NATIONAL REPORT BY CANADA (ENGLISH VERSION) – NOVEMBER 2015

Enhanced Black Carbon and Methane Emissions Reductions– an Arctic Council Framework for Action

Environment Canada
Environnement Canada

Canada's National Black Carbon and Methane Report

2015

Canada

Cat. No.: En14-240/2015E-PDF
ISBN: 978-0-660-03579-6

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Canada's National Black Carbon and Methane Report

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List of Acronyms, Abbreviations and Units

BC	British Columbia
CAD	Canadian dollars
CCAC	Climate and Clean Air Coalition
CEC	Commission for Environmental Cooperation
CLRTAP	Convention on Long-Range Transboundary Air Pollution
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
GHG	Greenhouse gas
Kt	Kilotonne
kW	Kilowatt
kWh	Kilowatt hour
LULUCF	Land Use, Land-use Change and Forestry sector
$PM_{2.5}$	Particulate matter up to 2.5 micrometres in size
ppm	Parts per million
SLCP	Short-lived climate pollutant
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change

Introduction

Canada is pleased to submit its first National Black Carbon and Methane Report to the Arctic Council Secretariat, as the first part of the important work that will support the implementation of the Arctic Council *Framework for Enhanced Action on Black Carbon and Methane Emissions Reductions* (the Framework).

Canada recognizes the importance of climate change and, as an Arctic nation, is particularly affected by its impacts. Advancing work globally to tackle short-lived climate pollutants (SLCPs) is part of Canada's comprehensive climate change approach. Through its Chairmanship of the Arctic Council (2013-2015), one of Canada's priority initiatives was to advance work on addressing black carbon and methane. This initiative is especially important for Canada as SLCPs significantly impact the health and well-being of Northern communities and their environment.

Canada currently reports its black carbon emissions to the United Nations Economic Commission for Europe (UNECE) and its greenhouse gas emissions and mitigation activities, including methane to the United Nations Framework Convention on Climate Change (UNFCCC).

This report, however, is the first of its kind for Canada. It provides a snapshot of the policies, measures and activities Canada has in place at both the national and subnational levels to address black carbon and methane emissions and their impacts on the Arctic. This report will aim to assist the Framework Expert Group in their development of advice and recommendations concerning black carbon and methane to Arctic Council Ministers for 2017.

This first report establishes a necessary baseline for Canada's future submissions and moving forward, we will be able to learn from the experiences of other Arctic States and participating Observer States to build upon the information made available here.

The Framework is an important achievement for all Arctic States, as we share in the commitment to achieve enhanced black carbon and methane emissions reductions in the Arctic, and to continue improvements for climate and health in the Arctic.

Canada is committed to supporting the implementation of the Framework domestically and internationally, including through our bilateral, regional, and global partnerships and reporting under the UNFCCC and CLRTAP.

Chapter 1
Black Carbon Emissions

Canada submitted its first national inventory of anthropogenic black carbon emissions to the United Nations Economic Commission for Europe (UNECE) in February 2015, for the year 2013. In 2013, approximately 45,000 tonnes (45 kt) of black carbon were emitted in Canada. Mobile sources were the most important source of black carbon emissions in Canada, accounting for 65% of total emissions on that year (Table 1).

Black carbon emissions in Canada can be grouped into three main categories:

Industrial sources

Black carbon emissions from industrial sectors represent 9% of total black carbon 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.

Non-industrial sources

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.

Mobile sources

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.

The sources included in Canada's 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, such as from electric power generation and prescribed burning, and refining base data and estimation techniques.

Further information on the results of Canada's initial efforts to develop an inventory of anthropogenic black carbon emissions, including details on the key sources of black carbon emissions, can be found at the following location: http://ec.gc.ca/pollution/default.asp?lang=En&n=D9D3F803-1

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

Sector	Black Carbon (tonnes)	Percentage of Total
Industrial Sources	4 100	9%
Total of Aluminum, Cement and Concrete, Foundries, Mining and Rock Quarrying, and Pulp and Paper Industry	500-600 (550)	1%
Aluminum 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%

Chapter 2
Methane Emissions

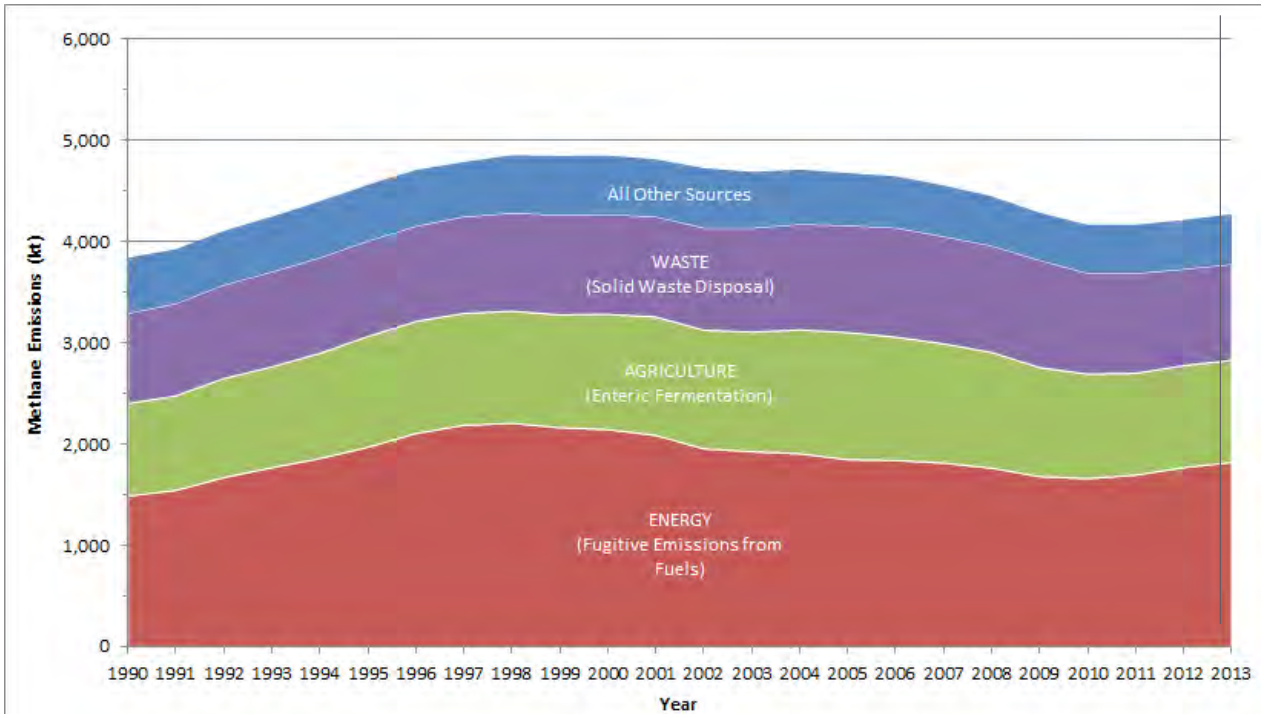
Canada's first greenhouse gas (GHG) inventory containing methane emissions was prepared in 1992, followed by a second in 1994. Since 1996, GHG inventories have been prepared and submitted to the United Nations Framework Convention on Climate Change (UNFCCC)[1] annually.

Based on Canada's 2015 National GHG Inventory Submission, Canada's total methane emissions in 2013 were estimated to be 4,270 kt or 106,758 kt in carbon dioxide equivalent[2] excluding the Land Use, Land-use Change and Forestry (LULUCF) sector. Methane emissions represent 15% of Canada's total GHG emissions. The primary sources of methane in Canada for 2013 were fugitive emissions (energy sector), enteric fermentation (agricultural sector) and solid waste disposal (waste sector), respectively representing 43%, 24% and 22% of total methane emissions.

National methane emissions increased by 26% from 1990 to 1998, decreased by 14% between 1998 and 2011, slightly increasing (by 2%) thereafter through 2013 (Figure 1).

Table 10.3 from the Common Reporting Format tables submitted to the UNFCCC presents Canada's methane emission trends by source and sink categories from 1990 to 2013. Refer to the appendix of this report.

Figure 1: Trends in Canada's Methane Emissions by Largest Contributing Sources, excluding LULUCF



1 Available at http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/8812.php

2 Using a 100-yr global warming potential for methane of 25, from the Intergovernmental Panel on Climate Change's Fourth Assessment Report.

Fugitive Emissions

Fugitive emissions from fuels are the intentional or unintentional releases of GHGs from the production, processing, transmission, storage and delivery of fossil fuels. Released gases that are combusted before disposal (e.g. flaring of natural gases at oil and gas production and processing facilities) are also considered fugitive emissions.

In 2013, fugitive methane emissions from fuels were 1,819 kt. Between 1990 and 2013, fugitive methane emissions have increased by 332 kt (22%) and since their peak in 1998, have decreased by 387 kt (18%). The growth in emissions is a result of the increased production of natural gas, heavy oil, crude bitumen and synthetic crude oil; however provincial measures introduced by the Governments of Alberta, Saskatchewan and British Columbia have resulted in a decrease in fugitive emissions intensity in the industry. Additional information on these provincial measures is provided in Chapter 3.

Enteric Fermentation

All of enteric fermentation emissions come from agricultural livestock, resulting in emissions of 1,009 kt of methane in 2013. Since 1990, methane emissions from this source have increased by 96 kt (10%) and have decreased by 246 kt (20%) since their peak in 2005. The main drivers of this trend are the intensification, expansion and then decline of the beef cattle and swine populations throughout the time series.

