



Environment
Canada

Environnement
Canada

Canada's First Black Carbon Inventory

2013



Canada 

Cat. No.: En14-217/2015E-PDF

ISBN: 978-1-100-25678-8

Unless otherwise specified, you may not reproduce materials in this publication, in whole or in part, for the purposes of commercial redistribution without prior written permission from Environment Canada's copyright administrator. To obtain permission to reproduce Government of Canada materials for commercial purposes, apply for Crown Copyright Clearance by contacting:

Environment Canada
Inquiry Centre
10 Wellington Street, 23rd Floor
Gatineau QC K1A 0H3
Telephone: 819-997-2800
Toll Free: 1-800-668-6767 (in Canada only)
Fax: 819-994-1412
TTY: 819-994-0736
Email: enviroinfo@ec.gc.ca

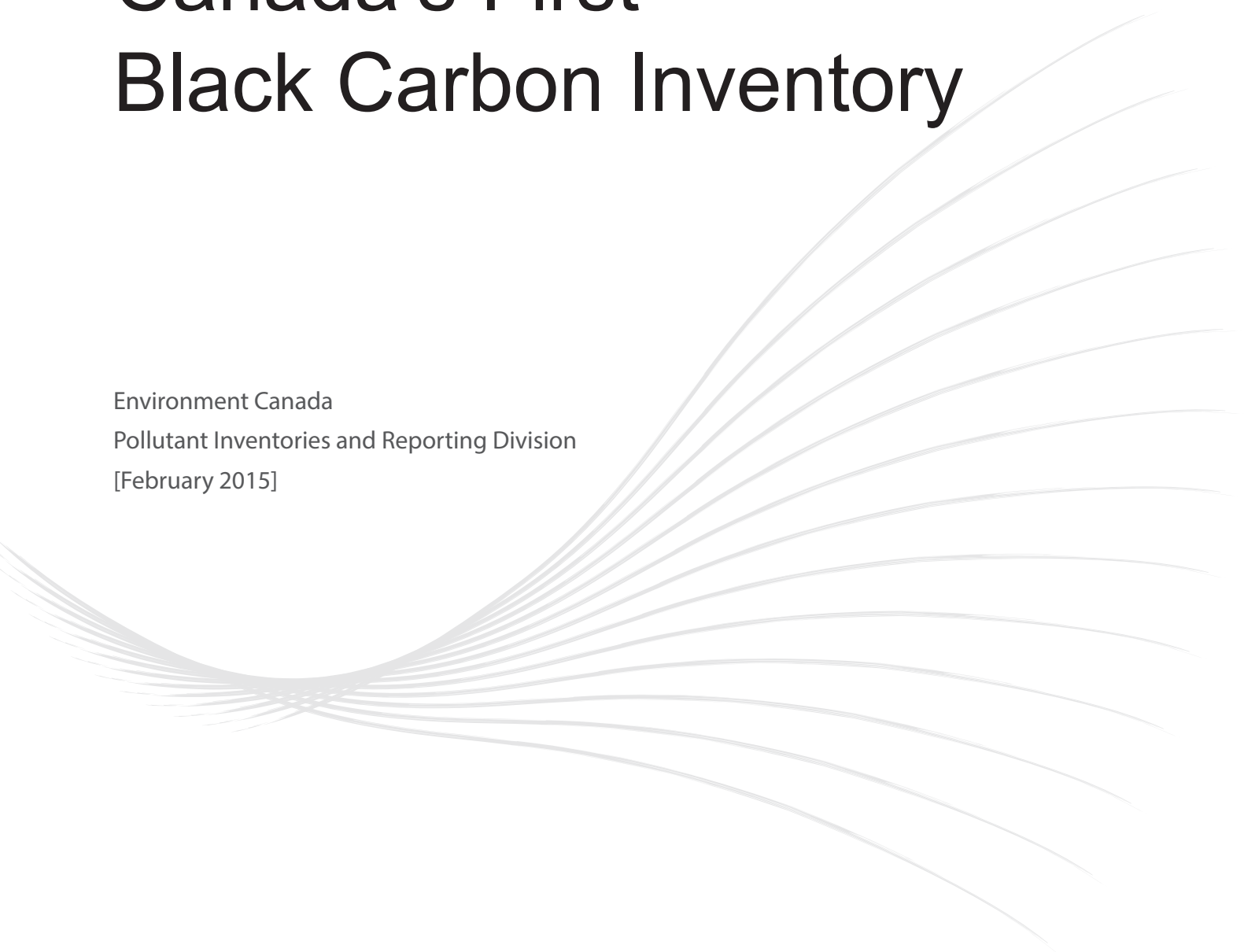
Photos: © thinkstockphotos.ca

© Her Majesty the Queen in Right of Canada, represented by the Minister of the Environment, 2014

Aussi disponible en français

Canada's First Black Carbon Inventory

Environment Canada
Pollutant Inventories and Reporting Division
[February 2015]



Acknowledgements

The Pollutant Inventories and Reporting Division (PIRD) of Environment Canada (EC) wishes to acknowledge the individuals and organizations that contributed to *Canada's First Black Carbon Inventory* for submission under the Convention on Long-range Transboundary Pollution (CLRTAP) of the United Nations Economic Commission for Europe (UNECE). The Division would like to highlight the contributions of the following inventory compilers, authors and/or reviewers, whose work helped to develop the black carbon inventory report and estimates:

Luc Allard, Susan Charles, Jason Hawirko, Francois Lavallée, John Moritz, David Niemi, Steve Smyth, Valeria Sula, Brett Taylor, Kristine Tracey and Emily West.

