ($3.7 M – $22 M)**
Air + Marine + Rail	**<**	**<**	**<**	**1 (< - 1)**	**$4.5 M ($1.5 M – $9.0 M)**
Air	<	<	<	<	$82 K ($30 K – $160 K)
Marine	<	<	<	<	$450 K ($150 K – $870 K)
Rail	<	<	<	1 (< - 1)	$4.0 M ($1.3 M – $8.0 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**<**	**<**	**<**	**1 (< - 1)**	**$4.4 M ($1.5 M – $8.7 M)**
Cement manufacture	<	<	<	<	$160 K ($57 K – $310 K)
Non – ferrous refining and smelting	<	<	<	<	$1.9 M ($0.65 M – $3.6 M)
Oil and gas industry[g]	**1**	**<**	**<**	**2 (1 - 4)**	**$19 M ($6.3 M – $37 M)**
Upstream oil and gas	1	<	<	2 (1 - 3)	$17 M ($5.8 M – $34 M)
Downstream oil and gas	<	<	<	<	$1.4 M ($0.47 M – $2.8 M)
Electric power generation	**2**	**<**	**<**	**2 (1 - 3)**	**$16 M ($5.2 M – $31 M)**
Coal – fired electric power generation	1	<	<	2 (1 - 3)	$16 M ($5.1 M – $31 M)
Manufacturing	**<**	**<**	**<**	**< (< - 1)**	**$3.9 M ($1.3 M – $7.6 M)**
Chemicals industry	<	<	<	< (< - 1)	$2.9 M ($0.99 M – $5.6 M)
Pulp and paper industry	<	<	<	<	$0.60 M ($0.21 M – $1.2 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**<**	**<**	**<**	**<**	**$0.56 M ($0.18 M – $1.1 M)**
Home firewood burning	**<**	**<**	**<**	**<**	**$2.5 M ($0.87 M – $4.9 M)**
TOTAL OF MODELLED SECTORS[h]	**5**	**<**	**<**	**9 (5 - 14)**	**$72 M ($24 M - $140 M)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).
[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.
[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.
[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).
[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.
[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.
[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).
[h] Estimate from sum of all sector model runs (not modelled separately).
[i] < denotes mortality count less than 1.

Table A-28. SK Grasslands air zone – all-cause premature mortality and valuation by sector and pollutant (2015).

Air Zone SK – GRASSLANDS (pop. <0.1 M)	MORTALITY BY POLLUTANT[a, b, c, i]			ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
	$PM_{2.5}$	NO_2	O_3[d]		
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On – road	**<**	**<**	**<**	**1 (0 - 1)**	**$7.1 M ($2.4 M – $14 M)**
On – road LDV	<	<	<	<	$1.6 M ($0.54 M – $3.2 M)
On – road HDV	<	<	<	1 (< - 1)	$5.3 M ($1.7 M – $10 M)
Off-road vehicles & mobile equipment	**<**	**<**	**<**	**1 (1 - 2)**	**$8.9 M ($3.0 M – $17 M)**
Air + Marine + Rail	**<**	**<**	**<**	**1 (< - 1)**	**$3.8 M ($1.2 M – $7.5 M)**
Air	<	<	<	<	$120 K ($41 K – $240 K)
Marine	<	<	<	<	$480 K ($160 K – $930 K)
Rail	<	<	<	< (< - 1)	$3.2 M ($1.0 M – $6.4 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**<**	**<**	**<**	**<**	**$1.8 M ($0.62 M – $3.6 M)**
Cement manufacture	<	<	<	<	$240 K ($80 K – $470 K)
Non – ferrous refining and smelting	<	<	<	<	$0.54 M ($0.18 M – $1.0 M)
Oil and gas industry[e]	**1**	**<**	**1**	**2 (1 - 4)**	**$18 M ($6.1 M – $36 M)**
Upstream oil and gas	1	<	1	2 (1 - 3)	$17 M ($5.8 M – $34 M)
Downstream oil and gas	<	<	<	<	$0.83 M ($0.28 M – $1.6 M)
Electric power generation	**2**	**<**	**<**	**2 (1 - 3)**	**$16 M ($5.3 M – $31 M)**
Coal – fired electric power generation	2	<	<	2 (1 - 3)	$16 M ($5.1 M – $31 M)
Manufacturing	**<**	**<**	**<**	**< (< - 1)**	**$3.8 M ($1.3 M – $7.5 M)**
Chemicals industry	<	<	<	< (< - 1)	$2.9 M ($1.0 M – $5.7 M)
Pulp and paper industry	<	<	<	<	$470 K ($160 K – $930 K)
RESIDENTIAL SECTORS					
Residential fuel combustion	**<**	**<**	**<**	**<**	**$390 K ($130 K – $770 K)**
Home firewood burning	**<**	**<**	**<**	**<**	**$1.4 M ($0.50 M – $2.8 M)**
TOTAL OF MODELLED SECTORS[f]	**3**	**<**	**1**	**8 (4 - 12)**	**$61 M ($21 M - $120 M)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.

[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

A.2.4 Manitoba air zone

Table A-29. MB Manitoba air zone – all-cause premature mortality and valuation by sector and pollutant (2015).

Air Zone **MB – MANITOBA (pop. 1.3 M)**	**MORTALITY BY POLLUTANT**[a, b, c, i]			**ALL-POLLUTANT MORTALITY**[e, i] median (2.5% - 97.5% CI)	**TOTAL VALUATION**[f] **(mortality and morbidity)** median (2.5% - 97.5% CI)
	$PM_{2.5}$	**NO_2**	**O_3**[d]		
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On – road	**24**	**14**	**1**	**38 (15 - 61)**	**$290 M ($65 M – $620 M)**
On – road LDV	7	4	<	10 (4 - 17)	$81 M ($13 M – $180 M)
On – road HDV	16	9	<	25 (10 - 40)	$190 M ($40 M – $410 M)
Off-road vehicles & mobile equipment	**10**	**2**	**5**	**17 (9 - 26)**	**$130 M ($45 M – $260 M)**
Air + Marine + Rail	**6**	**2**	**1**	**10 (4 - 15)**	**$74 M ($21 M – $150 M)**
Air	1	<	<	1 (< - 1)	$6.9 M ($1.7 M – $14 M)
Marine	<	<	<	< (< - 1)	$3.2 M ($1.1 M – $6.3 M)
Rail	5	2	1	8 (4 - 13)	$63 M ($18 M – $130 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**17**	**<**	**<**	**18 (9 - 26)**	**$140 M ($48 M – $280 M)**
Cement manufacture	<	<	<	<	$0.84 M ($0.30 M – $1.6 M)
Non – ferrous refining and smelting	4	<	<	4 (2 - 6)	$31 M ($10 M – $61 M)
Oil and gas industry[g]	**9**	**<**	**4**	**13 (7 - 19)**	**$100 M ($34 M – $200 M)**
Upstream oil and gas	9	<	4	13 (7 - 19)	$99 M ($34 M – $190 M)
Downstream oil and gas	<	<	<	<	$2.0 M ($0.67 M – $4.0 M)
Electric power generation	**9**	**<**	**1**	**10 (5 - 15)**	**$81 M ($27 M – $160 M)**
Coal – fired electric power generation	9	<	<	10 (5 - 15)	$79 M ($26 M – $160 M)
Manufacturing	**5**	**<**	**<**	**6 (3 - 9)**	**$48 M ($16 M – $97 M)**
Chemicals industry	2	<	<	3 (1 - 4)	$24 M ($7.4 M – $48 M)
Pulp and paper industry	<	<	<	<	$2.5 M ($0.85 M – $4.8 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**3**	**1**	**<**	**4 (2 - 7)**	**$32 M ($6.3 M – $70 M)**
Home firewood burning	**17**	**<**	**<**	**17 (9 - 25)**	**$130 M ($45 M – $260 M)**
TOTAL OF MODELLED SECTORS[h]	**100**	**19**	**12**	**130 (63 - 200)**	**$1.0 B ($0.31 B - $2.1 B)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.