Solid Waste Disposal

Emissions from solid waste disposal were 950 kt in 2013, and consisted of the combined emissions from municipal solid waste landfills and wood waste landfills. Since 1990, methane emissions from this subsector have increased by 56 kt (6.3%) and since their peak in 2006, have decreased by 130 kt (12%). Emissions have increased due to increases in landfill operations; however, these increases have lessened by the growing volumes of landfill gas captured and combusted at the landfill sites.

All Other Sources

Emissions from all other sources of methane include those from fossil fuel combustion, manure management, and wastewater treatment and discharge. Combined, all other sources emitted 493 kt in 2013, representing about 11% of total methane emissions. Refer to the appendix of this report for additional details.

Land Use and Land-Use Change and Forestry

Emissions from wildfires in Canada's managed forests can episodically be significant, such as in 1995 when these non-anthropogenic emissions would have added 20% to total methane emissions from human-caused sources.

Chapter 3
Summary of National Actions, National Action Plans, Mitigation Strategies

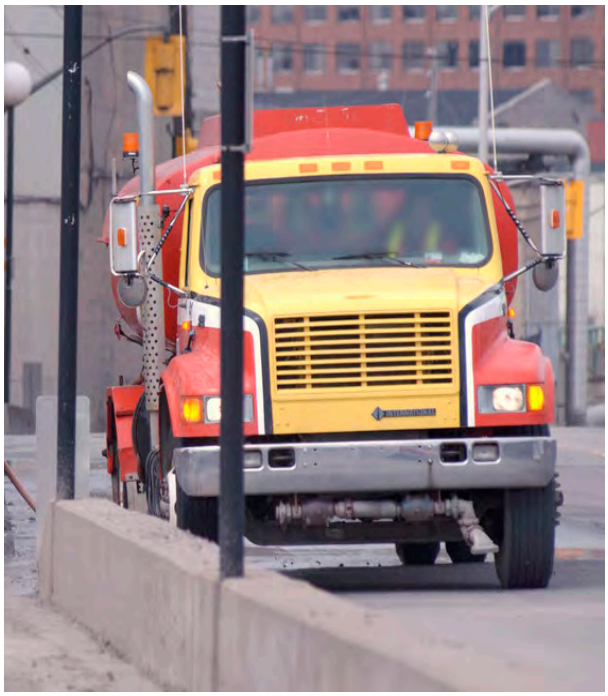
Protection of the environment is a shared responsibility in Canada. Federal, provincial and territorial governments have implemented a broad range of regulatory and non-regulatory measures that already reduce, or will reduce, black carbon and methane emissions. While not representative of all the activities within Canada that help to address black carbon and methane emissions, the sections below highlight examples of key initiatives.

Summary of Black Carbon Mitigation Actions

Canada is taking domestic action to address air pollution through a range of measures and regulations that are or will reduce emissions of black carbon across major-emitting sectors and throughout the country. Federally, these include a suite of air pollution regulations for the transportation sector and the implementation of the nation-wide *Air Quality Management System* to reduce emissions of air pollutants from industrial sources. Canada's approach to reducing greenhouse gas (GHG) emissions has also resulted in regulations that achieve co-benefits of black carbon reductions. In addition, a number of provinces and territories have implemented measures that reduce emissions of black carbon, including from on-road vehicles, wood-burning appliances, agricultural burning, open biomass burning, electricity generation, and flaring operations in the oil and gas sector.

Transportation

At the federal level, some of the most significant measures impacting black carbon have been taken in the transportation sector. Air pollutant emission regulations are in place for a broad range of on-road and off-road vehicles and engines, and for the sulphur content in gasoline and diesel fuel. Canada's *On-Road Vehicle and Engine Emission Regulations*[3], *Off-Road Compression-Ignition Engine Emission Regulations*[4], Off-Road Small Spark-Ignition Engine Emission Regulations[5], and Sulphur in Diesel Fuel



Regulations[6] contribute to reducing emissions of black carbon as a component of particulate matter (PM) from diesel exhaust emissions. These regulations establish air pollutant emission standards for various types of vehicles, in alignment with U.S. Environmental Protection Agency (EPA) regulations. Canada's transportation regulations were made more stringent in July 2015 when Canada adopted the Tier 3 Vehicle and Fuel Standards; cutting smog-forming air pollutant emissions for new vehicles by up to 80 percent compared to the current standards. The *Sulphur in Diesel Fuel Regulations* enable the use and effective operation of vehicle and engine exhaust after-treatment systems and contribute to reducing emissions of a range of harmful air pollutants.

In the marine sector, Canada's *Marine Spark-Ignition Engine, Vessel and Off-Road Recreational Vehicle Emission Regulations*[7] contribute to reductions of black carbon emissions as a component of PM, and in 2012 the Government of Canada published the *Vessel Pollution and Dangerous Chemicals Regulations*[8] which limit air pollutants, including PM, from marine shipping in Canadian waters. Canada also established, in collaboration with the United States (U.S.), the North American Emission Control Area (ECA) within which marine vessels are required to reduce their air

3 http://laws-lois.justice.gc.ca/eng/regulations/SOR-2003-2/index.html
4 http://laws-lois.justice.gc.ca/eng/regulations/SOR-2005-32/index.html
5 http://www.ec.gc.ca/lcpe-cepa/eng/regulations/detailReg.cfm?intReg=81
6 http://www.ec.gc.ca/lcpe-cepa/eng/regulations/DetailReg.cfm?intReg=211
7 http://www.ec.gc.ca/lcpe-cepa/eng/regulations/detailReg.cfm?intReg=109
8 http://laws-lois.justice.gc.ca/eng/regulations/sor-2012-69/page-1.html

pollutant emissions (including fine particulate matter ($PM_{2.5}$)). The North American ECA came into force in August 2012 and as of January 1, 2015, ships operating in the ECA have been required to use fuels with 0.1% (1,000 ppm) or less sulphur content or apply equivalent emission controls. The Global standard outside of the North American ECA is 3.5%. The ECA is expected to reduce PM emissions from ships by 74% by 2020, resulting in associated reductions in black carbon emissions.

Canada is also developing regulations to control air pollutant emissions under the *Railway Safety Act*. The proposed regulations would be aligned with those of the U.S., and would apply to federal railway companies operating in Canada. The Government of Canada has a Memorandum of Understanding with the Rail Association of Canada to align with U.S. EPA Tier 4 standards for locomotive emissions. There is also a 15 ppm limit for sulphur in diesel fuel produced or imported for use in locomotives under the *Sulphur in Diesel Fuel Regulations*.

Beyond the regulatory measures, information and awareness raising measures also exist. The *SmartWay Transport Partnership*[9], for example, delivered in Canada by Natural Resources Canada and in the U.S. by the EPA, is a collaborative initiative designed to help businesses reduce fuel costs while transporting goods in the cleanest, most efficient way possible. SmartWay uses fuel, mileage and payload data about carriers to estimate freight carrier emissions rates, including of PM. Companies that hire freight transportation services can use SmartWay emissions information to compare carriers for contracting purposes. At the end of each year, businesses can calculate their own freight emissions footprints using emissions information from the SmartWay carriers they worked with.

Several Canadian provinces also have transportation programs and policies in place that impact emissions of black carbon, including legislated annual motor vehicle inspections for exhaust systems, vehicle anti-idling campaigns, anti-tampering of emissions control devices, and scrappage or retrofitting programs for older, higher polluting vehicles. Nova Scotia's *Sustainable Transportation Strategy*[10] also includes grant programs to support community-based sustainable transportation initiatives across the province. Ontario's *Drive Clean* program[11] requires periodic emissions testing for light- and heavy-duty vehicles and the province's *Electric Vehicle Incentive* program[12] encourages the adoption by individual, businesses, non-profits and non-governmental organization of light-duty electric passenger vehicles. Quebec's *Drive Electric Program*[13] offers a purchase or lease rebate for individuals, businesses, non-profit organizations, and municipalities that wish to acquire an all-electric, plug-in hybrid, hybrid or low-speed electric vehicle, or for individuals wishing to install a charging station for their vehicle at home.

Electricity Generation

In 2012, Canada finalized its *Reduction of Carbon Dioxide Emissions from Coal-Fired Generation of Electricity Regulations*[14] to reduce GHG emissions from coal-fired electricity generation. With these regulations, Canada became the first major coal user to ban the construction of traditional coal-fired electricity generation units. In addition to reducing GHG emissions, these regulations will lead to reductions of PM emissions, of which black carbon is a component, resulting in improved air quality and human health.

The Province of Nova Scotia has a number of regulations that reduce GHG emissions with the co-benefit of reduced black carbon emissions from electricity generation. These include renewable electricity regulations that require 25% of electricity supply to be generated from renewal sources by 2015 and 40% by 2020[15], and GHG and air pollutant emissions regulations that apply a declining cap on emissions from electricity generation facilities[16]. Prince Edward Island has also moved to address black carbon emissions from electricity generation by implementing a renewable portfolio standard that, to date, has resulting in 25% of electricity consumption in that province being sourced from on-island wind farms.

The governments of Manitoba, Quebec, Newfoundland and Labrador, the Northwest Territories, Yukon and Ontario are establishing a Pan-Canadian Task Force to reduce the use of diesel fuel to generate electricity in remote communities. This is part of a shared commitment of these provinces and territories to address climate change, support energy innovation, secure energy supply and strengthen the

9 http://www.nrcan.gc.ca/energy/efficiency/transportation/commercial-vehicles/smartway/7615
10 http://novascotia.ca/sustainabletransportation/
11 https://www.ontario.ca/page/drive-clean
12 http://www.mto.gov.on.ca/english/vehicles/electric/electric-vehicle-incentive-program.shtml
13 http://vehiculeselectriques.gouv.qc.ca/english/particuliers/rabais.asp
14 http://www.ec.gc.ca/lcpe-cepa/eng/regulations/detailReg.cfm?intReg=209
15 https://www.novascotia.ca/just/regulations/regs/elecrenew.htm
16 https://climatechange.novascotia.ca/what-ns-is-doing

economy. Reducing or eliminating diesel use in these communities would reduce harmful emissions and help promote cleaner and more economical energy solutions. The main objective of the task force is to prepare a joint report on existing practices, to share information on efforts currently underway, as well as to identify opportunities for collaboration and risk mitigation strategies.