The compilation and coordination of the emission summary tables for the UNECE submission was managed by John Moritz.

Overall coordination of the Black Carbon Inventory Report was managed by Emily West and Mona Jennings. Compilation and layout of the report was carried out by Mona Jennings. Editing was provided by Len Goldberg and the translation services were provided by the Translation Bureau of Public Works Canada. Special thanks to Ian Hickey for providing comments on the report and David Maher for webpage development.

Of the numerous people and organizations that provided support and information, we are especially indebted to the many individuals in various federal departments, provincial ministries, industries and industry associations, consulting firms, and universities who provided technical and scientific support.

Readers' Comments

Comments regarding the contents of this report should be addressed to:

Director, Pollutant Inventories and Reporting Division
Science and Risk Assessment
Science and Technology Branch
Environment Canada
200 Sacré-Coeur Boulevard, 10th Floor
Gatineau QC K1A 0H3

Email: apei-iepa@ec.gc.ca

List of Acronyms, Abbreviations and Units

APEI	Air Pollutant Emissions Inventory
BC	Black carbon
CO ₂ eq	Carbon dioxide equivalent
EEA	European Environment Agency
EMEP	European Monitoring and Evaluation Programme
HDDV	Heavy-duty diesel vehicle
kt	Kilotonne
MOVES	Motor Vehicle Emission Simulator
NFR	Nomenclature for Reporting
OC	Organic carbon
PM	Particulate matter
PM _{2.5}	Particulate matter less than or equal to 2.5 micrometres in diameter
SLCP	Short-lived climate pollutant
TFBCM	Task Force for Action on Black Carbon and Methane
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
U.S. EPA	United States Environmental Protection Agency

Table of Contents

Acknowledgements	4
List of Acronyms, Abbreviations and Units	5
Executive Summary	7
Chapter 1 Introduction	9
Chapter 2 Initial Estimates of Black Carbon Emissions in Canada for 2013	9
2.1 Industrial Sources	10
2.2 Non-Industrial Sources	12
2.3 Mobile Sources	12
2.4 Completeness	13
2.4.1 Industrial Sources	13
2.4.2 Non-Industrial Sources	13
2.4.3 Other Sources not Included in the APEI	14
2.5 Sources of Uncertainty	14
2.6 Comparisons with other Inventories	14
Chapter 3 Submission of the UNECE Report on Black Carbon	14
Chapter 4 Considerations for Future Versions of this Inventory	14
Annex A: Sector Description	16
Annex B: Rounding Protocol	16
References	17

Executive Summary

Black carbon (BC) is both a short-lived climate pollutant (SLCP) and an air pollutant linked to adverse health effects. Emissions of black carbon have recently become a focus of attention for policy makers, due to the emissions' effects on the near-term warming of the atmosphere and on human health. Reducing black carbon emissions is of particular interest in polar regions such as the Arctic, which are especially sensitive to the effects of black carbon.

During Canada's Chairmanship of the Arctic Council (2013–2015), the Arctic Council Task Force for Action on Black Carbon and Methane (TFBCM) is promoting actions to achieve enhanced black carbon and methane emission reductions in the Arctic. Part of the follow-up will require all participating countries to voluntarily submit their national inventories of black carbon emissions. Arctic Environment Ministers also agreed to submit a black carbon inventory for their countries to the United Nations Economic Commission for Europe (UNECE) by February 2015.

This report presents the results of Canada's initial effort to develop an inventory of black carbon emissions. Emissions in this first inventory are grouped by the following sources:

- Mobile sources
- Non-industrial sources
- Industrial sources

In 2013, approximately 45 000 tonnes (45 kilotonnes [kt]) of black carbon were emitted in Canada (Table ES–1). Mobile sources are by far the most important sources of black carbon in Canada, accounting for a little over 29 kt (65%) of total emissions in 2013. Off road-transport, specifically diesel engines, accounts for 15 kt (33%) of the total emissions. The other large mobile source is on-road transport, again mostly diesel engines, which account for 9 kt (20%) of total emissions.

Non-industrial sources (residential wood combustion) are the second-largest contributor to black carbon emissions in Canada, representing emissions of 12 kt, or slightly more than 26% of total emissions. Wood is an abundant fuel in Canada; it is estimated that 14 million tonnes of wood are burned annually in Canadian homes. More information on the estimation methods can be found in Section 2.2.

Black carbon emissions in industrial sectors represent 9% of total emissions. An important source in this sector is the upstream petroleum industry, which accounts for 8% of total emissions. Stationary diesel engines contribute over half of these emissions. Estimation methods are outlined in Section 2.1.

The sources included in this initial inventory are estimated to account for at least 90% of anthropogenic black carbon emissions. Work will continue to improve the completeness and accuracy of the inventory, quantifying the industrial and non-industrial emissions that are not captured yet, and refining base data and estimation techniques.



Table ES-1 Canadian Black Carbon Emissions by Sector (2013)

Sector	Black Carbon (tonnes)	Percentage of Total
Industrial Sources	4 100	9%
Total of Aluminium, Cement and Concrete, Foundries, Mining and Rock Quarrying, and Pulp and Paper Industry	500-600 (550)	1%
Aluminium Industry		<1%
Cement and Concrete Industry		<1%
Foundries		<1%
Mining and Rock Quarrying		<1%
Pulp and Paper Industry		<1%
Upstream Petroleum Industry	3 600	8%
Stationary sources - Diesel combustion	1 900	4%
Stationary sources - Natural Gas combustion	770	2%
Flaring	930	2%
Non-industrial Sources	12 000	26%
Residential Wood Combustion	12 000	26%
Wood Stoves	4 100	9%
Furnaces	4 200	9%
Fireplaces	3 400	7%
Mobile Sources	29 000	65%
Air Transportation	690	2%
On-Road Transport	9 200	20%
Gasoline	1 000	2%
Diesel	8 200	18%
Off-Road Transport	16 000	35%
Gasoline, Natural Gas	700	2%
Diesel	15 000	33%
Marine	1 600	4%
Rail	2 200	5%
TOTAL	45 000	100%