[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

A.2.5 Ontario air zones

Table A-30. ON Southern Ontario air zone – all-cause premature mortality and valuation by sector and pollutant (2015).

Air Zone ON – SOUTHERN ONTARIO (pop. 12 M)	MORTALITY BY POLLUTANT[a, b, c, i] $PM_{2.5}$	NO_2	O_3 [d]	ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On – road	**330**	**130**	**10**	**470 (190 - 740)**	**$3.7 B ($0.75 B – $7.8 B)**
On – road LDV	150	42	-1	190 (79 - 300)	$1.5 B ($0.33 B – $3.2 B)
On – road HDV	180	78	-4	250 (91 - 410)	$2.0 B ($0.28 B – $4.3 B)
Off-road vehicles & mobile equipment	**280**	**56**	**37**	**370 (180 - 560)**	**$2.9 B ($0.90 B – $5.8 B)**
Air + Marine + Rail	**58**	**25**	**4**	**88 (33 - 140)**	**$0.69 B ($0.12 B – $1.5 B)**
Air	10	9	-6	14 (0 - 28)	$110 M ($-40 M – $300 M)
Marine	18	3	6	27 (13 - 40)	$210 M ($68 M – $410 M)
Rail	30	13	4	47 (20 - 74)	$360 M ($91 M – $760 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**390**	**9**	**6**	**400 (210 - 600)**	**$3.3 B ($1.1 B – $6.7 B)**
Cement manufacture	54	4	1	59 (27 - 92)	$0.48 B ($0.12 B – $1.0 B)
Non – ferrous refining and smelting	100	<	<	100 (55 - 150)	$0.88 B ($0.29 B – $1.7 B)
Oil and gas industry[g]	**53**	**3**	**11**	**66 (34 - 98)**	**$0.53 B ($0.17 B – $1.1 B)**
Upstream oil and gas	15	1	9	24 (13 - 36)	$190 M ($65 M – $370 M)
Downstream oil and gas	38	2	2	42 (21 - 62)	$340 M ($110 M – $680 M)
Electric power generation	**22**	**5**	**<**	**27 (12 - 42)**	**$210 M ($51 M – $430 M)**
Coal – fired electric power generation	14	<	<	15 (8 - 22)	$120 M ($39 M – $230 M)
Manufacturing	**82**	**6**	**16**	**100 (54 - 160)**	**$0.84 B ($0.27 B – $1.7 B)**
Chemicals industry	27	2	2	30 (15 - 45)	$250 M ($79 M – $510 M)
Pulp and paper industry	14	1	2	18 (9 - 26)	$140 M ($46 M – $280 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**99**	**31**	**-11**	**120 (49 - 190)**	**$0.94 B ($0.18 B – $2.0 B)**
Home firewood burning	**510**	**1**	**2**	**510 (270 - 760)**	**$4.1 B ($1.4 B – $8.0 B)**
TOTAL OF MODELLED SECTORS[h]	**1800**	**260**	**75**	**2200 (1000 - 3300)**	**$17 B ($4.9 B - $35 B)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).
[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.
[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.
[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).
[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.
[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.
[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).
[h] Estimate from sum of all sector model runs (not modelled separately).
[i] < denotes mortality count less than 1.

Table A-31. ON Hamilton air zone – all-cause premature mortality and valuation by sector and pollutant (2015).

Air Zone ON – HAMILTON (pop. 0.5 M)	MORTALITY BY POLLUTANT[a, b, c, i]			ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
	$PM_{2.5}$	NO_2	O_3[d]		
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On – road	**18**	**7**	**2**	**27 (13 - 42)**	**$210 M ($68 M – $420 M)**
On – road LDV	7	2	1	10 (5 - 15)	$78 M ($24 M – $160 M)
On – road HDV	11	5	1	16 (7 - 25)	$120 M ($38 M – $250 M)
Off-road vehicles & mobile equipment	**11**	**2**	**2**	**16 (8 - 24)**	**$120 M ($41 M – $240 M)**
Air + Marine + Rail	**3**	**1**	**<**	**5 (2 - 8)**	**$41 M ($12 M – $83 M)**
Air	<	<	<	1 (< - 1)	$4.3 M ($0.38 M – $9.7 M)
Marine	1	<	<	2 (1 - 3)	$13 M ($4.3 M – $26 M)
Rail	2	1	<	3 (1 - 5)	$24 M ($7.4 M – $47 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**55**	**2**	**-1**	**56 (27 - 84)**	**$450 M ($130 M – $910 M)**
Cement manufacture	3	<	<	4 (2 - 5)	$28 M ($9.4 M – $55 M)
Non – ferrous refining and smelting	5	<	<	5 (3 - 7)	$39 M ($13 M – $77 M)
Oil and gas industry[g]	**4**	**<**	**<**	**5 (3 - 7)**	**$40 M ($13 M – $78 M)**
Upstream oil and gas	1	<	<	2 (1 - 3)	$14 M ($4.7 M – $27 M)
Downstream oil and gas	3	<	<	3 (2 - 5)	$26 M ($8.5 M – $51 M)
Electric power generation	**1**	**<**	**<**	**2 (1 - 2)**	**$13 M ($4.1 M – $25 M)**
Coal – fired electric power generation	1	<	<	1 (< - 1)	$6.6 M ($2.2 M – $13 M)
Manufacturing	**6**	**<**	**<**	**7 (3 - 10)**	**$57 M ($17 M – $110 M)**
Chemicals industry	3	<	<	3 (1 - 5)	$29 M ($5.3 M – $61 M)
Pulp and paper industry	<	<	<	1 (< - 1)	$4.5 M ($1.5 M – $8.9 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**5**	**2**	**<**	**6 (3 - 10)**	**$47 M ($12 M – $99 M)**
Home firewood burning	**35**	**<**	**<**	**36 (19 - 53)**	**$280 M ($96 M – $550 M)**
TOTAL OF MODELLED SECTORS[h]	**140**	**14**	**3**	**160 (78 - 240)**	**$1.3 B ($0.40 B - $2.5 B)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.

[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

Table A-32. ON Northern Ontario air zone – all-cause premature mortality and valuation by sector and pollutant (2015).

Air Zone ON – NORTHERN ONTARIO (pop. 0.6 M)	MORTALITY BY POLLUTANT[a, b, c, i]			ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
	$PM_{2.5}$	NO_2	O_3[d]		
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On – road	**1**	**<**	**2**	**4 (2 - 6)**	**$28 M ($9.7 M – $55 M)**
On – road LDV	1	<	<	1 (1 - 2)	$9.5 M ($3.3 M – $18 M)
On – road HDV	1	<	2	2 (1 - 4)	$18 M ($6.1 M – $35 M)
Off-road vehicles & mobile equipment	**1**	**<**	**2**	**3 (1 - 4)**	**$19 M ($6.7 M – $37 M)**
Air + Marine + Rail	**<**	**<**	**1**	**2 (1 - 3)**	**$16 M ($5.2 M – $31 M)**
Air	<	<	<	<	$110 K ($39 K – $220 K)
Marine	<	<	<	1 (< - 1)	$3.8 M ($1.3 M – $7.5 M)
Rail	<	<	1	2 (1 - 2)	$12 M ($3.9 M – $23 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**7**	**<**	**<**	**8 (4 - 12)**	**$66 M ($22 M – $130 M)**
Cement manufacture	<	<	<	< (< - 1)	$2.9 M ($0.98 M – $5.6 M)
Non – ferrous refining and smelting	6	<	<	6 (3 - 9)	$51 M ($17 M – $100 M)
Oil and gas industry[g]	**1**	**<**	**1**	**2 (1 - 3)**	**$17 M ($5.9 M – $33 M)**
Upstream oil and gas	1	<	1	2 (1 - 3)	$13 M ($4.6 M – $26 M)
Downstream oil and gas	<	<	<	< (< - 1)	$3.8 M ($1.3 M – $7.3 M)
Electric power generation	**1**	**<**	**<**	**2 (1 - 3)**	**$14 M ($4.7 M – $26 M)**
Coal – fired electric power generation	1	<	<	1 (1 - 2)	$10 M ($3.6 M – $20 M)
Manufacturing	**1**	**<**	**<**	**2 (1 - 3)**	**$15 M ($5.3 M – $30 M)**
Chemicals industry	<	<	<	<	$2.2 M ($0.76 M – $4.3 M)
Pulp and paper industry	1	<	<	1 (1 - 2)	$8.6 M ($3.0 M – $17 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**<**	**<**	**<**	**<**	**$1.9 M ($0.65 M – $3.9 M)**
Home firewood burning	**4**	**<**	**<**	**4 (2 - 6)**	**$30 M ($10 M – $58 M)**
TOTAL OF MODELLED SECTORS[h]	**16**	**<**	**6**	**26 (14 - 39)**	**$210 M ($70 M - $410 M)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.