Oil and Gas

Provincial flaring and venting measures in Alberta, Saskatchewan, and British Columbia, detailed in the following "Summary of Methane Mitigation Actions" section, also lead to reductions in black carbon emissions, as would proposed federal methane regulations.

Residential Wood Burning

The Canadian Council of Ministers of the Environment (CCME), an intergovernmental forum of federal, provincial and territorial Ministers of the Environment in Canada that facilitates collective action on environmental issues of national and international concern, has led a major domestic initiative for mitigation of various sources of black carbon and other air pollutants from residential wood combustion.

The CCME's 2012 *Code of Practice for Residential Wood Burning Appliances*[17] was designed to assist jurisdictions with implementing more stringent regulations, developing economic incentives, and launching educational initiatives to mitigate residential wood burning emissions. The Code also aids municipalities in by-law and program development to help drive replacement of conventional wood burning appliances in favour of advanced technology (certified) appliances and fireplaces, and includes a *Model Municipal By-law for Regulating Wood Burning Appliances*. The model by-law was developed for use by municipalities to assist in regulating the use of wood-burning appliances. It lays out mitigation options, including restrictions on fuel types, suggested no-burn days, and the provision of information on the proper installation of wood-burning appliances.

The Provinces of British Columbia[18], Newfoundland, Nova Scotia[19] and Quebec[20] have regulations on the sale of wood-burning appliances, requiring conformity with particulate emissions standards, as defined by the U.S. EPA or Canadian Standards Association (CSA) codes. The Territory of Nunavut has a guideline for the operation of wood-burning appliance that recommends the use of stoves meeting EPA or CSA standards, and the Provinces of Ontario, British Columbia, and Quebec have empowered municipalities to regulate wood-burning appliances and produced a model municipal Code of Practice to guide municipalities wishing to take measures to reduce emissions from these appliances.

Some also have regulated codes of practice and/or wood stove change out programs[21]. British Columbia established a wood stove change out program in 2007, with the long term goal of changing out 50,000 wood stoves and reducing $PM_{2.5}$ emissions by 3,100 tonnes per year. So far (in 2014), approximately 6000 stoves had been changed out, reducing PM emissions by an estimated 370 tonnes per year. Also in place in British Columbia is a wood residue burner and incinerator regulation that establishes phase-out dates and operating conditions for specified burners, and sets emissions limits and fees for the discharge of PM for all burner facilities in the province.

The Government of the Northwest Territories' *Biomass Energy Strategy*[22] includes measures to upgrade conventional wood stoves through change out programs, rebates for new appliances and public education. The Northwest Territories also has measures in place to promote the use of wood pellets for residential, commercial and institutional space heating, replacing the use of heating oil. In addition,

17 http://www.ccme.ca/en/resources/air/wood_burning.html

18 http://www.bcairquality.ca/topics/wood-burning-appliances.html
19 http://www.novascotia.ca/just/regulations/regs/eeappliances.htm
20 http://www.mddelcc.gouv.qc.ca/air/chauf-bois/index-en.htm
21 http://www.bcairquality.ca/topics/wood-stove-exchange-program/
22 http://www.nwtclimatechange.ca/content/biomass

Yukon's *Good Energy Rebate Program*[23] provides 20% off pre-tax purchase of wood (including pellets) boilers, furnaces and stoves required to meet energy efficiency and safety standards. Yukon's *Draft Biomass Strategy* also promotes replacing old, inefficient systems with modern, efficient and clean-burning appliance to reduce emissions associated with wood-burning.

Industrial Sectors

Canada's *Air Quality Management System* (AQMS) is a comprehensive, cross-Canada system for coordinated federal, provincial and territorial action to protect human health and the environment through continuous improvement of air quality[24].

As part of implementing the AQMS, in 2013 new *Canadian Ambient Air Quality Standards* (CAAQS) for $PM_{2.5}$ and ground-level ozone (the major components of smog) for 2015 were established, which become more stringent in 2020[25]. Work also includes the development of new CAAQS for sulphur dioxide and nitrogen dioxide, two other air pollutants of concern. These standards are more stringent and more comprehensive than the previous Canada-wide Standards for these pollutants. Furthermore, the CAAQS introduced a new long-term standard for $PM_{2.5}$. Under the AQMS framework, the Government of Canada is also implementing industrial emission requirements that will achieve reductions of black carbon emissions through emissions limits on $PM_{2.5}$. In June 2014, Canada published proposed regulations for the cement industry, industrial boilers and heaters, and stationary engines as well as two Codes of Practices which will help to reduce $PM_{2.5}$[26].

At the provincial and territorial level, the main mechanism for control of industrial air emissions is through permitting requirements for specific industries. Permits are issued by the provincial, territorial, regional or municipal government. In some cases, industries are governed through separate legislation or codes of practice established by provinces. In the Northwest Territories, used oil and waste fuel management regulations include procedures for the burning of waste oil and permits such as burning only in non-residential areas.

Agricultural and Open Burning

Many Canadian provinces and territories have regulations on agricultural burning, including waste control regulations such as those in British Columbia that establish practices for using, storing and managing agricultural waste[27]. As a result of Yukon's 2009 *Solid Waste Action Plan*, open burning has been phased out at the territory's public, government operated waste disposal facilities. The Northwest Territories has also prohibited the burning of unsegregated waste in community dumps. Many provinces also have regulations governing the burning of crop residue and non-crop herbage, including limiting it to specific periods of the year. In Prince Edward Island, regulations set limits on emissions as well as requirements for the design and operation of municipal solid waste incinerators and, in Ontario, a model municipal code of practice provides recommendations for municipalities to from outdoor fireplaces, waste burning, agricultural burning and construction and demolition fires.

Education and incentive programs are also used by provinces to promote improvements in crop residue management and to reduce burning. Quebec, for example, provides financial support for manure processing and energy from agricultural, forest and municipal biomass through a program that supports municipalities and private industry to establish infrastructure to process organic matter through biomethanization or composting.

Most provinces also have forest protection and fire management legislation and regulations under their air quality regulations, as well as municipal by-laws regulating solid waste and open burning. The Province of British Columbia is revising the *Open Burning Smoke Control Regulation promulgated under the Environmental Management Act*[28].

Summary of Methane Mitigation Actions

Current and planned GHG regulatory and non-regulatory measures at federal, provincial and territorial levels in the agriculture, waste and oil and gas sectors are reducing and will continue to reduce methane emissions.

23 http://www.goodenergyyukon.ca/?utm_source=oldappliancepage
24 http://www.ccme.ca/en/current_priorities/air/
25 http://www.ec.gc.ca/default.asp?lang=En&n=56D4043B-1&news=A4B2C28A-2DFB-4BF4-8777-ADF29B4360BD
26 http://ec.gc.ca/lcpe-cepa/eng/regulations/detailReg.cfm?intReg=220
27 BC's Agriculture Waste Control Regulation regulates the managing, storing, using and disposing of agricultural waste. http://www.bclaws.ca/Recon/document/ID/freeside/10_131_92
28 The Open Burning Smoke Control Regulation – regulates Open Burning (prohibits certain materials –i.e., plastics, manure- from being open burned, and regulates open burning for other materials – i.e., land clearing from Agriculture). http://www.bclaws.ca/Recon/document/ID/freeside/34_145_93

Agriculture

Federal-provincial-territorial cost-shared programming under Canada's agricultural policy framework, *Growing Forward 2*, funds on-farm planning and incentives to accelerate action to reduce environmental impacts from production, including GHG emissions[29]. On-farm beneficial management practices can have multiple environmental co-benefits, so while practices are not targeted solely at methane reduction, many, such as manure storage and treatment, contribute to this objective. Research into GHG mitigation strategies for Canada's agriculture industry, includes the five-year *Agricultural Greenhouse Gases Program* (AGGP), where a third of the funded projects are addressing methane emissions from livestock systems[30].

Canadian provinces have also introduced programs and measures to reduce methane emissions from the agricultural sector. For example, Quebec's *Programme Prime Vert* aims to help farmers protect the environment by supporting the capture, destruction or recycling of methane from manure pits and providing project funding to promote GHG emissions reductions in the agricultural sector[31]. Other provinces, such as New Brunswick, are encouraging farm management best practices to reduce methane emissions from fertilizer, feed and other agricultural sources[32].

29 http://www.agr.gc.ca/eng/about-us/key-departmental-initiatives/growing-forward-2/?id=1294780620963
30 http://www.agr.gc.ca/eng/?id=1331047113009
31 http://www.mapaq.gouv.qc.ca/fr/Productions/md/programmesliste/agroenvironnement/Pages/primevert.aspx
32 http://www2.gnb.ca/content/gnb/en/services/services_renderer.201324.Environmentally_Sustainable_Agricultural_Production_Program.html

Waste

Canada has established funding incentives and programs for provincial, territorial and municipal governments, public sector bodies, non-profit organizations, and private sector companies to promote recycling, organics processing, and technologies such as landfill gas capture, some of which reduce methane emissions. Funding programs include: the *Gas Tax fund*[33], *Green Infrastructure Fund*[34], *Green Municipal Fund*[35], *ecoENERGY for Renewable Power*[36], *EcoAction Community Funding Program*[37], and funding through Sustainable Development Technology Canada[38].