Note: Totals may not add up due to rounding



1 Introduction

Black carbon is both a short-lived climate pollutant (SLCP) and an air pollutant linked to adverse health effects. Emissions of black carbon have recently become a focus of attention for policy makers due to the emissions' effects on the near-term warming of the atmosphere and on human health. Reducing black carbon emissions is of particular interest in polar regions such as the Arctic, which are especially sensitive to the effects of black carbon because there is an additional warming effect from the deposition of black carbon onto snow and ice, which results in increased melting.

The Arctic Council was one of the first fora to recognize the importance of taking action to address SLCPs such as black carbon, methane and ground-level ozone. During Canada's Chairmanship (2013–2015), the Arctic Council Task Force for Action on Black Carbon and Methane (TFBCM) is promoting actions to achieve enhanced black carbon and methane emission reductions in the Arctic. Part of the follow-up will require all participating countries to voluntarily submit their national inventories of black carbon emissions. In 2013, Arctic Environment Ministers also agreed to submit a black carbon inventory for their countries to the United Nations Economic Commission for Europe (UNECE) by February 2015.

This document describes Canada's first inventory of anthropogenic black carbon emissions. It is sometimes referred to as a "partial inventory" because, while the major black carbon emitting sectors are included, an estimated 10% of total emissions remain unaccounted for (Section 2.4).

Background on Black Carbon Emission Quantification

Black carbon is an aerosol (airborne particle) emitted from combustion processes in the form of very fine particulate matter ($PM_{2.5}$). Black carbon is not emitted on its own, but as a component of $PM_{2.5}$, along with other components such as organic carbon (OC) and inorganic compounds such as sulfates.

Two important assumptions underlie the present inventory: black carbon is a fraction of particulate matter (PM) less than or equal to 2.5 microns (micrometres) in diameter, i.e., $PM_{2.5}$; and only $PM_{2.5}$ emissions resulting from combustion contain significant amounts of black carbon. Therefore, the basis for the black carbon inventory is the $PM_{2.5}$ emitted from combustion processes, multiplied by black carbon ratios specific to each type of source.

For this first inventory, priority has been given to known sources that account for significant quantities of black carbon emissions at the national level: industrial sources, non-industrial sources (residential wood combustion) and mobile sources (on-road and off-road transport, rail, air and marine). These sources were

identified based on preliminary estimates completed in 2009, combustion-emissions of $PM_{2.5}$ for the year 2012 with an emphasis on sources using high-black carbon-emitting combustion equipment such as engines and wood-burning equipment, and by reviewing available information on elemental carbon fractions of $PM_{2.5}$. Other sources or sectors, specifically other industries and energy production, are believed to also contribute to national emissions, but have not yet been estimated. The dataset that breaks down the $PM_{2.5}$ emitted from a particular source (e.g. diesel engine emissions) into its different components, including black carbon and organic carbon, is known as a speciation profile. Most speciation profiles contain a fraction for elemental carbon; these fractions are commonly used as a surrogate to quantify black carbon emissions. The current inventory primarily relies on the United States Environmental Protection Agency's (U.S. EPA's) SPECIATE database (EPA 2014) to calculate black carbon emissions from compiled combustion- $PM_{2.5}$ emissions.

The estimates in this inventory of black carbon emissions are based on the best available information at the time of compilation. Estimates of $PM_{2.5}$ emissions originate from the 2015 Air Pollutant Emission Inventory (APEI). Please refer to the APEI Report (Environment Canada 2015) for a description of estimation methods for $PM_{2.5}$; the present document will describe how black carbon emissions were estimated from $PM_{2.5}$ emissions.

2 Initial Estimates of Black Carbon Emissions in Canada for 2013

In Canada's initial inventory, approximately 45 000 tonnes (45 kt) of black carbon were emitted in Canada in 2013 (Table 1). Emissions have been grouped by the following sources:

- Industrial
- Non-industrial
- Mobile

Black carbon emissions in industrial sectors represent 9% of total emissions. An important source in this sector is the upstream petroleum industry, which accounts for 8% of total emissions; stationary engines burning diesel fuel in this industry amount to over half of these emissions. Estimation methods are outlined in Section 2.1.

Non-industrial sources (residential wood combustion) are the second-largest contributor to black carbon emissions in Canada, representing emissions of 12 kt, i.e., slightly more than 26% of total emissions. Wood is an abundant fuel in Canada; it is

estimated that 14 million tonnes of wood are burned annually in Canadian homes. More information on the estimation methods can be found in Section 2.2.

Mobile sources are by far the most important sources of black carbon in Canada, accounting for 29 kt, i.e., 65%, of total emissions in 2013. Off-road transport, primarily through the use of diesel engines, accounts for just over one third (35%) of total emissions. The other major source in this sector is on-road transport, again primarily diesel engines, which account for 20% of total emissions. More information on estimation methodologies is provided in Section 2.3.

The sources that have not been included in this first inventory are estimated to account for less than 10% of the overall emissions. Those sources include the use of diesel engines for electricity generation in remote communities, commercial fuel combustion and residential fuel combustion (other than wood), and prescribed burning. Further explanations are provided in Section 2.4.