[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

Table A-33. ON Sudbury air zone – all-cause premature mortality and valuation by sector and pollutant (2015).

Air Zone ON – SUDBURY (pop. 0.2 M)	MORTALITY BY POLLUTANT[a, b, c, i] $PM_{2.5}$	 NO_2	 O_3[d]	ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On – road	**2**	**<**	**<**	**3 (2 - 5)**	**$24 M ($7.9 M – $47 M)**
On – road LDV	1	<	<	1 (1 - 2)	$8.3 M ($2.8 M – $16 M)
On – road HDV	1	<	<	2 (1 - 3)	$14 M ($4.6 M – $28 M)
Off-road vehicles & mobile equipment	**1**	**<**	**<**	**1 (1 - 2)**	**$11 M ($3.6 M – $21 M)**
Air + Marine + Rail	**<**	**<**	**<**	**1 (1 - 2)**	**$9.2 M ($3.0 M – $18 M)**
Air	<	<	<	<	$1.1 M ($0.38 M – $2.1 M)
Marine	<	<	<	<	$1.9 M ($0.63 M – $3.6 M)
Rail	<	<	<	1 (< - 1)	$6.3 M ($2.0 M – $12 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**8**	**<**	**<**	**8 (4 - 12)**	**$80 M ($23 M – $160 M)**
Cement manufacture	<	<	<	<	$1.3 M ($0.43 M – $2.5 M)
Non – ferrous refining and smelting	6	<	<	7 (4 - 10)	$67 M ($19 M – $140 M)
Oil and gas industry[g]	**<**	**<**	**<**	**1 (< - 1)**	**$5.7 M ($1.9 M – $11 M)**
Upstream oil and gas	<	<	<	< (< - 1)	$3.4 M ($1.2 M – $6.6 M)
Downstream oil and gas	<	<	<	<	$2.3 M ($0.78 M – $4.5 M)
Electric power generation	**<**	**<**	**<**	**< (< - 1)**	**$2.7 M ($0.94 M – $5.2 M)**
Coal – fired electric power generation	<	<	<	<	$2.2 M ($0.77 M – $4.4 M)
Manufacturing	**1**	**<**	**<**	**1 (< - 1)**	**$7.1 M ($2.4 M – $14 M)**
Chemicals industry	<	<	<	<	$1.3 M ($0.43 M – $2.5 M)
Pulp and paper industry	<	<	<	1 (< - 1)	$5.4 M ($1.9 M – $11 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**<**	**<**	**<**	**< (< - 1)**	**$2.8 M ($0.81 M – $5.8 M)**
Home firewood burning	**3**	**<**	**<**	**3 (1 - 4)**	**$20 M ($6.8 M – $39 M)**
TOTAL OF MODELLED SECTORS[h]	**15**	**<**	**<**	**19 (10 - 28)**	**$160 M ($51 M - $320 M)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.

[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

A.2.6 Quebec air zones

Table A-34. QC South air zone – all-cause premature mortality and valuation by sector and pollutant (2015).

Air Zone QC – SOUTH (pop. 7.6 M)	MORTALITY BY POLLUTANT[a, b, c, i] $PM_{2.5}$	NO_2	O_3[d]	ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On – road	**260**	**120**	**25**	**400 (170 - 630)**	**$3.1 B ($0.74 B – $6.5 B)**
On – road LDV	77	30	4	110 (47 - 180)	$0.87 B ($0.21 B – $1.8 B)
On – road HDV	181	79	8	270 (110 - 430)	$2.1 B ($0.46 B – $4.4 B)
Off-road vehicles & mobile equipment	**150**	**26**	**30**	**200 (100 - 310)**	**$1.6 B ($0.52 B – $3.2 B)**
Air + Marine + Rail	**54**	**29**	**17**	**100 (44 - 160)**	**$0.78 B ($0.22 B – $1.6 B)**
Air	5	4	-1	8 (2 - 14)	$65 M ($4.9 M – $150 M)
Marine	28	15	11	55 (24 - 84)	$420 M ($130 M – $840 M)
Rail	21	10	7	38 (17 - 60)	$300 M ($85 M – $600 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**330**	**8**	**10**	**350 (180 - 520)**	**$2.9 B ($0.95 B – $5.7 B)**
Cement manufacture	43	4	3	50 (24 - 76)	$420 M ($120 M – $840 M)
Non – ferrous refining and smelting	66	<	<	67 (35 - 99)	$0.55 B ($0.18 B – $1.1 B)
Oil and gas industry[g]	**27**	**4**	**3**	**35 (15 - 54)**	**$290 M ($63 M – $610 M)**
Upstream oil and gas	5	<	5	11 (6 - 16)	$82 M ($28 M – $160 M)
Downstream oil and gas	22	4	-2	24 (10 - 39)	$210 M ($35 M – $450 M)
Electric power generation	**11**	**<**	**4**	**15 (8 - 22)**	**$120 M ($39 M – $230 M)**
Coal – fired electric power generation	7	<	<	8 (4 - 12)	$63 M ($21 M – $120 M)
Manufacturing	**58**	**7**	**9**	**74 (37 - 110)**	**$0.60 B ($0.19 B – $1.2 B)**
Chemicals industry	12	1	1	14 (7 - 21)	$120 M ($35 M – $240 M)
Pulp and paper industry	17	2	6	24 (12 - 36)	$190 M ($64 M – $380 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**20**	**6**	**-1**	**26 (11 - 41)**	**$200 M ($49 M – $420 M)**
Home firewood burning	**1400**	**3**	**2**	**1400 (730 - 2000)**	**$11 B ($3.7 B – $21 B)**
TOTAL OF MODELLED SECTORS[h]	**2300**	**200**	**99**	**2600 (1300 - 3900)**	**$20 B ($6.5 B - $40 B)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.

[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

Table A-35. QC East air zone – all-cause premature mortality and valuation by sector and pollutant (2015).