In 2013, Environment Canada published a *Technical Document on Municipal Solid Waste Organics Processing*, which provides science-based, objective and user-friendly information on organic waste management processing[39]. The Technical Document draws on lessons learned and expert knowledge from professionals, practitioners and academics across North America, and covers a wide range of topics including the science and principles of composting and anaerobic digestion, proven processing technologies, biogas utilization, facility design, odor control, compost quality, procurement approaches, and system selection.

In 2014, Environment Canada commissioned Ecology North, a non-profit that aims to bring people and knowledge together for a healthy northern environment, to complete a feasibility study for centralized composting of organic waste in Hay River, Northwest Territories[40]. The study report includes a detailed review of centralized composting initiatives in other small- to medium-sized northern communities in Alaska, the Canadian Territories and Greenland.

Many Canadian provinces, territories and municipalities have implemented regulations requiring landfill gas capture, regulations aimed at diverting waste away from landfills, and programs to support improved waste management practices that will

33 http://www.infrastructure.gc.ca/plan/gtf-fte-eng.html
34 http://www.infrastructure.gc.ca/prog/gif-fiv-eng.html
35 http://www.fcm.ca/home/programs/green-municipal-fund.htm
36 https://www.nrcan.gc.ca/ecoaction/14145
37 http://www.ec.gc.ca/ecoaction/
38 http://www.ec.gc.ca/scitech/default.asp?lang=En&n=7C0A752B-1
39 The report is available online: http://ec.gc.ca/Publications/default.asp?lang=En&xml=6CC55580-0271-46F0-99CC-CADD171C1976
40 The report is available online: http://ecologynorth.ca/mwg-internal/de5fs23hu73ds/progress?id=XiDpxQLiQMCowEpFvoB26rSxAsH-ZZbTlaLHcZ6drS4

reduce methane emissions from the waste sector. Nova Scotia's *Solid Waste Resource Management Regulations* resulted in Nova Scotia having the highest waste diversion rate in Canada, and includes a ban on organics entering landfills[41]. Currently 70% of Nova Scotia organic waste is diverted from all landfills into aerobic processing; converting the potential methane from these organics to CO_2 emissions (25 times lower global warming potential)[42]. Alberta's 2007 *Specified Gas Emitters Regulation* sets increasingly stringent emissions intensity reduction targets for all existing large industrial facilities emitting 100,000 tonnes of CO_2e or more per year, including landfills. Companies can meet their targets by making facility improvements, payments into a *Climate Change and Emissions Management Fund* or through the purchase of offset credits or emissions performance credits[43].

Oil and Gas

In May 2015, the Government of Canada announced its intent to develop regulations to reduce emissions of methane from the oil and gas sector, in alignment with U.S. action in this area[44]. The existing and recently proposed U.S. requirements that reduce methane, which are being considered for the Canadian context, include: reduced emissions completions at hydraulically fractured wells; emission limits for pneumatic devices, compressors and storage tanks; and leak detection and repair requirements. The proposed federal methane regulations would build on provincial actions and ensure consistent requirements across Canada.

Many oil and gas producing provinces have also implemented measures that help to reduce methane emissions. The province of Alberta has reduced flaring and venting, and associated emissions of methane and black carbon, through regulatory measures and financial incentives[45]. Gas associated with upstream oil production is subject to royalties, however royalties are not paid on volumes of raw gas that are flared or vented. Companies venting or flaring large volumes of gas are required to recover the gas subject to an economic test, and will then pay royalties on the gas recovered. If, however, gas recovery occurs despite failing the economic test, companies may apply for a royalty waiver on the conserved gas. Companies emitting less than 100,000 tonnes of CO_2e annually are also incentivized to reduce emissions by being permitted to sell offset credits for emissions reductions achieved from fuel efficiency of natural gas combustion engines and the capture of gases (primarily methane) that would otherwise be vented, and from switching from instrument gas to instrument air in process control systems to reduce released gas (primarily methane) from these devices. Alberta is currently reviewing its approach to climate change and has noted in their August 2015 *Climate Leadership Discussion Document* that there is a significant opportunity for further methane reductions from the oil and gas sector[46].

Saskatchewan[47] and British Columbia (BC) have similar requirements to those of Alberta. When natural gas is flared in BC, it is subject to BC's revenue neutral carbon tax[48]. The 2007 *BC Energy Plan* set a target to eliminate routine associated gas flaring by 2016, and this was achieved in 2010. There is also a BC *Oil and Gas Commission Flaring Venting and Reduction Guideline* in place, and it is reviewed and updated regularly to ensure efficiency. A key component of the Guideline is that venting is not considered to be an acceptable alternative to flaring. If gas volumes are sufficient to sustain stable combustion, the gas must be contained or conserved[49]. In addition, the Northwest Territories' territorial government has published draft hydraulic fracturing regulations, which include filing requirements for air quality assessment, monitoring and waste gas management[50].

In addition, Natural Resources Canada is undertaking research and developing a technology roadmap to address wellbore leakage. Boreholes that are drilled to access oil and gas reservoirs have been identified as the most important cause of methane leakage in the oil and gas sector. Currently, about 5% of wells in Canada are estimated to be leaking. However, technologies and methods to effectively detect, prevent and repair these leaks are not well understood. The roadmap will identify the knowledge and technology gaps that must

41 https://www.novascotia.ca/just/regulations/regs/envsolid.htm
42 http://www.novascotia.ca/nse/waste/strategysummary.asp
43 http://esrd.alberta.ca/focus/alberta-and-climate-change/regulating-greenhouse-gas-emissions/greenhouse-gas-reduction-program/default.aspx
44 http://news.gc.ca/web/article-en.do?nid=974959
45 https://www.aer.ca/rules-and-regulations/by-topic/flaring-and-venting
46 http://alberta.ca/climate-leadership.cfm
47 http://www.flarevent.com/wp-content/uploads/2011/06/Saskatchewan-directive-S-20-July-1-2011.pdf
48 http://www.fin.gov.bc.ca/tbs/tp/climate/carbon_tax.htm
49 The Commission has produced a series flaring reports that are publically available since the 2008 calendar year. The latest 2013 report is available online at https://www.bcogc.ca/node/12290/download
50 http://www.iti.gov.nt.ca/infopage/hydraulic-fracturing-filing-regulations-information

be filled in order to address the significant methane emissions from wellbore leakage. The roadmap is being developed in collaboration with stakeholders from provincial and territorial jurisdictions as well as industry and academia across Canada and the U.S[51].

Transportation

Recent GHG emissions regulations for new on-road light- and heavy-duty vehicles and engines, aligned with those in the U.S., will reduce GHG emissions in all regions of Canada – including the North[52]. Alongside reducing emissions of CO_2, these GHG regulations include limits on emissions of methane and nitrous oxide (N_2O) from new light duty vehicles and heavy duty vehicles and engines.

In October 2010, Canada published its *Passenger and Automobile and Light Truck Greenhouse Gas Emission Regulations*. These regulations set greenhouse gas emission standards for light-duty vehicles for model years 2011-2016 and are aligned with the U.S. In October 2014, Canada published final regulations to establish more stringent standards for model years 2017-2025. With these regulations, 2025 model year vehicles are projected to consume up to 50% less fuel and produce about 50% fewer GHG emissions than 2008 vehicles.

In March 2013, the *Heavy-Duty Vehicle and Engine Greenhouse Gas Emissions Regulations* were published. These regulations limit greenhouse gas emissions from new on-road heavy-duty vehicles for model years 2014-2018 and are aligned with the U.S. With these regulations, emissions from 2018 model years are projected to be reduced by 23% compared to current standards. Canada is also moving forward with regulations for post-2018 model year heavy-duty vehicles.

51 http://www.nrcan.gc.ca/energy/offices-labs/canmet/5765
52 https://www.ec.gc.ca/cc/default.asp?lang=En&n=E97B8AC8-1

Chapter 4
International Cooperation

Canada's domestic efforts to achieve measurable climate and health benefits in the North are complemented by our engagement on SLCP work internationally. This includes engagement in the Arctic Council, which is also advancing global action to reduce black carbon and methane. Recognizing that black carbon and methane emitted within, as well as, beyond the border of Arctic nations have substantial impact on the Arctic, we recognize the necessity to address SLCPs within our bilateral, trilateral (e.g. Commission for Environmental Cooperation), and multilateral partnerships (e.g. Climate and Clean Air Coalition).

Summary of International and Regional Actions to Address Black Carbon and Methane

Commission for Environmental Cooperation

Under the Commission for Environmental Cooperation's (CEC) *2013-2014 Operational Plan*, Canada, alongside the U.S. and Mexico, coordinated trilateral work to identify and develop methodologies to improve the accuracy of black carbon and co-pollutant emissions estimates. This work by experts from Canada, Mexico and the U.S. aims to support the development of reliable inventories, establishing baselines and determining reduction priorities for relevant pollutants by source category or location. A guidance document for estimating black carbon from certain sources has been completed.

Convention on Long-Range Transboundary Air Pollution

Under the United Nations Economic Commission for Europe (UNECE), Canada is a signatory to the Convention on Long-Range Transboundary Air Pollution (LRTAP). The Gothenburg Protocol became the first international treaty to explicitly include a SLCP when it was amended in 2012 to include $PM_{2.5}$ and black carbon as a component of $PM_{2.5}$.

Canada submitted its first national inventory of black carbon emissions to the UNECE in February 2015, for the year 2013[53].