Generally, the two factors that influence black carbon emissions are emissions of $PM_{2.5}$ from combustion processes and the fraction of black carbon in the $PM_{2.5}$. Diesel engines have relatively high emission rates of $PM_{2.5}$ per unit energy, and the fraction of black carbon in these $PM_{2.5}$ emissions is also relatively high. The majority of diesel fuel in Canada is used for mobile sources. Other combustion sources with high $PM_{2.5}$ emissions include solid fuel

combustion units such as coal- and wood-fired boilers. These industrial sources are generally equipped with highly effective $PM_{2.5}$ controls on boiler emissions, with PM -control efficiencies often in the 90% range. This is reflected in the lower $PM_{2.5}$ emissions compared to other sources. In contrast, the smaller and markedly different equipment used for residential wood combustion (fireplaces, wood stoves or furnaces) have poorer $PM_{2.5}$ -control efficiencies than larger units, notwithstanding the different types of fuel and firing practices used for burning firewood. The lack of treatment of the stack gases result in residential wood-burning devices being by far the largest sources of combustion-related $PM_{2.5}$ emissions in Canada, but black carbon emissions from residential wood burning are only one third that of mobile sources due to a lower $BC/PM_{2.5}$ fraction for wood devices than for diesel engines.

2.1 Industrial Sources

Industrial sources include primary resource extraction and processing, and manufacturing industries. For the purpose of this inventory, black carbon emissions were considered for the following sectors:

- Aluminium industry
- Cement and concrete industry
- Foundries

Table 1 Initial Canadian Black Carbon Emissions by Sector (2013)

Sector	Black Carbon (tonnes)	Percentage of Total
Industrial Sources	4 100	9%
Total of Aluminium, Cement and Concrete, Foundries, Mining and Rock Quarrying, and Pulp and Paper Industry	500-600 (550)	1%
Aluminium Industry		<1%
Cement and Concrete Industry		<1%
Foundries		<1%
Mining and Rock Quarrying		<1%
Pulp and Paper Industry		<1%
Upstream Petroleum Industry	3 600	8%
Stationary Sources – Diesel Combustion	1 900	4%
Stationary Sources – Natural Gas Combustion	770	2%
Flaring	930	2%
Non-industrial Sources	12 000	26%
Residential Wood Combustion	12 000	26%
Wood Stoves	4 100	9%
Furnaces	4 200	9%
Fireplaces	3 400	7%
Mobile Sources	29 000	65%
Air Transportation	690	2%
On-Road Transport	9 200	20%
Gasoline	1 000	2%
Diesel	8 200	18%
Off-Road Transport	16 000	35%
Gasoline, Liquid Petroleum Gas, Compressed Natural Gas	700	2%
Diesel	15 000	33%
Marine	1 600	4%
Rail	2 200	5%
Total	45 000	100%

Note: Totals may not add up due to rounding

- Mining and rock quarrying
- Pulp and paper industry
- Upstream petroleum industry

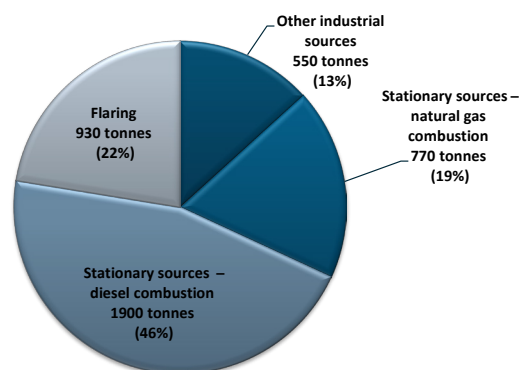
Only PM_{2.5} emissions resulting from combustion contain significant amounts of black carbon (industrial PM_{2.5} emissions originate from both combustion and non-combustion sources). Where readily available, the PM_{2.5} emissions data from combustion were used in conjunction with BC/PM_{2.5} fractions to estimate the black carbon emissions, with the one exception to the general approach being black carbon emissions from flaring in the upstream petroleum industry, which were directly calculated from the quantities of gas flared (Table 2). However, separating combustion from non-combustion sources¹ of PM_{2.5}, necessary for determining black carbon emissions, remains a challenge in some cases due to a lack of detailed activity data (i.e. quantity of fuel burned) and detailed non-combustion data (i.e. amount of PM_{2.5} emissions attributed to non-combustion sources, such as rock dust at a mine). Therefore, approximations are used to estimate combustion and non-combustion PM_{2.5}, and, from there, black carbon emissions from industrial sources. The one exception is for the upstream petroleum industry, where the information to distinguish between combustion and non-combustion sources currently exists (Clearstone 2014).

Among all industrial activities included in this initial inventory, stationary diesel engines used for fossil fuel extraction in the upstream petroleum industry sector account for the largest

proportion (46%) of black carbon emissions (Figure 1). Although total emissions of PM_{2.5} from industrial sources (44 kt; see Table 2) and mobile sources (55 kt; see Table 4) are comparable in magnitude, black carbon emissions from industrial sources (4.1 kt) are much lower than those from mobile sources (29 kt), because a large proportion of PM_{2.5} emissions from industrial sources do not arise from combustion sources, while all of the mobile PM_{2.5} emissions arise from combustion sources. Examples of relatively low black carbon emissions from industrial sources include the following:

- The mining and rock quarrying industry, where the majority of PM_{2.5} emissions are the result of fugitive emissions of ore and rock dust.

Figure 1 Black Carbon Emissions for Upstream Petroleum Industry Sector and Other Industrial Sources (2013)



Note: Totals may not add due to rounding.

1 Examples of non-combustion sources: PM_{2.5} emissions resulting from the production of clinker and the use of limestone chalk in the cement industry; dust generated during construction and mining operations.