Air Zone QC – EAST (pop. 0.2 M)	MORTALITY BY POLLUTANT[a, b, c, i]			ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
	$PM_{2.5}$	NO_2	O_3[d]		
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On – road	**1**	**<**	**2**	**3 (1 - 4)**	**$20 M ($6.8 M – $39 M)**
On – road LDV	<	<	<	1 (< - 1)	$5.5 M ($1.9 M – $11 M)
On – road HDV	1	<	2	2 (1 - 3)	$14 M ($4.9 M – $28 M)
Off-road vehicles & mobile equipment	**1**	**<**	**<**	**1 (1 - 2)**	**$10 M ($3.6 M – $20 M)**
Air + Marine + Rail	**1**	**<**	**2**	**3 (2 - 5)**	**$23 M ($7.7 M – $46 M)**
Air	<	<	<	<	$230 K ($75 K – $450 K)
Marine	1	<	2	2 (1 - 4)	$18 M ($6.0 M – $36 M)
Rail	<	<	<	1 (< - 1)	$4.8 M ($1.6 M – $9.5 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**4**	**<**	**<**	**4 (2 - 6)**	**$35 M ($12 M – $68 M)**
Cement manufacture	<	<	<	<	$2.0 M ($0.69 M – $3.9 M)
Non – ferrous refining and smelting	2	<	<	2 (1 - 2)	$13 M ($4.6 M – $26 M)
Oil and gas industry[g]	**<**	**<**	**<**	**1 (< - 1)**	**$6.0 M ($2.1 M – $12 M)**
Upstream oil and gas	<	<	<	< (< - 1)	$3.0 M ($1.0 M – $5.8 M)
Downstream oil and gas	<	<	<	< (< - 1)	$3.0 M ($1.0 M – $5.8 M)
Electric power generation	**1**	**<**	**<**	**1 (< - 1)**	**$7.6 M ($2.5 M – $15 M)**
Coal – fired electric power generation	1	<	<	1 (< - 1)	$6.4 M ($2.1 M – $13 M)
Manufacturing	**1**	**<**	**<**	**1 (1 - 2)**	**$9.0 M ($3.0 M – $18 M)**
Chemicals industry	<	<	<	<	$0.83 M ($0.29 M – $1.6 M)
Pulp and paper industry	<	<	<	1 (< - 1)	$5.5 M ($1.9 M – $11 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**<**	**<**	**<**	**<**	**$0.59 M ($0.20 M – $1.2 M)**
Home firewood burning	**6**	**<**	**<**	**6 (3 - 9)**	**$46 M ($16 M – $90 M)**
TOTAL OF MODELLED SECTORS[h]	**15**	**<**	**4**	**20 (11 - 30)**	**$160 M ($54 M - $310 M)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.

[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

Table A-36. QC North air zone – all-cause premature mortality and valuation by sector and pollutant (2015).

Air Zone QC – NORTH (pop. 0.4 M)	MORTALITY BY POLLUTANT[a, b, c, i]			ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
	$PM_{2.5}$	NO_2	O_3[d]		
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On – road	**<**	**<**	**1**	**1 (1 - 2)**	**$11 M ($3.6 M – $21 M)**
On – road LDV	<	<	<	<	$2.4 M ($0.81 M – $4.7 M)
On – road HDV	<	<	<	1 (< - 1)	$7.3 M ($2.5 M – $14 M)
Off-road vehicles & mobile equipment	**<**	**<**	**<**	**1 (< - 1)**	**$6.6 M ($2.3 M – $13 M)**
Air + Marine + Rail	**<**	**<**	**<**	**1 (1 - 2)**	**$7.7 M ($2.6 M – $15 M)**
Air	<	<	<	<	$58 K ($15 K – $120 K)
Marine	<	<	<	1 (< - 1)	$4.7 M ($1.6 M – $9.2 M)
Rail	<	<	<	< (< - 1)	$3.0 M ($1.0 M – $5.8 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**4**	**<**	**<**	**5 (2 - 7)**	**$39 M ($13 M – $77 M)**
Cement manufacture	<	<	<	<	$0.71 M ($0.24 M – $1.4 M)
Non – ferrous refining and smelting	2	<	<	2 (1 - 2)	$14 M ($4.6 M – $27 M)
Oil and gas industry[g]	**<**	**<**	**<**	**< (< - 1)**	**$3.2 M ($1.1 M – $6.3 M)**
Upstream oil and gas	<	<	<	<	$2.5 M ($0.87 M – $4.9 M)
Downstream oil and gas	<	<	<	<	$0.72 M ($0.24 M – $1.4 M)
Electric power generation	**<**	**<**	**<**	**< (< - 1)**	**$2.7 M ($0.91 M – $5.2 M)**
Coal – fired electric power generation	<	<	<	<	$1.4 M ($0.47 M – $2.8 M)
Manufacturing	**<**	**<**	**<**	**1 (< - 1)**	**$5.9 M ($2.0 M – $12 M)**
Chemicals industry	<	<	<	<	$260 K ($84 K – $520 K)
Pulp and paper industry	<	<	<	<	$2.2 M ($0.74 M – $4.2 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**<**	**<**	**<**	**<**	**$430 K ($150 K – $850 K)**
Home firewood burning	**3**	**<**	**<**	**3 (1 - 4)**	**$21 M ($7.1 M – $41 M)**
TOTAL OF MODELLED SECTORS[h]	**7**	**<**	**1**	**12 (6 - 18)**	**$97 M ($33 M - $190 M)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.

[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

A.2.7 New Brunswick air zones

Table A-37. NB Central Region air zone – all-cause premature mortality and valuation by sector and pollutant (2015).

Air Zone NB – CENTRAL REGION (pop. 0.5 M)	MORTALITY BY POLLUTANT[a, b, c, i] $PM_{2.5}$	NO_2	O_3[d]	ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On – road	**1**	**<**	**2**	**4 (2 - 6)**	**$33 M ($11 M – $64 M)**
On – road LDV	<	<	<	1 (1 - 2)	$9.7 M ($3.3 M – $19 M)
On – road HDV	1	<	2	3 (2 - 4)	$23 M ($7.6 M – $45 M)
Off-road vehicles & mobile equipment	**1**	**<**	**2**	**2 (1 - 3)**	**$13 M ($4.6 M – $26 M)**
Air + Marine + Rail	**<**	**<**	**2**	**3 (2 - 5)**	**$24 M ($8.1 M – $48 M)**
Air	<	<	<	<	$290 K ($98 K – $570 K)
Marine	<	<	2	2 (1 - 3)	$16 M ($5.3 M – $30 M)
Rail	<	<	<	1 (1 - 2)	$8.4 M ($2.7 M – $17 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**6**	**<**	**<**	**6 (3 - 9)**	**$50 M ($17 M – $99 M)**
Cement manufacture	<	<	<	1 (< - 1)	$4.1 M ($1.4 M – $7.9 M)
Non – ferrous refining and smelting	3	<	<	3 (1 - 4)	$21 M ($7.2 M – $41 M)
Oil and gas industry[g]	**1**	**<**	**<**	**2 (1 - 2)**	**$13 M ($4.3 M – $25 M)**
Upstream oil and gas	<	<	<	1 (< - 1)	$4.5 M ($1.6 M – $8.7 M)
Downstream oil and gas	1	<	<	1 (1 - 2)	$8.2 M ($2.7 M – $16 M)
Electric power generation	**1**	**<**	**<**	**2 (1 - 3)**	**$15 M ($5.1 M – $29 M)**
Coal – fired electric power generation	1	<	<	2 (1 - 2)	$12 M ($4.1 M – $24 M)
Manufacturing	**2**	**<**	**<**	**2 (1 - 3)**	**$18 M ($6.0 M – $35 M)**
Chemicals industry	<	<	<	<	$1.7 M ($0.58 M – $3.3 M)
Pulp and paper industry	1	<	<	1 (1 - 2)	$11 M ($3.8 M – $22 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**<**	**<**	**<**	**<**	**$1.9 M ($0.64 M – $3.8 M)**
Home firewood burning	**9**	**<**	**<**	**9 (5 - 14)**	**$72 M ($25 M – $140 M)**
TOTAL OF MODELLED SECTORS[h]	**21**	**<**	**6**	**31 (16 - 46)**	**$240 M ($82 M - $470 M)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).
[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.
[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.
[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).
[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.
[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.
[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).
[h] Estimate from sum of all sector model runs (not modelled separately).
[i] < denotes mortality count less than 1.

Table A-38. NB South Region air zone – all-cause premature mortality and valuation by sector and pollutant (2015).