53 https://www.ec.gc.ca/pollution/default.asp?lang=En&n=3F796B41-1

Global Methane Initiative

Canada participates in the Global Methane Initiative, providing overall direction and supporting capacity building and the development and implementation of public-private clean energy technology projects to reduce methane emissions. Between 2007 and 2012, Canada invested more than CAD 2.5 million in methane emission reduction projects, including feasibility studies, initial measurements, baseline monitoring and capacity building to help reduce fugitive emissions in the oil and gas sectors in China and Mexico, and in the waste sector in Mexico.

United Nation Framework Convention on Climate Change

Methane is one of the seven GHGs measured and reported on under the United Nations Framework Convention on Climate Change (UNFCCC), and reductions count towards Canada's 2020 and 2030 targets. Canada reports its methane emissions in its annual National Inventory[54] and describes mitigation actions, measures, and estimates for methane projections in its Biennial Report and its National Communication[55].

Climate and Clean Air Coalition

Under the Climate and Clean Air Coalition (CCAC), Canada is co-leading the development and implementation of several initiatives that address black carbon and methane emissions including: reducing black carbon from heavy-duty diesel vehicles and engines; reducing methane emissions from municipal solid waste; reducing black carbon and methane from agriculture; and leading demonstration projects in Mexico and Colombia to reduce black carbon from oil and gas operations utilizing innovative Canadian clean energy technologies. More information on Canada's leadership under the CCAC can be found in Chapter 5 of this National report.

United Nations Environment Programme Partnership for Clean Fuels and Vehicles

The *Partnership for Clean Fuels and Vehicles* is a leading global public-private initiative administered by the United Nations Environment Programme (UNEP) to promote cleaner fuels and vehicles in developing and transitional countries[56]. The latest initiative which Environment Canada provided funding to, through a Contribution Arrangement to UNEP, included the development of a toolkit to support developing and transitional countries to introduce requirements for a maximum 50 ppm sulphur fuels (e.g. diesel); produce or import lower emitting and more efficient vehicle technologies; establish vehicle emissions control roadmaps; and, ultimately improve air quality and human health in these countries[57]. The toolkit was developed in partnership with the U.S. Environmental Protection Agency.

Canada's Fast-Start Finance

Through Canada's fast-start financing, Canada has provided support for bilateral projects that reduce black carbon and methane emissions. Over CAD 7.5 million has been provided to support the development of Nationally Appropriate Mitigation Actions in Mexico, Chile, and Colombia in key sectors such as waste and oil and gas production - as well as to support the deployment of clean cookstoves in Africa, Latin America and the Caribbean through the Global Alliance for Clean Cookstoves.

Under fast-start finance, Canada also provided over CAD 3 million to the Center for Clean Air Policy for supporting the development of policy frameworks and projects for waste management, including a series of measures for the whole waste stream that will reduce emissions of SLCPs such as black carbon and methane.

Arctic Council and the International Arctic Science Committee

As a member state of the Arctic Council and the International Arctic Science Committee (IASC), Canada has established a Sustaining Arctic Observing Networks (SAON) National Coordinating Committee to encourage sustained and coordinated pan-Arctic observing and data sharing in Canada to serve societal needs. During Canada's Chairmanship of the Arctic Council (2013-2015), Canada was the international Chair of SAON. In support of SAON Canada, the Canadian Polar Commission released a report in 2015 on the *State of Environmental Monitoring in Northern Canada*[58]. The report provides a snapshot of monitoring activities in northern Canada as of December 2014, based on metadata on atmosphere, cryosphere, freshwater, marine, terrestrial, and human health monitoring initiatives in Canada's North. The maps featured in the report indicate which parameters are being measured at specific locations, to identify potential areas of overlap, gaps in coverage, and opportunities

54 https://www.ec.gc.ca/ges-ghg/default.asp?lang=En&n=83A34A7A-1

55 http://ec.gc.ca/Publications/default.asp?lang=En&xml=6FF30D6E-B8E3-4102-86E7-652D156E020A

56 www.unep.org/transport/new/pcfv/

57 http://www.unep.org/Transport/new/PCFV/RegulatoryToolKit/index.html

58 http://www.arcticobservingcanada.ca/state-of-monitoring.html

for synergies. The accompanying metadata-set is a key part of the report and is publicly accessible. The report and accompanying dataset provide the fundamental background to support decisions on investment in new monitoring sites, and re-deployment and expansion of existing sites to achieve increased coverage of key parameters in priority areas. They identify opportunities to maximize the benefit of monitoring efforts through increased collaboration and inform strategic planning. The value-added information available in the dataset can be used in further analyses.

World Bank

The province of Alberta recently renewed its partnership with the World Bank on its *Global Gas Flaring Reduction Partnership*, a public-private initiative that aims to promote continued reductions in global flaring, through monitoring and reporting, research, sharing of best practices, and developing country-specific gas flaring reduction programs.[59] Alberta contributed to the development of the World Bank's *Voluntary Standard for Global Gas Flaring and Venting Reduction* which provides guidance on how to achieve reductions in the flaring and venting of gas associated with crude oil production worldwide.[60]

Chapter 5
Best Practices and Lessons Learned

A key objective of the national submissions of Arctic States is to assist the Framework Expert Group in drawing from some of the best examples of actions that address black carbon and methane emissions, and to exchange information and experiences among Arctic States to promote collective learning for mutual benefit. Drawing from Canada's domestic activities and international engagements, as detailed in earlier chapters, the activities included below are some of best practices and lessons learned across key sectors.

Transportation

In the marine sector, the International Maritime Organization (IMO) is the global standard setting authority for international shipping. In Canada, an effective approach to reducing maritime PM emissions

was the establishment of the *North American Emission Control Area* (ECA) within which marine vessels are required to reduce their air pollutant emissions (including fine particulate matter ($PM_{2.5}$)). Designating U.S. and Canadian exclusive economic zone (i.e., 200 nautical miles out from shore) waters south of 60 degrees latitude as an ECA required a decision of the IMO to amend the International Convention for the Prevention of Pollution from Ships (MARPOL). The North American ECA came into force in August 2012. As of January 1, 2015, ships operating in the ECA have been required to use fuels with 0.1% (1,000 ppm) or less sulphur content or apply equivalent emission controls (vs 3.50% under the current global standard). The ECA is expected to reduce PM emissions from ships by 74% in 2020, resulting in associated reductions in black carbon emissions.

Oil and Gas

The issue of fugitive emissions management has and continues to be important to the upstream oil and gas (UOG) industry. The Alberta Energy and Utilities Board (EUB) along with Environment Canada, the Canadian Association of Petroleum Producers (CAPP), and the Small Explorers and Producers Association of Canada (SEPAC) have coordinated efforts to develop *Best Management Practices (BMP) for Fugitive Emissions Management*[61]. The purpose of the BMP is to assist the upstream oil and gas industry in managing fugitive

59 http://www.worldbank.org/en/programs/gasflaringreduction
60 http://documents.worldbank.org/curated/en/2004/05/4946640/voluntary-standard-global-gas-flaring-venting-reduction
61 http://www.capp.ca/publications-and-statistics/publications/116116

emissions and targeting sources that are most likely to have larger volume emissions and which would be more cost effective to address. The BMP identifies the typical key sources of fugitive emissions at UOG facilities, presents strategies for achieving cost-effective reductions in these emissions and summarizes key considerations and constraints.

Residential Wood Burning

The development of the *Code of Practice for Residential Wood Burning Appliances*, described in Chapter 3, is an example of successful collaborative engagement to deliver concrete results for the improvement of the environment, and to reduce the risks to human health[62].

As described above, the Code was developed through the Canadian Council of Ministers of the Environment (CCME), which established a Wood Combustion Working Group in 2011, including representatives from provincial and municipal governments, Health Canada and the CCME secretariat. Environment Canada and the Canadian Mortgage and Housing Corporation also provided advice and guidance. In total, input and assistance was provided by more than 50 participants including the U.S. Environmental Protection Agency, provinces, territories and States, municipalities, industry associations and non-government organizations. The outcome was a product that can assist federal, provincial and territorial governments with implementing more stringent regulations, developing economic incentives, and launching educational initiatives to mitigate residential wood burning emissions.

Best Management Strategies for Agricultural Methane

Canada has achieved significant increases in agricultural production efficiency, which has reduced methane emission intensities from the sector. Improved breeding and management practices in Canadian farms have achieved higher milk production per cow in the dairy industry and improved weight gains of beef cattle, resulting in lower emission intensities associated with beef and dairy production in all regions of Canada. Canada is also working to improve agriculture methane emissions reporting by improving models so that they represent the relationship between productivity, farm management and emission intensity at the regional level, better reflect national circumstances and account for methane mitigation practices. In addition, Canada is researching several options for the mitigation of agricultural methane[63]. For example, research on the effects of adding edible oils in feed shows some reduction of methane but also impacts productivity and emission intensity. Implementing this and other practices, such as bioenergy production, at the scale of the industry must also take into consideration economic or technological constraints.

International Engagement

Action on SLCPs has been one element of Canada's broader climate change and clean air agenda and complements global actions to reduce emissions of longer-lived GHGs. In February 2012, Canada, along with several countries and the United Nations Environment Programme, launched the Climate and Clean Air Coalition (CCAC) to Reduce Short-Lived Climate Pollutants with an initial focus on black carbon, methane and hydrofluorocarbons. Currently numbering over 100 partners, the CCAC is an international voluntary initiative to accelerate efforts to reduce SLCPs in ways that protect the environment and public health, promote food and energy security, and address near-term climate change.