Table 2 Industrial Sources Components of Black Carbon Estimation (2013)

Sector	PM _{2.5} (tonnes)	BC/PM _{2.5} fraction w/w and references	Black Carbon (tonnes)
Aluminium Industry	4 400	Average profile developed from individual SPECIATE profiles for sector ^a	550
Cement and Concrete Industry	6 600		
Foundries	5 200		
Mining and Rock Quarrying	10 000		
Pulp And Paper Industry	9 200		
Upstream Petroleum Industry			
Combustion - Flaring	3 900	0.24 ^d	930
Combustion - Natural Gas Fuel	2 000	0.384 ^b	770
Combustion - Propane Fuel	28		
Combustion - Drilling Rigs	2 000	0.77124 ^c	1 500
Combustion - Well Completion (pumping)	270	0.77124 ^c	210
Combustion - Well Service	170	0.77124 ^c	130
Combustion - Diesel Fuel	5.7	0.77124 ^c	4.4
Grand Total			4 100

Notes:

a. EPA 2014, SPECIATE 4.4;

b. SPECIATE4.4 profile 92112 (Natural Gas Combustion - Simplified);

c. SPECIATE4.4 profile 3914 (Diesel exhaust);

d. McEwen 2013.

Totals may not add up due to rounding

PM_{2.5} emissions for the aluminium industry, cement and concrete industry, foundries, and mining and rock quarrying originate from both combustion and non-combustion sources.

- The aluminium, foundries, and pulp and paper industries, which are equipped with effective $PM_{2.5}$ controls and relatively low $BC/PM_{2.5}$ fractions.
- The cement and concrete industry, where the majority of $PM_{2.5}$ emissions occur from concrete batching, which has minimal combustion emissions.

The APEI Report (Environment Canada 2015) provides more information on the development of $PM_{2.5}$ emission estimates from industrial and non-industrial sources.

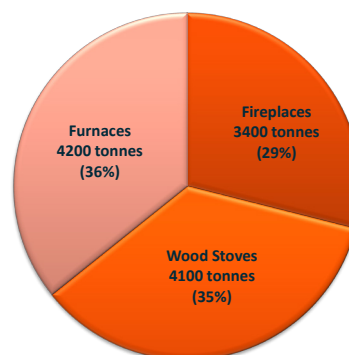
2.2 Non-Industrial Sources

Non-industrial sources include commercial, institutional and residential fuel combustion of all types of fuel, although not all fuel types are included in this inventory. The majority of emissions in this source are due to combustion, either in larger, more efficient boilers in the case of commercial fuel combustion, or small, inefficient fireplaces and woodstoves in the case of residential wood combustion.

The sole non-industrial source in this first inventory is residential wood combustion. Black carbon was estimated as a fraction of the $PM_{2.5}$ emissions from the different types of wood-burning devices in use in Canada in 2013. For details on the development of the residential wood quantity and emissions estimation, see the APEI Report (Environment Canada 2015).

Large sources of black carbon are those where either large quantities of $PM_{2.5}$ are emitted or where the $BC/PM_{2.5}$ fraction is large. Wood furnaces, even though they emitted less $PM_{2.5}$ than other devices in 2013, account for the largest black carbon emissions in the residential wood combustion sector because the $BC/PM_{2.5}$ fraction is more than twice the fraction for other wood-burning devices (Table 3). Conventional wood stoves emitted more $PM_{2.5}$ in 2013, but come second for black carbon emissions for this source because the $BC/PM_{2.5}$ fraction is lower.

Figure 2 Black Carbon Emissions from the Residential Wood Combustion Sector (2013)



Note: Totals may not add due to rounding.

Overall, wood stoves, furnaces and fireplaces each account for approximately one third of black carbon emissions (Figure 2). The key determinant is the relative quantities of wood burned in each type of wood-burning device.

2.3 Mobile Sources

The Mobile sources sector includes air transportation, marine transportation, on-road vehicles, off-road fuel use and rail transportation. Off-road is a highly diverse source that includes lawn and garden equipment, recreational vehicles such as pleasure craft and snowmobiles, farm equipment, construction and mining equipment, and portable generators and pumps.

To estimate emissions from mobile sources, bottom-up approaches were adopted, i.e., obtaining emission factors and applying them to disaggregated activity data. Generally, emission factors (by application class, age, load and fuel type), activity data (i.e. vehicle-kilometres travelled, or number of applications, their hours-of-use and load factor) and $BC/PM_{2.5}$ fractions were taken from the most recent models and sources. In all cases other than on-road vehicles, $PM_{2.5}$ was estimated first, and, from these

Table 3 Non-Industrial Sources Components of Black Carbon Estimation (2013)

Appliance Type	Appliance Detail	$PM_{2.5}$ (tonnes)	$BC/PM_{2.5}$ ^a fraction w/w	Black Carbon (tonnes)
Advanced Technology Fireplace	Non-Catalytic	7 600	0.05581	420
Conventional Fireplace	With Glass Doors	18 000	0.05581	980
	Without Glass Doors	20 000	0.05581	1 100
Fireplace Insert	Advanced Technology	2 200	0.05581	120
	Conventional	14 000	0.05581	760
Pellet Stove	All	710	0.05581	39
Wood Stove	Conventional	64 000	0.05581	3 600
	EPA Certified	9 400	0.05581	520
Wood Furnace	All	30 000	0.138	4 200
Grand total				12 000

Notes:

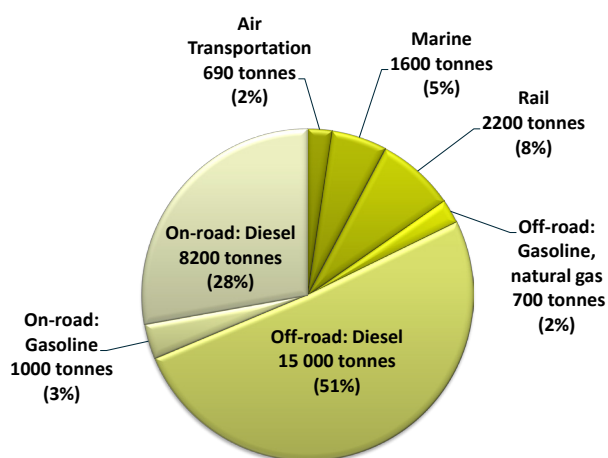
a. EPA 2006. SPECIATE 4.0. (http://www.epa.gov/ttn/chief/software/speciate/speciate4/speciate4_2006dec.zip)

Totals may not add up due to rounding

results, black carbon was estimated. For on-road vehicles, the Motor Vehicle Emission Simulator (MOVES) model (EPA 2014-2) directly outputs black carbon estimates, and therefore, in this case, only one step was required to estimate black carbon. The methods for estimating PM_{2.5} emissions from mobile sources are described in the APEI Report (Environment Canada 2015).

Larger sources of black carbon are those that either emit large quantities of PM_{2.5}, or where the BC/PM_{2.5} fraction is large, such as with off-road engines. Off-road engines represent the largest sources of total black carbon emissions, with 16 kt emitted in 2013. Off-road engines emit significant quantities of PM_{2.5}, and diesel engines have the highest BC/PM_{2.5} fractions (Table 4). As a result, off-road diesel engines account for 51% of all black carbon emissions in the mobile sector (Figure 3).

Figure 3 Black Carbon Emissions for the Mobile Sources Sector (2013)



Note: Totals may not add due to rounding.

2.4 Completeness

A quantitative assessment of completeness is challenging, because detailed analyses have not been completed for all sources. The sources included in this initial inventory are estimated to account for at least 90% of anthropogenic black carbon emissions in Canada.

2.4.1. Industrial Sources

Table 1 lists an aggregate estimate of black carbon emissions of 550 tonnes for the aluminium, cement and concrete, mining and rock quarrying, pulp and paper, and foundries industries, which represent approximately 13% of industrial emissions and approximately 1.3% of overall black carbon emissions. Although other non-estimated sectors contribute to black carbon, the total of non-estimated industrial sources is believed to be small.

2.4.2. Non-Industrial Sources

Other non-industrial sources currently excluded from this inventory are electricity generation, commercial fuel combustion, and residential fuel combustion (other than wood). PM_{2.5} emissions from each of these sources contribute insignificantly to the overall black carbon emissions, because of either inherently low PM_{2.5} emissions (e.g. combustion of light fuel oil or natural gas) or effective control of PM_{2.5} emissions. It is estimated that PM_{2.5} emissions from these sectors combined account for less than 5% of the total from non-industrial sources.

One source not accounted for is the use of diesel engines for electrical generation. Canada does have diesel generators for

Table 4 Mobile Sources Components of Black Carbon Estimation (2013)

Sector	Fuel type	PM _{2.5} (tonnes)	BC/PM _{2.5} fraction w/w and references	Black Carbon (tonnes)
Air Transportation	Aviation turbo fuel (Jet A or B)	900	0.77124 ^a	690
Air Transportation	Aviation gasoline	1.5	0.12178 ^b	
Marine Transportation	Heavy Fuel Oil	10 000	0.12 ^c	1 600
Marine Transportation	Marine Diesel Oil		0.31 ^c	
Marine Transportation	Marine Gasoline Oil		0.31 ^c	
On-road vehicles	all	17000	EC data extracted from MOVES model; values are variable according to model input and vehicle class	9 200
Off-road fuel use	Diesel	24 000	0.771241 ^a	16 000
Off-road fuel use	Gasoline		0.12178 ^b	
Off-road fuel use	Natural Gas		0.384 ^a	
Rail Transportation	Diesel	2 900	0.771241 ^a	2 200
Grand total				29 000

Note:

a. SPECIATE4.3 profile 92106 (HDDV Exhaust),

b. SPECIATE4.3 profile 92113 (NONROAD Gasoline Exhaust);

c. Table A2 of "International navigation, national navigation, national fishing and military (shipping)" (Section 1.A.3.d) of EMEP/EEA Emission Inventory Guidebook 2013;

d. SPECIATE4.3 profile 92112 (Natural Gas Combustion - Composite).

Totals may not add up due to rounding

remote communities, and for generation of electricity for remote industrial sites, primarily for mines. These sources of black carbon emissions may be locally significant, such as in northern communities. The National Inventory of Sources and Sinks of Greenhouse Gases in Canada (Environment Canada 2014) estimates that 4 million tonnes of carbon dioxide equivalent (CO₂ eq) are emitted by the total aggregated refined fuel (other than coal and natural gas) used to generate electricity. This can be compared to the sum of all diesel fuel used in transport, i.e., 82 million tonnes of CO₂ eq (the sum of on-road and off-road diesel and railways). Diesel generators represent almost 5% of the diesel used in these sectors. On the assumption that emission rates are similar for diesel generators, they are estimated to account for less than 3% of national black carbon emissions.

2.4.3. Other Sources not Included in the APEI

One source that has not been estimated in this inventory is prescribed burning. This practice is not extensive in Canada, and is not expected to be a large source of anthropogenic emissions.

2.5 Sources of Uncertainty

One source of uncertainty with black carbon inventories is the inconsistencies between definitions and measurements (Bond et al. 2013). Scientists use different methods to measure black carbon particles emitted at the sources and in the atmosphere, and therefore measured quantities are not strictly comparable.