Air Zone NB – SOUTH REGION (pop. 0.2 M)	MORTALITY BY POLLUTANT[a, b, c, i] PM$_{2.5}$	NO$_2$	O$_3$[d]	ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On – road	**<**	**<**	**<**	**1 (1 - 2)**	**$10 M ($3.4 M – $20 M)**
On – road LDV	<	<	<	< (< - 1)	$3.0 M ($1.0 M – $5.9 M)
On – road HDV	<	<	<	1 (< - 1)	$6.9 M ($2.3 M – $14 M)
Off-road vehicles & mobile equipment	**<**	**<**	**<**	**1 (< - 1)**	**$3.9 M ($1.4 M – $7.7 M)**
Air + Marine + Rail	**<**	**<**	**<**	**1 (1 - 2)**	**$11 M ($3.5 M – $22 M)**
Air	<	<	<	<	$120 K ($44 K – $230 K)
Marine	<	<	<	1 (1 - 2)	$8.7 M ($2.8 M – $17 M)
Rail	<	<	<	<	$2.1 M ($0.68 M – $4.1 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**5**	**<**	**<**	**5 (3 - 8)**	**$41 M ($14 M – $80 M)**
Cement manufacture	<	<	<	<	$0.91 M ($0.32 M – $1.8 M)
Non – ferrous refining and smelting	1	<	<	1 (< - 1)	$6.1 M ($2.1 M – $12 M)
Oil and gas industry[g]	**1**	**<**	**<**	**1 (1 - 2)**	**$9.7 M ($2.1 M – $20 M)**
Upstream oil and gas	<	<	<	<	$0.98 M ($0.35 M – $1.9 M)
Downstream oil and gas	1	<	<	1 (< - 2)	$8.7 M ($1.8 M – $18 M)
Electric power generation	**1**	**<**	**<**	**1 (< - 1)**	**$5.5 M ($1.9 M – $11 M)**
Coal – fired electric power generation	<	<	<	1 (< - 1)	$4.0 M ($1.3 M – $7.8 M)
Manufacturing	**1**	**<**	**<**	**1 (< - 1)**	**$7.2 M ($2.3 M – $14 M)**
Chemicals industry	<	<	<	<	$120 K ($44 K – $230 K)
Pulp and paper industry	<	<	<	1 (< - 1)	$5.0 M ($1.6 M – $9.9 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**<**	**<**	**<**	**<**	**$260 K ($84 K – $520 K)**
Home firewood burning	**3**	**<**	**<**	**3 (2 - 4)**	**$23 M ($7.8 M – $44 M)**
TOTAL OF MODELLED SECTORS[h]	**11**	**<**	**<**	**14 (7 - 21)**	**$110 M ($37 M - $220 M)**

[a] Chronic exposure mortality (PM$_{2.5}$), acute exposure mortality (NO$_2$, O$_3$), and chronic exposure respiratory mortality (summer O$_3$).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O$_3$ health impacts may occur in areas with high NO$_x$ emissions.

[d] Sum of annual O$_3$ (acute exposure mortality) and summer O$_3$ (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO$_2$, O$_3$), chronic exposure mortality (PM$_{2.5}$), and chronic exposure respiratory mortality (summer O$_3$). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

Table A-39. NB North Region air zone – all-cause premature mortality and valuation by sector and pollutant (2015).

Air Zone NB – NORTH REGION (pop. 0.1 M)	MORTALITY BY POLLUTANT[a, b, c, i] $PM_{2.5}$	 NO_2	 O_3[d]	ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On – road	**<**	**<**	**<**	**1 (0 - 1)**	**$6.4 M ($2.2 M – $13 M)**
On – road LDV	<	<	<	<	$1.5 M ($0.50 M – $2.9 M)
On – road HDV	<	<	<	1 (< - 1)	$4.4 M ($1.5 M – $8.6 M)
Off-road vehicles & mobile equipment	**<**	**<**	**<**	**< (< - 1)**	**$3.0 M ($1.0 M – $5.8 M)**
Air + Marine + Rail	**<**	**<**	**<**	**1 (< - 1)**	**$5.7 M ($1.9 M – $11 M)**
Air	<	<	<	<	$270 K ($99 K – $530 K)
Marine	<	<	<	1 (< - 1)	$3.8 M ($1.3 M – $7.3 M)
Rail	<	<	<	<	$1.6 M ($0.55 M – $3.2 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**1**	**<**	**<**	**2 (1 - 2)**	**$13 M ($4.3 M – $26 M)**
Cement manufacture	<	<	<	<	$440 K ($150 K – $860 K)
Non – ferrous refining and smelting	1	<	<	1 (< - 1)	$6.1 M ($2.0 M – $12 M)
Oil and gas industry[g]	**<**	**<**	**<**	**<**	**$2.2 M ($0.76 M – $4.2 M)**
Upstream oil and gas	<	<	<	<	$1.1 M ($0.37 M – $2.0 M)
Downstream oil and gas	<	<	<	<	$1.1 M ($0.39 M – $2.2 M)
Electric power generation	**<**	**<**	**<**	**1 (< - 1)**	**$4.6 M ($1.5 M – $9.1 M)**
Coal – fired electric power generation	<	<	<	1 (< - 1)	$4.2 M ($1.4 M – $8.4 M)
Manufacturing	**<**	**<**	**<**	**< (< - 1)**	**$3.2 M ($1.1 M – $6.2 M)**
Chemicals industry	<	<	<	<	$290 K ($100 K – $550 K)
Pulp and paper industry	<	<	<	<	$1.8 M ($0.61 M – $3.5 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**<**	**<**	**<**	**<**	**$390 K ($140 K – $760 K)**
Home firewood burning	**2**	**<**	**<**	**2 (1 - 3)**	**$16 M ($5.6 M – $32 M)**
TOTAL OF MODELLED SECTORS[h]	**5**	**<**	**2**	**7 (4 - 10)**	**$55 M ($19 M - $110 M)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.

[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

A.2.8 Nova Scotia air zones

Table A-40. NS Central air zone – all-cause premature mortality and valuation by sector and pollutant (2015).

Air Zone NS – CENTRAL (pop. 0.5 M)	MORTALITY BY POLLUTANT[a, b, c, i]			ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
	$PM_{2.5}$	NO_2	O_3[d]		
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On – road	**1**	**<**	**2**	**3 (2 - 5)**	**$24 M ($7.9 M – $47 M)**
On – road LDV	<	<	<	1 (< - 1)	$6.8 M ($2.3 M – $13 M)
On – road HDV	1	<	2	2 (1 - 3)	$16 M ($5.4 M – $32 M)
Off-road vehicles & mobile equipment	**<**	**<**	**<**	**1 (1 - 2)**	**$8.5 M ($2.9 M – $17 M)**
Air + Marine + Rail	**<**	**<**	**4**	**4 (2 - 7)**	**$33 M ($11 M – $65 M)**
Air	<	<	<	<	$0.52 M ($0.16 M – $1.0 M)
Marine	<	<	4	4 (2 - 6)	$30 M ($9.8 M – $58 M)
Rail	<	<	<	< (< - 1)	$3.0 M ($1.0 M – $5.9 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**3**	**<**	**<**	**3 (2 - 4)**	**$24 M ($8.2 M – $47 M)**
Cement manufacture	<	<	<	<	$1.1 M ($0.36 M – $2.3 M)
Non – ferrous refining and smelting	1	<	<	1 (1 - 2)	$9.7 M ($3.3 M – $19 M)
Oil and gas industry[g]	**<**	**<**	**<**	**1 (< - 1)**	**$5.5 M ($1.9 M – $11 M)**
Upstream oil and gas	<	<	<	<	$2.3 M ($0.81 M – $4.4 M)
Downstream oil and gas	<	<	<	< (< - 1)	$3.2 M ($1.1 M – $6.3 M)
Electric power generation	**3**	**<**	**1**	**4 (2 - 6)**	**$31 M ($10 M – $60 M)**
Coal – fired electric power generation	2	<	<	3 (1 - 4)	$22 M ($7.2 M – $44 M)
Manufacturing	**1**	**<**	**<**	**1 (< - 1)**	**$6.6 M ($2.2 M – $13 M)**
Chemicals industry	<	<	<	<	$370 K ($120 K – $730 K)
Pulp and paper industry	<	<	<	< (< - 1)	$3.5 M ($1.2 M – $6.8 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**<**	**<**	**<**	**<**	**$0.95 M ($0.28 M – $2.0 M)**
Home firewood burning	**6**	**<**	**<**	**6 (3 - 9)**	**$50 M ($17 M – $98 M)**
TOTAL OF MODELLED SECTORS[h]	**14**	**<**	**7**	**23 (12 - 35)**	**$180 M ($61 M - $360 M)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.