Canada is co-leading the development and implementation of several initiatives including leading demonstration projects in Mexico and Colombia to reduce black carbon from oil and gas operations utilizing innovative Canadian clean energy technologies. Early project results from the oil and gas demonstration project in Mexico have demonstrated substantial measureable emission reductions, increased environmental performance and decreased operational costs, validated by Measurement, Monitoring and Verification (MRV). For example, technologies deployed at one flare at an oil terminal and gas processing facility resulted in savings of CAD 53 million annually, and virtually immediate payback through the implementation of innovative technologies.

A Trust Fund, managed by the UNEP-hosted Secretariat, has also been established to support the Coalition's efforts. To date, the Government of Canada has delivered CAD 13 million to the CCAC Trust Fund.

62 http://www.ccme.ca/en/resources/air/wood_burning.html

63 http://publications.gc.ca/mwg-internal/de5fs23hu73ds/progress?id=tIfcrQAlDVVYhET-rxDnP4ZXvnq76bxv5TCDLFEGy_s

Chapter 6
Projects Relevant for the Arctic

Research on black carbon and methane is part of the Government of Canada's work on short lived climate pollutants and greenhouse gas emissions. From atmospheric monitoring to emissions measurement and reporting methodologies, modeling studies, and exploring mitigation options, our activities contribute to the international body of climate change research, with increasing attention being paid to the impacts on the Arctic. Our climate research aims not only to shape our own policies for the health and environment of all Canadians, but also to inform policy discussions in our regional and multilateral partnerships concerning the Arctic.

Highlights of Canadian Climate Research Activities Relevant for the Arctic

Atmospheric Monitoring

Canadian atmospheric monitoring capacity in the Arctic has grown through both implementation of new sites and enhanced technology. Through Canada's involvement in international organizations, agreements and commitments, data is collected, quality-controlled and disseminated according to international standards. Environment Canada maintains continuous long term observations of atmospheric concentrations of black carbon (two sites using optical and/or filter based methods) and methane (five sites using flask and/or in-situ instruments). Shorter project based monitoring occurs at additional sites. These data are collected in accordance with the World Meteorological Organization's Global Atmosphere Watch (WMO GAW) protocols and submitted to the WMO GAW data centres[64].

Canada also participated in the Arctic Council's Sustaining Arctic Observing Networks (SAON) initiative. The purpose of SAON is to support and strengthen the development of multinational engagement for sustained and coordinated pan-Arctic observing and data sharing systems that serve societal needs, particularly related to environmental, social, economic and cultural issues. SAON promotes the vision of well-defined observing networks that enable users to have access to free, open and high quality data that will realize pan-Arctic and global value-added services and provide societal benefits. Its goal is to enhance Arctic-wide observing activities by facilitating partnerships and synergies among existing observing and data networks ("building blocks"), and promoting sharing and synthesis of data and information.

64 Black carbon data can be found at the WMO World Data Centre for Aerosols: http://www.gaw-wdca.org and methane data can be found at the WMO World Data Centre for Greenhouse Gases: http://ds.data.jma.go.jp/gmd/wdcgg/

At the subnational level, the province of Newfoundland and Labrador is engaged in technology projects to support improved GHG monitoring and data aggregation methods, including for the Arctic. LOOKNorth[65] (Leading Operational Observations and Knowledge for the North) is a Canadian Centre of Excellence for Commercialization and Research, in partnership with the Governments of Canada and Newfoundland and Labrador that works with industry, researchers and communities to identify and validate industry-relevant technologies that have been developed beyond the proof-of-concept stage, but may require additional development to reach operational maturity. Some of their projects include validation of a pilot carbon capture and storage monitoring solution in Alberta and a laser-based remote sensing technology for quantifying and monitoring GHG emissions from large-area sources in the Arctic and sub-Arctic.

Emissions Measurements and Reporting

Improving emissions measurements and reporting methods is an important part of Canada's contributions internationally to ensure our methodology and outputs not only align with international standards, but that those standards are constantly improving accuracy. As part of their *Heavy-Duty Diesel Vehicles and Engines Initiative*[66], the Climate and Clean Air Coalition (CCAC) has funded a two year project to increase our understanding of black carbon emissions from shipping in the Arctic. The outcome of this project will be a refined global marine black carbon emissions inventory, as well as a technology performance database for black carbon mitigation strategies. This work will also outline a recommended measurement approach including the establishment of appropriate testing protocols, instrumentation and reporting requirements. Canada is engaged in this work, and is contributing emissions testing instrumentation and expertise to the project. In addition to developing its initial black carbon inventory, Environment Canada contributed to the Commission for Environmental Cooperation's *North American Black Carbon Emissions Estimation Guidelines*, which were developed to encourage the use of consistent methodologies in North America[67]. The CEC North American Black Carbon Emissions Estimation Guidelines report has been completed and is expected to be published in late 2015.

Atmospheric Processes and Modelling Studies to Understand the Impacts of Emissions

EC scientists are engaged in researching definitive methods of measuring black carbon in air, recognizing that the majority of previous black carbon data reports have relied on inferential methods. This research is conducted in coordination with international programs (e.g., WMO GAW).

EC scientists also participate in special studies to understand sources of, distribution of, and atmospheric processes affecting black carbon in the Arctic. Sources of interest include the oil and gas sector (oil sands, shale gas fracturing), emissions from shipping including in the high latitudes, while special studies were initiated to understand vertical and spatial distribution of black carbon in the Arctic troposphere; radiative forcing potential of black carbon; atmospheric processes studies on black carbon atmospheric evolution and deposition.

Modelling studies are also being conducted on the air quality impacts of black carbon emissions (including from shipping and wildfires) on the Arctic environment and human health. Climate modelling using an earth system model (CanESM) is underway to improve representation of black carbon and methane processes and simulation of the climate response from Arctic and global source regions. The monitoring and modelling work is reported regularly in the peer reviewed science literature and international science assessment activities.

65 https://www.looknorth.org/
66 http://new.ccacoalition.org/en/initiatives/diesel
67 http://www.cec.org/Page.asp?PageID=122&ContentID=25617&SiteNodeID=1280

Development of Mitigation Options, including Technology Demonstration Projects

Transport Canada's *ecoTECHNOLOGY for Vehicles Program* (eTV)[68] conducts in-depth safety, environmental and performance testing on a range of new and emerging advanced vehicle technologies for passenger cars and heavy-duty trucks. Results are helping to inform the development of environmental and safety policies and regulations to ensure that these technologies can be introduced in Canada in a safe and timely manner. eTV is currently testing several gasoline direct injection (GDI) engine technologies. GDI is a fast emerging technology with a demonstrated potential to reduce fuel consumption and greenhouse gas emissions from on road vehicles. These benefits, however, can be accompanied by an increase in particulate matter emissions, including emissions of black carbon. Joint vehicle emission test projects between eTV and Environment Canada are evaluating the fuel consumption and black carbon emissions of different GDI engine technologies, and investigating potential mitigation technologies such as gasoline particulate filters and alternative fuels.

Climate Science and Research Bodies of relevance to the Arctic

Canadian research on SLCPs and the Arctic helps to inform and contribute to the greater international body of climate science. The CCAC has established a dedicated Scientific Advisory Panel[69] to keep the Coalition abreast of new scientific developments on SLCPs, answer specific questions posed by CCAC Partners, and inform policy discussions. The Science Advisory Panel plays an instrumental role in raising awareness amongst CCAC Partners of the latest scientific findings on SLCPs, including on their impacts in sensitive regions such as the Arctic, as well as in helping to inform the activities of the Coalition.

ArcticNet[70] is a Network of Centres of Excellence of Canada that brings together scientists and managers in the natural, human health and social sciences with their partners from Inuit organizations, northern communities, federal and provincial agencies and the private sector to study the impacts of climate change in the coastal Canadian Arctic. This evidence translates into practical recommendations for minimizing negative impacts and maximizing benefits. Over 145 ArcticNet researchers have the opportunity to collaborate with research teams in Denmark, Finland, France, Greenland, Japan, Norway, Poland, Russia, Spain, Sweden, the United Kingdom and the U.S. ArcticNet's first Integrated Regional Impact Study includes important policy recommendations for improving the health and sustainability of people living in Nunavik and Nunatsiavut.

Canada participates in the International Arctic Science Committee (IASC)[71], which encourages and facilitates cooperation in all aspects of Arctic research, in all countries engaged in Arctic research and in all areas of the Arctic region. More broadly, IASC promotes and supports leading-edge multi-disciplinary research in order to foster a greater scientific understanding of the Arctic region and its role in the Earth system.

Canadian representatives are involved in the terrestrial, marine, cryosphere, atmosphere, and social and human working groups, and IASC's Arctic Data Committee. IASC's Atmosphere Working Group supports activities that aim to improve understanding in areas such as Arctic air pollution, Arctic climate change and mid-latitude weather phenomena, and dynamics of atmosphere-ice-ocean interactions in high latitudes. Canada has also been involved with the IASC-supported Multidisciplinary Drifting Observatory for the Study of Arctic Change (MOSAiC). Through cross-cutting, observational and modeling activities, MOSAiC aims to address the need for multi-year, detailed, and comprehensive measurements (including atmosphere, sea-ice, and ocean) of the central Arctic Basin to improve understanding and modeling of Arctic climate and weather.

Canadian scientists are strongly engaged in projects under the World Climate Research Program (WCRP)[72], sponsored by the WMO, the International Council for Science (ICSU) and the Intergovernmental Oceanographic Commission (IOC) of UNESCO) facilitates analysis and prediction of Earth system variability and change for use in an increasing range of practical applications of direct relevance, benefit and value to society. WCRP coordinated research underpins a significant amount of IPCC assessment reporting. With particular regard to the Arctic, their core climate and cryosphere project, aims to assess and quantify the impacts of climatic variability and change on components of the cryosphere and their consequences for the climate system, and determine the stability of the global cryosphere.