Although not quantified, uncertainty about black carbon estimates in this initial inventory is primarily driven by the uncertainty with the BC/PM_{2.5} ratios. There is large variability in the size of measurement samples used to derive these ratios; the same ratios are by default applied to several different technologies. An example of the limitation in available BC/PM_{2.5} ratios is demonstrated in the use of the same ratio for all the appliance types for the non-industrial sources, except for wood furnaces (Table 3). The same challenge with the lack of different ratios is demonstrated with the application of the diesel BC/PM_{2.5} ratio for aviation turbo fuel. The refinement of BC/PM_{2.5} ratios is expected to improve over time with supplemental testing.

The uncertainty is high in determining the proportion of PM_{2.5} emissions that arise from combustion emissions for industrial sources. The primary data source for estimating PM_{2.5} emissions from many industrial sources is the National Pollutant Release Inventory (NPRI), whose emissions are reported by facilities by stack or as one aggregate value for the facility as a whole; emissions are not broken down between combustion and non-combustion emissions. Assumptions were necessary to attribute a ratio to each sector, with varying degrees of accuracy.

2.6 Comparisons with other Inventories

Denmark's 2010 black carbon emissions inventory indicates emissions from the domestic (primarily wood combustion) and transportation sectors were 83% and 15% of total national emissions, respectively. Other participating countries also report significant emissions from these two sectors, in addition to contributions from energy and industrial sectors that, together, are similar to Canada's industrial sources in terms of national percentages. For example: the 2012 Finnish inventory indicates that nearly 100% of emissions are attributed to residential and transportation; "other" sources account for 9% of total black carbon emissions in the 2012 Norwegian inventory; Norway attributed 12% of its 2012 black carbon emissions to the upstream petroleum industry; U.S. estimates of 2011 black carbon emissions include a 21% contribution by wildfires, which, when subtracted from the total, mean that mobile sources represent 52% of black carbon emissions in the United States.

3 Submission of the UNECE Report on Black Carbon

Canada is using the UNECE report (template) and the associated Nomenclature for Reporting (NFR) codes for reporting its black carbon emissions internationally. Table 5 lists the NFR codes used for reporting Canada's black carbon emissions in 2013.

The emissions from the three sectors (see Chapter 2) were mapped to the NFR codes in Table 5. The resulting UNECE report can be seen in Table 6.

The "IE" (included elsewhere) code indicates emissions were estimated but included elsewhere in the inventory instead of the listed source category.

4 Considerations for Future Versions of this Inventory

This initial inventory is estimated to provide 90% coverage of Canadian black carbon emissions. Improvement will focus on expanding the coverage as well as improving the accuracy of emissions estimates. Further refinement of emissions for the industrial sectors will require improved disaggregation of the PM_{2.5} emissions by source (combustion vs. non-combustion emissions).

Table 5 UNECE NFR Codes used by the 2013 Black Carbon Report

NFR Code	Description
1A1c	Manufacture of solid fuels and other energy industries
1A2gvii	Mobile combustion in manufacturing industries and construction
1A2gviii	Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR)
1A3aii(i)	Domestic aviation LTO (civil)
1A3aii(ii)	Domestic aviation cruise (civil)
1A3bi	Road transport: Passenger cars
1A3bii	Road transport: Light-duty vehicles
1A3biii	Road transport: Heavy-duty vehicles and buses
1A3biv	Road transport: Mopeds & motorcycles
1A3c	Railways
1A3dii	National navigation (shipping)
1A4aii	Commercial/institutional: Mobile
1A4bi	Residential: Stationary
1A4cii	Agriculture/Forestry/Fishing: Off-road vehicles and other machinery
1A5b	Other, Mobile (including military, land-based and recreational boats)
1A4bii	Residential: Household and gardening (mobile)
1B2c	Venting and flaring (oil, gas, combined oil and gas)

Table 6 2013 Canadian Black Carbon UNECE report

NFR Aggregation for Gridding and LPS (GNFR)	NFR Code	Longname	BC emissions (kt)
B_Industry	1A1c	Manufacture of solid fuels and other energy industries	2.7
I_Offroad	1A2gvii	Mobile Combustion in manufacturing industries and construction: (please specify in the IIR)	6.8
B_Industry	1A2gviii	Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR)	0.55
H_Aviation	1A3ai(i)	International aviation LTO (civil)	IE
H_Aviation	1A3aii(i)	Domestic aviation LTO (civil)	0.22
O_AviCruise	1A3aii(ii)	Domestic aviation cruise (civil)	0.47
F_RoadTransport	1A3bi	Road transport: Passenger cars	0.61
F_RoadTransport	1A3bii	Road transport: Light duty vehicles	0.53
F_RoadTransport	1A3biii	Road transport: Heavy duty vehicles and buses	8.0
F_RoadTransport	1A3biv	Road transport: Mopeds & motorcycles	0.0074
I_Offroad	1A3c	Railways	2.2
G_Shipping	1A3di(ii)	International inland waterways	IE
G_Shipping	1A3dii	National navigation (shipping)	1.6
I_Offroad	1A4aii	Commercial/institutional: Mobile	0.77
C_OtherStationaryComb	1A4bi	Residential: Stationary	12
I_Offroad	1A4cii	Agriculture/Forestry/Fishing: Off-road vehicles and other machinery	7.0
I_Offroad	1A4ciii	Agriculture/Forestry/Fishing: National fishing	IE
I_Offroad	1A5b	Other, Mobile (including military, land based and recreational boats)	0.85
I_Offroad	1A4bii	Residential: Household and gardening (mobile)	0.36
D_Fugitive	1B2c	Venting and flaring (oil, gas, combined oil and gas)	0.93
TOTAL			45

Note:
Totals may not add up due to rounding

Work will be carried out to allow for expansion of the non-industrial sectors coverage, specifically electric power generation (utilities) and the use of diesel engines for electricity generation. Commercial fuel combustion and residential fuel combustion (other than wood) will be included in planned improvements.