[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

Table A-41. NS Northern air zone – all-cause premature mortality and valuation by sector and pollutant (2015).

Air Zone NS – NORTHERN (pop. 0.2 M)	MORTALITY BY POLLUTANT[a, b, c, i]			ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
	$PM_{2.5}$	NO_2	O_3[d]		
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On – road	**<**	**<**	**2**	**2 (1 - 2)**	**$11 M ($3.9 M – $23 M)**
On – road LDV	<	<	<	< (< - 1)	$3.5 M ($1.2 M – $6.9 M)
On – road HDV	<	<	<	1 (1 - 2)	$8.5 M ($2.8 M – $17 M)
Off-road vehicles & mobile equipment	**<**	**<**	**<**	**1 (< - 1)**	**$4.6 M ($1.6 M – $8.9 M)**
Air + Marine + Rail	**<**	**<**	**2**	**2 (1 - 3)**	**$13 M ($4.2 M – $25 M)**
Air	<	<	<	<	$110 K ($33 K – $220 K)
Marine	<	<	2	1 (1 - 2)	$10 M ($3.3 M – $20 M)
Rail	<	<	<	< (< - 1)	$2.9 M ($0.94 M – $5.7 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**2**	**<**	**<**	**2 (1 - 3)**	**$14 M ($5.0 M – $28 M)**
Cement manufacture	<	<	<	<	$1.7 M ($0.59 M – $3.4 M)
Non – ferrous refining and smelting	1	<	<	1 (< - 1)	$6.2 M ($2.2 M – $12 M)
Oil and gas industry[g]	**<**	**<**	**<**	**1 (< - 1)**	**$3.9 M ($1.3 M – $7.5 M)**
Upstream oil and gas	<	<	<	<	$1.9 M ($0.66 M – $3.7 M)
Downstream oil and gas	<	<	<	<	$1.9 M ($0.67 M – $3.8 M)
Electric power generation	**2**	**<**	**<**	**3 (1 - 4)**	**$22 M ($7.0 M – $44 M)**
Coal – fired electric power generation	2	<	<	2 (1 - 3)	$19 M ($6.1 M – $39 M)
Manufacturing	**1**	**<**	**<**	**1 (1 - 2)**	**$9.2 M ($3.1 M – $18 M)**
Chemicals industry	<	<	<	<	$350 K ($120 K – $670 K)
Pulp and paper industry	1	<	<	1 (< - 1)	$7.3 M ($2.5 M – $14 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**<**	**<**	**<**	**<**	**$0.93 M ($0.32 M – $1.8 M)**
Home firewood burning	**3**	**<**	**<**	**3 (2 - 5)**	**$24 M ($8.3 M – $47 M)**
TOTAL OF MODELLED SECTORS[h]	**8**	**<**	**4**	**13 (7 - 20)**	**$100 M ($35 M - $200 M)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.

[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

Table A-42. NS Western air zone – all-cause premature mortality and valuation by sector and pollutant (2015).

Air Zone NS – WESTERN (pop. 0.2 M)	MORTALITY BY POLLUTANT[a, b, c, i] $PM_{2.5}$	 NO_2	 O_3[d]	ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On – road	**<**	**<**	**2**	**1 (1 - 2)**	**$11 M ($3.7 M – $22 M)**
On – road LDV	<	<	<	< (< - 1)	$3.1 M ($1.0 M – $6.1 M)
On – road HDV	<	<	<	1 (1 - 2)	$7.9 M ($2.6 M – $15 M)
Off-road vehicles & mobile equipment	**<**	**<**	**<**	**1 (< - 1)**	**$4.5 M ($1.6 M – $8.8 M)**
Air + Marine + Rail	**<**	**<**	**2**	**2 (1 - 3)**	**$14 M ($4.6 M – $27 M)**
Air	<	<	<	<	$77 K ($25 K – $160 K)
Marine	<	<	2	2 (1 - 2)	$12 M ($4.0 M – $24 M)
Rail	<	<	<	<	$1.6 M ($0.54 M – $3.1 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**2**	**<**	**<**	**2 (1 - 3)**	**$16 M ($5.7 M – $32 M)**
Cement manufacture	<	<	<	<	$1.4 M ($0.48 M – $2.7 M)
Non – ferrous refining and smelting	1	<	<	1 (< - 1)	$6.9 M ($2.4 M – $13 M)
Oil and gas industry[g]	**<**	**<**	**<**	**1 (< - 1)**	**$4.6 M ($1.6 M – $9.0 M)**
Upstream oil and gas	<	<	<	<	$1.7 M ($0.59 M – $3.3 M)
Downstream oil and gas	<	<	<	< (< - 1)	$3.0 M ($1.0 M – $5.8 M)
Electric power generation	**1**	**<**	**<**	**1 (1 - 2)**	**$9.7 M ($3.3 M – $19 M)**
Coal – fired electric power generation	1	<	<	1 (< - 1)	$7.3 M ($2.5 M – $14 M)
Manufacturing	**<**	**<**	**<**	**1 (< - 1)**	**$4.1 M ($1.4 M – $8.1 M)**
Chemicals industry	<	<	<	<	$420 K ($150 K – $820 K)
Pulp and paper industry	<	<	<	<	$2.1 M ($0.71 M – $4.0 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**<**	**<**	**<**	**<**	**$310 K ($94 K – $630 K)**
Home firewood burning	**3**	**<**	**<**	**3 (2 - 5)**	**$27 M ($9.2 M – $52 M)**
TOTAL OF MODELLED SECTORS[h]	**6**	**<**	**4**	**12 (6 - 18)**	**$91 M ($31 M - $180 M)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.

[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

Table A-43. NS Eastern air zone – all-cause premature mortality and valuation by sector and pollutant (2015).

Air Zone NS – EASTERN (pop. 0.1 M)	MORTALITY BY POLLUTANT[a, b, c, i] $PM_{2.5}$	NO_2	O_3[d]	ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On – road	**<**	**<**	**<**	**1 (1 - 2)**	**$8.7 M ($2.9 M – $17 M)**
On – road LDV	<	<	<	< (< - 1)	$2.6 M ($0.87 M – $5.1 M)
On – road HDV	<	<	<	1 (< - 1)	$6.1 M ($2.0 M – $12 M)
Off-road vehicles & mobile equipment	**<**	**<**	**<**	**< (< - 1)**	**$3.4 M ($1.2 M – $6.6 M)**
Air + Marine + Rail	**<**	**<**	**2**	**2 (1 - 3)**	**$17 M ($5.6 M – $34 M)**
Air	<	<	<	<	$65 K ($18 K – $140 K)
Marine	<	<	2	2 (1 - 3)	$15 M ($4.8 M – $29 M)
Rail	<	<	<	<	$2.3 M ($0.77 M – $4.6 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**1**	**<**	**<**	**1 (1 - 2)**	**$8.8 M ($3.1 M – $17 M)**
Cement manufacture	<	<	<	<	$1.3 M ($0.45 M – $2.4 M)
Non – ferrous refining and smelting	1	<	<	1 (< - 1)	$4.4 M ($1.5 M – $8.4 M)
Oil and gas industry[g]	**<**	**<**	**<**	**< (< - 1)**	**$3.6 M ($1.2 M – $6.9 M)**
Upstream oil and gas	<	<	<	<	$2.3 M ($0.80 M – $4.5 M)
Downstream oil and gas	<	<	<	<	$1.3 M ($0.44 M – $2.4 M)
Electric power generation	**2**	**<**	**<**	**3 (2 - 5)**	**$28 M ($8.9 M – $54 M)**
Coal – fired electric power generation	2	<	<	3 (2 - 5)	$25 M ($8.0 M – $50 M)
Manufacturing	**<**	**<**	**<**	**< (< - 1)**	**$2.9 M ($1.0 M – $5.7 M)**
Chemicals industry	<	<	<	<	$0.97 M ($0.34 M – $1.9 M)
Pulp and paper industry	<	<	<	<	$1.5 M ($0.53 M – $3.0 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**<**	**<**	**<**	**<**	**$1.0 M ($0.35 M – $2.0 M)**
Home firewood burning	**3**	**<**	**<**	**3 (1 - 4)**	**$20 M ($6.9 M – $38 M)**
TOTAL OF MODELLED SECTORS[h]	**6**	**<**	**2**	**12 (6 - 18)**	**$93 M ($31 M - $180 M)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.