68 https://www.tc.gc.ca/eng/programs/environment-etv-menu-eng-118.htm
69 http://www.unep.org/ccac/Science/ScientificAdvisoryPanel/tabid/130291/Default.aspx
70 http://www.arcticnet.ulaval.ca/
71 http://www.iasc.info/
72 http://wcrp-climate.org/

Canada participates in the *International Surface Ocean – Lower Atmosphere Study* (SOLAS)[73] initiative under the umbrella of the International Global Atmospheric Chemistry (IGAC) Project, which facilitates and coordinates international collaboration on atmospheric chemistry and other multi-disciplinary research. SOLAS is an international research initiative aiming to understand feedbacks between the ocean and atmosphere. This will enable better understanding and quantification of the role of atmosphere-ocean interactions on the climate system.

Highlights of Canadian Assessments Relevant for the Arctic

Canada has been involved in domestic and international work related to assessments to improve the understanding of climate change and SLCPs. Multiple federal government departments and agencies are engaged in work and the activities span a wide range of topics. Several examples of this work are highlighted below.

Scientists from Environment Canada participate in variety of climate assessment reporting activities including through engagement in the Arctic Monitoring and Assessment Programme (AMAP) Expert Groups on Short-Lived Climate Forcers and the resulting Technical Reports; contributions to Intergovernmental Panel on Climate Change Fifth Assessment Report (IPCC AR5), the annual National Oceanic and Atmospheric Administration Arctic Report Card, and the United Nations Environment Programme /World Meteorological Organization Ozone Assessment.

A key Government of Canada report is the Natural Resources Canada-led *Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation*[74], which provides a contextual basis for understanding how climate is changing across Canada, including in the Arctic regions. This report highlights the global air quality and health co-benefits of mitigating near-term climate change through black carbon emission measures and that further research is needed to estimate the contribution of black carbon emissions in Canada, in particular, originating from certain sources such as open biomass burning and wood stove burning. Several different departments and agencies contributed to this report.

Health Canada has conducted a number of studies related to traffic-related air pollution and black carbon has been included as a pollutant of interest in several of these studies. One of the goals of this work is to provide better estimates of the co-benefits of reducing black carbon emissions. In particular, studies of commuters' exposures to traffic-related air pollution suggest that diesel vehicles are an important source of black carbon exposure in Canada. Research in Canada and elsewhere have shown associations between traffic related air pollution and a range of health impacts including cardio-vascular disease, respiratory disease and cancer; however, it is difficult to attribute these

73 http://www.solas-int.org/

74 The report is available online at: http://www.nrcan.gc.ca/environment/resources/publications/impacts-adaptation/reports/assessments/2014/16309

effects to any single pollutant as traffic-related air pollution is a complex mixture of particles and gases.

Fisheries and Oceans Canada's (DFO) *Climate Adaptation Program* completed a climate risk assessment for Canada's five Arctic Ocean basins: the Beaufort Sea, Canadian Polar Shelf, Baffin Bay/ Davis Strait, Hudson Bay and Mackenzie Basin[75]. The assessment, comprised of an analysis of past trends and future projections of key climatic variables and, a vulnerability and opportunity assessment, underscored the complex interactions between climate systems and the aquatic environment and and contributed to a process to define DFO's climate sensitive decisions. The Program financed projects in the Canadian Arctic, targeting fish redistribution, phytoplankton phenology and composition, ecosystem models, coastal erosion, sea-level, and real-time ice forecasts. Scientists from DFO also participated in the IPCC AR5 and in AMAP activities, including the recent Arctic Ocean Acidification Assessment.

75 http://www.dfo-mpo.gc.ca/csas-sccs/Publications/ScR-RS/2012/2012_042-eng.html

Appendix

Detailed Emissions Data

Appendix - Detailed Emissions Data

Table 10.3 from the Common Reporting Format tables submitted to the UNFCCC: Historical trends in Canada's methane emissions; Part 1 of 3

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	1990	1991	1992	1993	1994	1995	1996	1997
	(kt)							
1. Energy	1,867.06	1,913.62	2,034.89	2,143.80	2,243.85	2,346.92	2,479.98	2,547.07
A. Fuel combustion (sectoral approach)	380.48	370.56	365.55	376.77	386.70	378.04	375.95	361.45
1. Energy industries	76.24	71.60	75.94	75.14	78.99	80.93	79.90	76.45
2. Manufacturing industries and construction	2.49	2.38	2.42	2.43	2.77	2.74	2.71	2.76
3. Transport	32.01	30.60	32.78	32.96	33.85	35.38	37.29	36.88
4. Other sectors	269.72	265.96	254.41	266.23	271.07	258.98	256.05	245.36
5. Other	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
B. Fugitive emissions from fuels	1,486.58	1,543.06	1,669.34	1,767.03	1,857.16	1,968.88	2,104.03	2,185.62
1. Solid fuels	112.96	115.11	92.25	101.62	100.26	91.81	87.46	90.29
2. Oil and natural gas and other emissions from energy production	1,373.62	1,427.95	1,577.08	1,665.41	1,756.90	1,877.07	2,016.57	2,095.34
C. CO_2 transport and storage								
2. Industrial processes	4.72	4.37	3.97	3.89	3.98	3.86	3.97	3.81
A. Mineral industry								
B. Chemical industry	4.72	4.37	3.97	3.89	3.98	3.86	3.97	3.81
C. Metal industry	NA,IE	NA,IE	NA,IE	NA,IE	NA,IE	NA,IE	NA,IE	NA,IE
D. Non-energy products from fuels and solvent use	NA,IE	NA,IE	NA,IE	NA,IE	NA,IE	NA,IE	NA,IE	NA,IE
E. Electronic industry								
F. Product uses as ODS substitutes								
G. Other product manufacture and use	NA	NA	NA	NA	NA	NA	NA	NA
H. Other								
3. Agriculture	1,060.87	1,079.39	1,126.62	1,142.53	1,188.19	1,249.67	1,266.16	1,263.26
A. Enteric fermentation	913.52	933.44	978.28	995.15	1,038.37	1,092.71	1,107.97	1,105.11
B. Manure management	140.28	140.13	143.58	142.05	144.24	151.19	152.77	152.63
C. Rice cultivation	NO	NO	NO	NO	NO	NO	NO	NO
D. Agricultural soils	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE
E. Prescribed burning of savannas	NO	NO	NO	NO	NO	NO	NO	NO
F. Field burning of agricultural residues	7.06	5.81	4.76	5.34	5.58	5.77	5.42	5.52
G. Liming								
H. Urea application								
I. Other carbon-containing fertilizers								
J. Other								
4. Land use, land-use change and forestry	177.31	290.28	135.82	278.52	317.13	955.57	257.50	111.95
A. Forest land	140.08	248.64	81.74	251.97	275.40	934.70	230.06	83.84
B. Cropland	12.68	11.47	10.50	8.96	7.95	7.39	6.48	6.43
C. Grassland	19.66	24.62	37.97	12.56	29.42	9.16	16.50	16.85
D. Wetlands	0.31	0.46	0.73	0.18	0.00	0.01	NO,NE	0.15
E. Settlements	4.57	5.09	4.89	4.86	4.36	4.31	4.46	4.67
F. Other land	NO	NO	NO	NO	NO	NO	NO	NO
G. Harvested wood products								
H. Other	NO	NO	NO	NO	NO	NO	NO	NO
5. Waste	908.80	927.83	940.69	956.51	962.48	961.59	958.67	971.92
A. Solid waste disposal	893.30	912.15	924.83	940.69	946.52	945.45	942.43	956.19
B. Biological treatment of solid waste	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE
C. Incineration and open burning of waste	0.46	0.47	0.51	0.33	0.33	0.37	0.35	0.05
D. Waste water treatment and discharge	15.04	15.21	15.35	15.50	15.63	15.76	15.89	15.68
E. Other								
6. Other *(as specified in summary 1.A)*	NA	NA	NA	NA	NA	NA	NA	NA
Total CH_4 emissions without CH_4 from LULUCF	3,841.44	3,925.21	4,106.17	4,246.74	4,398.51	4,562.03	4,708.77	4,786.06
Total CH_4 emissions with CH_4 from LULUCF	4,018.75	4,215.49	4,241.99	4,525.27	4,715.64	5,517.60	4,966.27	4,898.00
Memo items:								
International bunkers	0.33	0.32	0.32	0.28	0.31	0.33	0.32	0.32
Aviation	0.08	0.06	0.05	0.04	0.05	0.06	0.06	0.06
Navigation	0.24	0.26	0.27	0.24	0.27	0.28	0.26	0.26
Multilateral operations	IE	IE	IE	IE	IE	IE	IE	IE
CO_2 emissions from biomass								
CO_2 captured								
Long-term storage of C in waste disposal sites								
Indirect N_2O								
Indirect CO_2								

Table 10.3 from the Common Reporting Format tables submitted to the UNFCCC: Historical trends in Canada's methane emissions; Part 2 of 3