Another source not currently estimated is prescribed burning. Although it is not expected to be a large source of emissions for Canada, it will be included as an additional source in future inventories.

Annex A: Sector Description

Table A-1 Sector Description

Industrial Sources	
Aluminium Industry	Emissions from alumina production through bauxite refining, and the production of primary aluminium through smelting and refining.
Cement and Concrete Industry	Emissions from the entire process of cement production in rotary kilns, and the preparation of ready-mix concrete.
Foundries	Emissions from facilities for the production of castings of various types of ferro-alloys and small iron and steel foundries not associated with integrated iron and steel facilities.
Mining and Rock Quarrying	Emissions from overburden removal, drilling in rock, blasting, loading of materials, transporting raw materials by conveyors or haulage trucks, scraping, bulldozing, grading, open storage pile losses and wind erosion from exposed areas.
Pulp and Paper Industry	Emissions from chemical, mechanical, recycling and semi-chemical mills, including the production of energy through the combustion of spent pulping liquor, biomass and fossil-fuel combustion. Also includes fugitive emissions from wood refining, screening and drying, and various steps in chemical recovery systems.
Upstream Petroleum Industry	
Stationary Sources - Diesel Combustion	Emissions from diesel oil combustion on drilling rigs and wells, and in the servicing of wells. Diesel engines include those in use on generators, hydraulic units and pumps.
Stationary Sources - Natural Gas Combustion	Emissions from natural gas combustion at gas processing plants, compressor stations, wells, and enhanced oil recovery systems, and other sector activities.
Flaring	Emissions from the flaring of gaseous streams containing hydrocarbons among other substances.
Non-industrial Sources	
Residential Wood Combustion	
Wood Stoves	Emissions from residential woodstoves burning both firewood and wood pellets.
Furnaces	Emissions from wood furnaces, particularly from larger, exterior units.
Fireplaces	Emissions from residential fireplaces, both sealed and open units.
Mobile Sources	
Air Transportation	Emissions from piston and turbine military, commercial and general aviation (landing and take-off only), and in-flight (cruise) emissions for turbine aircraft.
On-Road Transport - Gasoline	Emissions from gasoline road vehicles, including light- and heavy-duty trucks, automobiles and motorcycles.
On-Road Transport - Diesel	Emissions from diesel road vehicles, including light- and heavy-duty trucks, and automobiles.
Off-Road Transport - Gasoline, Natural Gas	Emissions from off-road vehicles using gasoline or natural gas, including 2- and 4-stroke mining, construction, recreational, agricultural, commercial, logging, railway maintenance, airport ground support, and lawn and garden equipment.
Off-Road Transport - Diesel	Emissions from off-road vehicles using diesel oil as a fuel source, including mining, construction, recreational, agricultural, commercial, logging, railway maintenance, airport ground support, and lawn and garden equipment.
Marine	Emissions from marine craft in anchored, berth and underway phases.
Rail	Emissions from freight and passenger trains, including yard-switching activities.

Annex B: Rounding Protocol

The rounding protocol for this report is taken from Annex 9 of the Environment Canada's *National Inventory Report 1990–2012: Greenhouse Gas Sources and Sinks in Canada* (Environment Canada 2014), submitted to the United Nations Framework Convention on Climate Change (UNFCCC) in April 2014 (http://unfccc.int/files/national_reports/annex_i_ghg_inventories/national_inventories_submissions/application/zip/can-2014-nir-11apr.zip). The protocol is based on an estimated uncertainty of 10–50% for all sectors, for which the protocol indicates rounding to two significant digits. Although the rounding protocol was applied to all data in tables and charts in this report, all subtotals and totals were calculated prior to its application.

References

- Bond et al. 2013. *Bounding the role of black carbon in the climate system: a scientific assessment*. J Geophys Res 118(11): 5380–5552.
- Clearstone Engineering Ltd. 2014. *Inventory of Emissions from the Upstream Oil and Natural Gas Industry in Canada*. DRAFT. Volumes 1–4.
- Environment Canada. 2014. *National Inventory Report 1990–2012: Greenhouse Gas Sources and Sinks in Canada*: The Canadian Government's Submission to the UN Framework Convention on Climate Change, submitted to the United Nations Framework Convention on Climate Change (April 2014).
- Environment Canada. 2015. *Air Pollutant Emission Inventory Report 1990–2013*: The Canadian Government's Submission under the Convention on Long-range Transboundary Air Pollution to the United Nations Economic Commission for Europe (February 2015).
- EPA 2006. *SPECIATE 4.0*. United States Environmental Protection Agency [accessed 2007 September]. Available from: www.epa.gov/ttn/chief/software/speciate/index.html.
- EPA 2014. *SPECIATE 4.4*. United States Environmental Protection Agency [accessed 2014 October]. Available from: www.epa.gov/ttnchie1/software/speciate/.
- EPA 2014-2 *User Guide for MOVES*. 2014. Washington (DC): Office of Transportation and Air Quality. Report No.: EPA-420-B-14-055.
- McEwen JDN, Johnson MR. 2012. *Black Carbon Particulate Matter Emission Factors for Buoyancy Driven Associated Gas Flares*. J Air Waste Ma 62(3): 307–321.