[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

A.2.9 Prince Edward Island air zone

Table A-44. PE Prince Edward Island air zone – all-cause premature mortality and valuation by sector and pollutant (2015).

Air Zone PE – PRINCE EDWARD ISLAND (pop. 0.2 M)	MORTALITY BY POLLUTANT[a, b, c, i]			ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
	$PM_{2.5}$	NO_2	O_3[d]		
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On – road	**1**	**<**	**<**	**2 (1 - 2)**	**$12 M ($3.8 M – $23 M)**
On – road LDV	<	<	<	< (< - 1)	$3.0 M ($0.98 M – $5.9 M)
On – road HDV	<	<	<	1 (1 - 2)	$8.0 M ($2.6 M – $16 M)
Off-road vehicles & mobile equipment	**<**	**<**	**<**	**1 (< - 1)**	**$4.8 M ($1.6 M – $9.3 M)**
Air + Marine + Rail	**<**	**<**	**<**	**1 (1 - 2)**	**$11 M ($3.7 M – $22 M)**
Air	<	<	<	<	$0.57 M ($0.20 M – $1.1 M)
Marine	<	<	<	1 (1 - 2)	$8.6 M ($2.9 M – $17 M)
Rail	<	<	<	<	$1.8 M ($0.61 M – $3.6 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**1**	**<**	**<**	**1 (1 - 2)**	**$11 M ($3.8 M – $22 M)**
Cement manufacture	<	<	<	<	$0.79 M ($0.27 M – $1.5 M)
Non – ferrous refining and smelting	1	<	<	1 (< - 1)	$4.4 M ($1.5 M – $8.6 M)
Oil and gas industry[g]	**<**	**<**	**<**	**< (< - 1)**	**$3.3 M ($1.1 M – $6.3 M)**
Upstream oil and gas	<	<	<	<	$1.3 M ($0.46 M – $2.6 M)
Downstream oil and gas	<	<	<	<	$1.9 M ($0.66 M – $3.8 M)
Electric power generation	**1**	**<**	**<**	**2 (1 - 2)**	**$13 M ($4.4 M – $26 M)**
Coal – fired electric power generation	1	<	<	1 (1 - 2)	$11 M ($3.4 M – $21 M)
Manufacturing	**<**	**<**	**<**	**1 (< - 1)**	**$4.1 M ($1.4 M – $8.0 M)**
Chemicals industry	<	<	<	<	$0.52 M ($0.19 M – $1.0 M)
Pulp and paper industry	<	<	<	< (< - 1)	$2.7 M ($0.95 M – $5.4 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**<**	**<**	**<**	**<**	**$0.74 M ($0.24 M – $1.5 M)**
Home firewood burning	**3**	**<**	**<**	**3 (1 - 4)**	**$20 M ($6.8 M – $39 M)**
TOTAL OF MODELLED SECTORS[h]	**6**	**<**	**<**	**10 (5 - 15)**	**$80 M ($27 M - $160 M)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.

[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

A.2.10 Newfoundland and Labrador air zones

Table A-45. NL Newfoundland air zone – all-cause premature mortality and valuation by sector and pollutant (2015).

Air Zone NL – NEWFOUNDLAND (pop. 0.5 M)	MORTALITY BY POLLUTANT[a, b, c, i] $PM_{2.5}$	 NO_2	 O_3[d]	ALL-POLLUTANT MORTALITY[e, i] median (2.5% - 97.5% CI)	TOTAL VALUATION[f] (mortality and morbidity) median (2.5% - 97.5% CI)
TRANSPORTATION & MOBILE EQUIPMENT SECTORS					
ALL On – road	**<**	**<**	**1**	**1 (1 - 2)**	**$11 M ($3.8 M – $22 M)**
On – road LDV	<	<	<	<	$2.3 M ($0.79 M – $4.5 M)
On – road HDV	<	<	<	1 (< - 1)	$7.1 M ($2.4 M – $14 M)
Off-road vehicles & mobile equipment	**<**	**<**	**<**	**1 (< - 1)**	**$7.2 M ($2.4 M – $14 M)**
Air + Marine + Rail	**<**	**<**	**3**	**3 (2 - 5)**	**$26 M ($8.7 M – $50 M)**
Air	<	<	<	<	$93 K ($36 K – $170 K)
Marine	<	<	3	3 (2 - 5)	$24 M ($8.0 M – $46 M)
Rail	<	<	<	<	$1.8 M ($0.64 M – $3.4 M)
INDUSTRIAL SECTORS					
Ore and mineral industry	**1**	**<**	**<**	**2 (1 - 2)**	**$12 M ($4.2 M – $23 M)**
Cement manufacture	<	<	<	<	$0.72 M ($0.26 M – $1.4 M)
Non – ferrous refining and smelting	1	<	<	1 (< - 1)	$4.4 M ($1.5 M – $8.4 M)
Oil and gas industry[g]	**1**	**<**	**<**	**1 (1 - 2)**	**$8.9 M ($2.8 M – $18 M)**
Upstream oil and gas	<	<	<	<	$2.4 M ($0.85 M – $4.6 M)
Downstream oil and gas	1	<	<	1 (< - 1)	$6.6 M ($1.9 M – $13 M)
Electric power generation	**2**	**<**	**<**	**3 (1 - 4)**	**$22 M ($7.4 M – $43 M)**
Coal – fired electric power generation	1	<	<	2 (1 - 3)	$15 M ($5.1 M – $30 M)
Manufacturing	**<**	**<**	**<**	**<**	**$2.0 M ($0.70 M – $3.9 M)**
Chemicals industry	<	<	<	<	$93 K ($36 K – $170 K)
Pulp and paper industry	<	<	<	<	$1.2 M ($0.43 M – $2.3 M)
RESIDENTIAL SECTORS					
Residential fuel combustion	**<**	**<**	**<**	**<**	**$330 K ($110 K – $650 K)**
Home firewood burning	**3**	**<**	**<**	**3 (2 - 5)**	**$26 M ($9.0 M – $51 M)**
TOTAL OF MODELLED SECTORS[h]	**7**	**<**	**4**	**15 (8 - 22)**	**$120 M ($39 M - $230 M)**

[a] Chronic exposure mortality ($PM_{2.5}$), acute exposure mortality (NO_2, O_3), and chronic exposure respiratory mortality (summer O_3).

[b] Median of premature death estimates, rounded to nearest integer and maximum two significant figures; total values may not correspond due to rounding.

[c] Negative mortality corresponds to negative difference in modelled ambient air pollutant concentration (base case less sector emissions set to zero). Negative O_3 health impacts may occur in areas with high NO_x emissions.

[d] Sum of annual O_3 (acute exposure mortality) and summer O_3 (chronic exposure respiratory mortality).

[e] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of acute exposure mortality (NO_2, O_3), chronic exposure mortality ($PM_{2.5}$), and chronic exposure respiratory mortality (summer O_3). Rounded to nearest integer and maximum of two significant figures; total values may not correspond due to rounding.

[f] Median, 2.5th percentile and 97.5th percentile (from Monte Carlo simulation of health modelling) sum of valuation estimates for health endpoints (all pollutants, all mortality and morbidity endpoints). Expressed in billions (B) or millions (M) of Canadian dollars and based on 2015 currency.

[g] Oil and gas industry sector data estimated as sum of comprising sectors (upstream oil and gas, downstream oil and gas).

[h] Estimate from sum of all sector model runs (not modelled separately).

[i] < denotes mortality count less than 1.

A.2.11 Air zone boundaries

Figure A-1 Air zone names and boundaries in Western region provinces (British Columbia, Alberta, Saskatchewan, Manitoba).