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	1998	1999	2000	2001	2002	2003	2004	2005
	(kt)							
1. Energy	2,597.79	2,566.35	2,542.06	2,466.89	2,353.46	2,287.24	2,252.67	2,172.03
A. Fuel combustion (sectoral approach)	392.10	404.66	398.80	380.52	399.52	362.56	348.74	325.61
1. Energy industries	90.01	114.40	117.57	117.82	115.85	112.71	103.37	89.92
2. Manufacturing industries and construction	2.82	2.91	2.99	2.89	3.08	3.08	3.36	3.30
3. Transport	37.99	37.34	35.26	33.68	34.12	32.78	32.28	32.84
4. Other sectors	261.28	250.01	242.98	226.12	246.46	213.98	209.74	199.53
5. Other	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00
B. Fugitive emissions from fuels	2,205.69	2,161.69	2,143.25	2,086.36	1,953.94	1,924.68	1,903.93	1,846.42
1. Solid fuels	78.94	66.63	68.77	69.66	62.24	56.28	59.63	65.87
2. Oil and natural gas and other emissions from energy production	2,126.75	2,095.06	2,074.49	2,016.70	1,891.70	1,868.39	1,844.31	1,780.55
C. CO_2 transport and storage								
2. Industrial processes	3.62	4.06	4.22	4.12	3.97	3.71	4.19	3.39
A. Mineral industry								
B. Chemical industry	3.62	4.06	4.22	4.12	3.97	3.71	4.19	3.39
C. Metal industry	NA,IE	NA,IE	NA,IE	NA,IE	NA,IE	NA,IE	NA,IE	NA,IE
D. Non-energy products from fuels and solvent use	NA,IE	NA,IE	NA,IE	NA,IE	NA,IE	NA,IE	NA,IE	NA,IE
E. Electronic industry								
F. Product uses as ODS substitutes								
G. Other product manufacture and use	NA	NA	NA	NA	NA	NA	NA	NA
H. Other								
3. Agriculture	1,268.42	1,275.56	1,300.76	1,337.10	1,343.18	1,354.08	1,395.95	1,429.14
A. Enteric fermentation	1,107.53	1,115.42	1,137.59	1,169.57	1,171.34	1,181.26	1,224.56	1,255.26
B. Manure management	154.74	155.61	159.10	164.08	168.38	168.68	170.31	172.47
C. Rice cultivation	NO	NO	NO	NO	NO	NO	NO	NO
D. Agricultural soils	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE
E. Prescribed burning of savannas	NO	NO	NO	NO	NO	NO	NO	NO
F. Field burning of agricultural residues	6.16	4.52	4.07	3.46	3.46	4.15	1.08	1.40
G. Liming								
H. Urea application								
I. Other carbon-containing fertilizers								
J. Other								
4. Land use, land-use change and forestry	797.62	333.71	104.07	180.31	699.38	469.17	596.09	299.26
A. Forest land	764.98	297.51	62.27	138.59	654.84	421.71	555.87	260.64
B. Cropland	6.13	5.92	5.35	6.38	5.31	4.94	5.18	4.91
C. Grassland	20.39	23.43	31.46	29.90	33.44	35.93	27.97	26.02
D. Wetlands	0.92	1.59	NO,NE	0.00	0.00	0.67	0.96	1.43
E. Settlements	5.19	5.25	4.99	5.44	5.79	5.93	6.11	6.27
F. Other land	NO	NO	NO	NO	NO	NO	NO	NO
G. Harvested wood products								
H. Other	NO	NO	NO	NO	NO	NO	NO	NO
5. Waste	984.84	1,001.25	1,003.95	1,006.06	1,026.27	1,043.88	1,058.76	1,072.69
A. Solid waste disposal	969.61	986.68	990.01	992.32	1,012.43	1,029.97	1,044.75	1,058.49
B. Biological treatment of solid waste	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE
C. Incineration and open burning of waste	0.06	0.06	0.07	0.08	0.08	0.08	0.09	0.09
D. Waste water treatment and discharge	15.16	14.51	13.87	13.66	13.76	13.83	13.92	14.11
E. Other								
6. Other *(as specified in summary 1.A)*	NA	NA	NA	NA	NA	NA	NA	NA
Total CH_4 emissions without CH_4 from LULUCF	4,854.67	4,847.21	4,850.99	4,814.18	4,726.87	4,688.91	4,711.58	4,677.25
Total CH_4 emissions with CH_4 from LULUCF	5,652.29	5,180.92	4,955.06	4,994.48	5,426.26	5,158.09	5,307.67	4,976.51
Memo items:								
International bunkers	0.36	0.32	0.32	0.34	0.29	0.23	0.26	0.29
Aviation	0.07	0.06	0.06	0.07	0.05	0.04	0.04	0.04
Navigation	0.29	0.26	0.25	0.27	0.24	0.19	0.22	0.26
Multilateral operations	IE	IE	IE	IE	IE	IE	IE	IE
CO_2 emissions from biomass								
CO_2 captured								
Long-term storage of C in waste disposal sites								
Indirect N_2O								
Indirect CO_2								

Table 10.3 from the Common Reporting Format tables submitted to the UNFCCC: Historical trends in Canada's methane emissions; Part 3 of 3

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	2006	2007	2008	2009	2010	2011	2012	2013
	(kt)							
1. Energy	2,157.41	2,134.57	2,078.42	1,979.36	1,970.08	2,007.69	2,087.56	2,142.82
A. Fuel combustion (sectoral approach)	318.63	322.35	315.37	300.86	311.57	314.20	319.78	324.10
1. Energy industries	89.39	93.29	86.39	81.07	79.50	80.99	85.97	90.00
2. Manufacturing industries and construction	3.33	3.44	3.23	3.00	3.13	3.16	3.29	3.53
3. Transport	31.25	31.03	29.16	27.53	28.14	28.09	27.57	28.83
4. Other sectors	194.66	194.58	196.58	189.25	200.79	201.95	202.94	201.73
5. Other	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
B. Fugitive emissions from fuels	1,838.78	1,812.22	1,763.05	1,678.50	1,658.51	1,693.50	1,767.78	1,818.72
1. Solid fuels	59.43	62.73	61.18	56.72	63.65	63.06	63.72	69.13
2. Oil and natural gas and other emissions from energy production	1,779.35	1,749.49	1,701.88	1,621.78	1,594.86	1,630.44	1,704.06	1,749.59
C. CO_2 transport and storage								
2. Industrial processes	3.36	3.38	3.06	2.63	2.65	2.69	2.75	3.02
A. Mineral industry								
B. Chemical industry	3.36	3.38	3.06	2.63	2.65	2.69	2.75	3.02
C. Metal industry	NA,IE	NA,IE	NA,IE	NA,IE	NA,IE	NA,IE	NA,IE	NA,IE
D. Non-energy products from fuels and solvent use	NA,IE	NA,IE	NA,IE	NA,IE	NA,IE	NA,IE	NA,IE	NA,IE
E. Electronic industry								
F. Product uses as ODS substitutes								
G. Other product manufacture and use	NA	NA	NA	NA	NA	NA	NA	NA
H. Other								
3. Agriculture	1,390.27	1,339.52	1,297.40	1,226.56	1,181.04	1,152.80	1,154.52	1,159.00
A. Enteric fermentation	1,218.76	1,177.18	1,142.04	1,076.56	1,032.79	1,005.65	1,007.41	1,009.37
B. Manure management	170.01	161.14	153.83	148.49	147.24	146.23	145.93	148.05
C. Rice cultivation	NO	NO	NO	NO	NO	NO	NO	NO
D. Agricultural soils	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE
E. Prescribed burning of savannas	NO	NO	NO	NO	NO	NO	NO	NO
F. Field burning of agricultural residues	1.51	1.20	1.54	1.52	1.01	0.93	1.19	1.59
G. Liming								
H. Urea application								
I. Other carbon-containing fertilizers								
J. Other								
4. Land use, land-use change and forestry	393.47	338.86	207.22	280.81	503.68	514.73	475.24	251.82
A. Forest land	345.72	313.88	180.74	256.43	482.94	484.65	417.22	220.33
B. Cropland	5.03	5.02	4.71	4.97	4.77	4.80	4.69	4.98
C. Grassland	35.91	13.11	14.73	12.89	9.73	19.28	47.46	20.82
D. Wetlands	0.14	NO,NE	0.54	0.57	0.51	NO,NE	NO,NE	NO,NE
E. Settlements	6.67	6.85	6.50	5.96	5.74	6.00	5.87	5.69
F. Other land	NO	NO	NO	NO	NO	NO	NO	NO
G. Harvested wood products								
H. Other	NO	NO	NO	NO	NO	NO	NO	NO
5. Waste	1,094.19	1,077.22	1,069.05	1,076.51	1,013.67	1,003.39	969.95	965.49
A. Solid waste disposal	1,079.79	1,062.70	1,054.12	1,061.48	998.39	987.95	954.34	949.71
B. Biological treatment of solid waste	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE
C. Incineration and open burning of waste	0.09	0.10	0.10	0.11	0.11	0.12	0.13	0.12
D. Waste water treatment and discharge	14.30	14.42	14.83	14.92	15.17	15.32	15.49	15.66
E. Other								
6. Other *(as specified in summary 1.A)*	NA	NA	NA	NA	NA	NA	NA	NA
Total CH_4 emissions without CH_4 from LULUCF	4,645.23	4,554.69	4,447.94	4,285.06	4,167.44	4,166.57	4,214.78	4,270.34
Total CH_4 emissions with CH_4 from LULUCF	5,038.70	4,893.55	4,655.16	4,565.87	4,671.13	4,681.30	4,690.02	4,522.16
Memo items:								
International bunkers	0.24	0.31	0.30	0.24	0.25	0.20	0.17	0.17
Aviation	0.04	0.05	0.06	0.05	0.05	0.05	0.05	0.05
Navigation	0.20	0.25	0.25	0.19	0.20	0.15	0.12	0.12
Multilateral operations	IE	IE	IE	IE	IE	IE	IE	IE
CO_2 emissions from biomass								
CO_2 captured								
Long-term storage of C in waste disposal sites								
Indirect N_2O								
Indirect CO_2								

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Additional information can be obtained at:

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