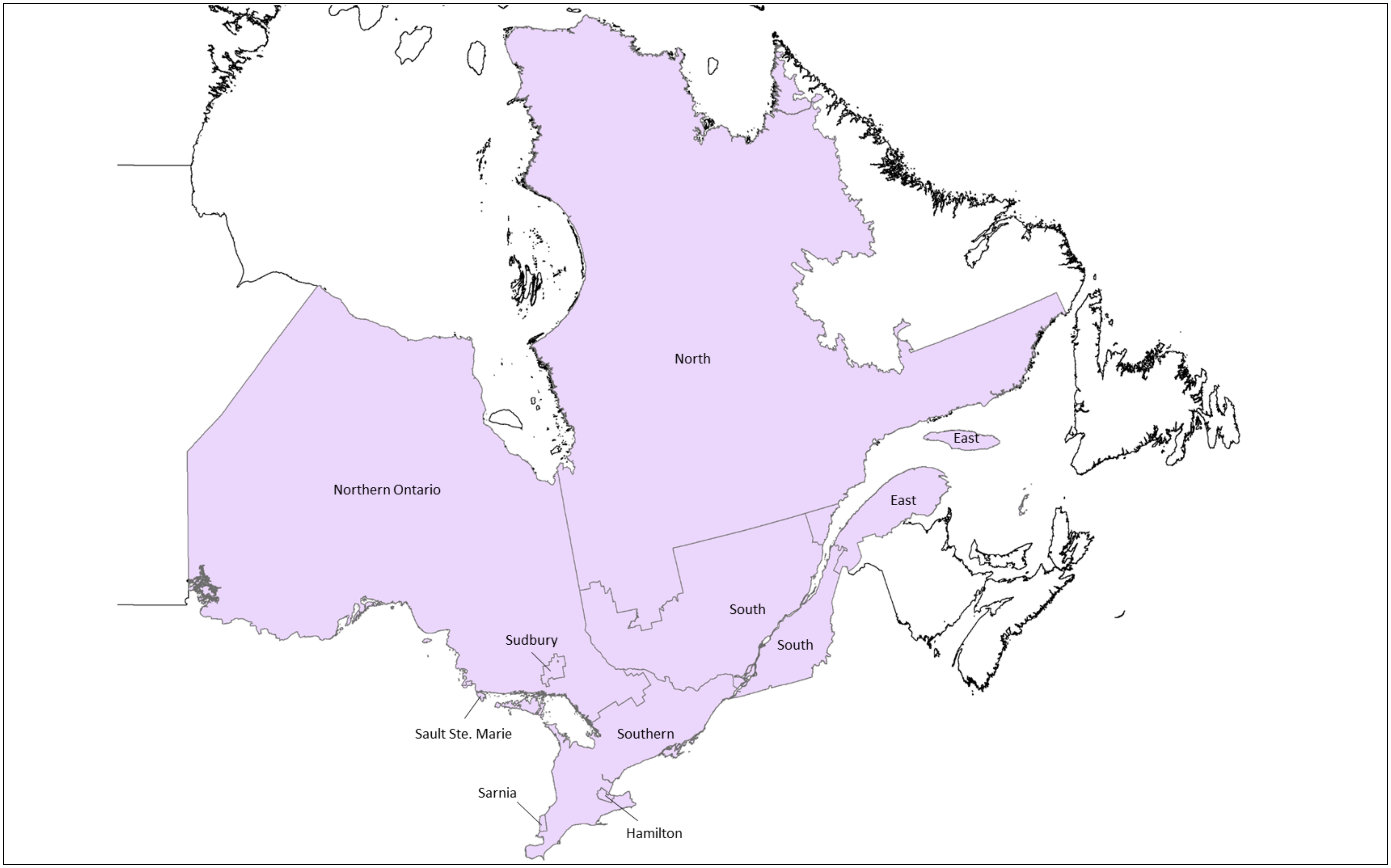

Figure A-2 Air zone names and boundaries in Central region provinces (Ontario, Quebec).

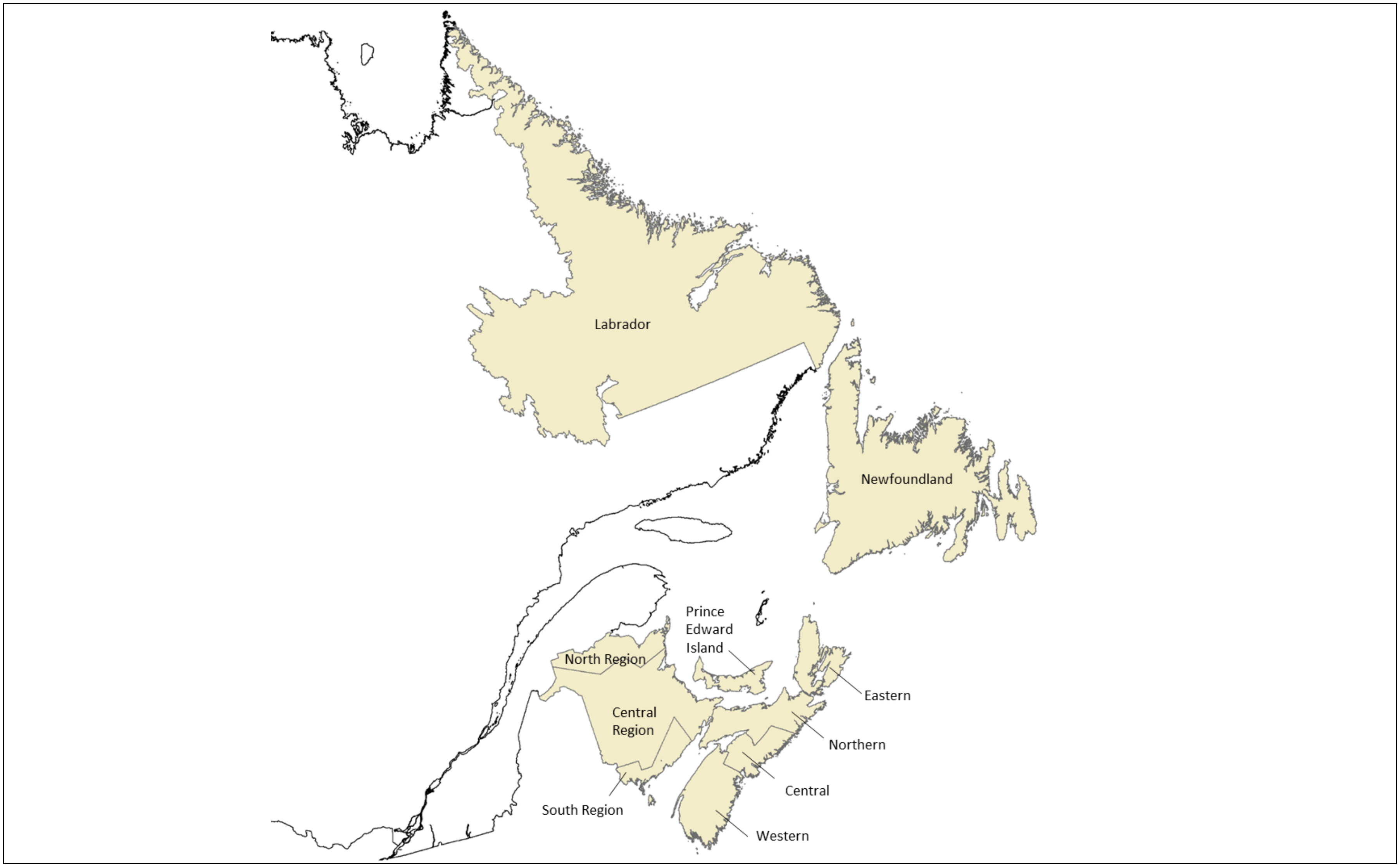

Figure A-3 Air zone names and boundaries in Atlantic region provinces (New Brunswick, Nova Scotia, Prince Edward Island, Newfoundland and Labrador).

Figure A-4 Air zone names and boundaries in North region territories (Yukon, Northwest Territories, Nunavut).