

METHODOLOGY DOCUMENT FOR THE BRITISH COLUMBIA PROVINCIAL GREENHOUSE GAS INVENTORY



Ministry of
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1. PURPOSE AND STRUCTURE OF THE METHODOLOGY DOCUMENT

1.1 Purpose

The *British Columbia Greenhouse Gas Inventory* (B.C. GHG Inventory or Provincial Inventory) has been prepared to provide sound, science-based, comparable and consistent reporting of greenhouse gas (GHG) sources and sinks in B.C. in support of section 4(a) of the *Greenhouse Gas Reductions Target Act* ([GGRTA](#))¹. The Provincial Inventory is the foundation on which progress towards the legislated GGRTA targets is measured.

This Provincial Inventory Methodology document is intended to:

- Explain the methodology and data sources used by B.C. when compiling the Provincial Inventory;
- Support a general understanding of the methodology and data sources used by Environment and Climate Change Canada (ECCC) in preparing the *National Inventory Report on Greenhouse Gases and Sinks in Canada* (NIR) for the line items in the B.C. Provincial Inventory that mirror the NIR;
- Serve as a reference source for evaluation of GHG emissions in B.C.

Caution should be exercised when interpreting year to year changes in GHG emissions. Some changes may be due to data collection gaps, methodology or error correction refinements. Other changes in emissions figures may be the result of one-time or specific events or actions (such as natural disasters or production disruptions). Variations in seasonal weather conditions (e.g., precipitation on electricity generation, heating/cooling degree days on building energy use) also influence emissions.

Uncertainty in inventory estimates is inherent and the inventory should only be viewed as an approximation of total emissions. Changes over three and ten year periods (or longer) provide a better indication of trends in emissions than annual differences.

1.2 Structure

The Provincial Inventory Methodology document is grouped by the sectors outlined below. Each section includes: a brief description of the sector and its sub-sectors; the data sources; and the methodology used to calculate the GHG emissions in producing the NIR (and in turn Provincial Inventory). Where B.C. deviates from the NIR methodology for any line items, the differing methodology is detailed in [section 2.2](#).

- *Energy* – stationary combustion sources, transportation, fugitive sources and CO₂ transport and storage ([Section 3](#))

¹ http://www.bclaws.ca/civix/document/id/complete/statreg/07042_01

- *Industrial Processes and Product Use* – mineral products, chemical industry, metal production, consumption of halocarbons, SF₆, and NF₃; non-energy products from fuels and solvent use and other product manufacture and use ([Section 4](#))
- *Agriculture* – enteric fermentation, manure management, agricultural soils, field burning of agricultural residues and liming, urea application and other carbon-containing fertilizers ([Section 5](#))
- *Waste* – solid waste disposal, biological treatment of solid waste, wastewater handling and waste incineration ([Section 6](#))
- *Land Use, Land-Use Change and Forestry (LULUCF)* – afforestation, deforestation, conversions to cropland and wetlands; other land use ([Section 7](#))

2. REPORTING METHODOLOGY

The United Nations Framework Convention on Climate Change ([UNFCCC](http://unfccc.int/))² sets out reporting categories and methodologies for estimating emissions and removals of specified GHGs. Canada's National Inventory Report (NIR) is prepared and submitted annually by ECCC to the UNFCCC.

The B.C. Provincial Inventory uses the same categorical breakdown of GHG sources and sinks presented in the NIR. The data and the methodology within the Provincial Inventory follow the NIR except where explicitly specified in this document.

2.1 Data Sources for Preparation of the Provincial Inventory

Environment and Climate Change Canada's Greenhouse Gas Division is the lead agency for GHG inventory reporting (e.g. NIR) in Canada. To prepare and verify the GHG inventory information, ECCC works closely with other federal agencies (such as Statistics Canada and Natural Resources Canada), provincial governments, academic and consulting groups, and industries.

NIR data is provided to B.C. by ECCC. B.C. also amends some line items from the NIR source data for the Provincial Inventory where it has a more accurate data source than the NIR.

The specific inventory data sources are listed by [Chapter](#)³ in Part 1 of Canada's submission (the NIR) on GHG Sources and Sinks in Canada posted on the UNFCCC website.

2.1.1 Differences in Reported Emissions between Canada and B.C.

B.C.'s Provincial Inventory varies from the NIR in the following ways:

- The NIR does not include provincial level data for the LULUCF sector.
- The Provincial Inventory includes afforestation and deforestation emissions data.
- The Provincial Inventory breaks out the Forest Management category into sub-sectors.
- The Provincial Inventory may also include recalculations of certain line items, as described in [section 2.2](#).

2.1.2 Methodological Approaches Used in Deriving Inventory Data

Approaches used to produce GHG emissions data are categorized in one of three tiers. Tier 1 is a top down approach that utilizes aggregated statistical data to estimate emissions; tier 2 is an intermediate level approach; and tier 3 is a bottom up approach such as site-specific quantification of emissions. In progressing through the tiers from 1 to 3 the level of accuracy increases, however the methodological complexity also increases. The NIR and the Provincial Inventory use methods across all three tiers.

² <http://unfccc.int/>

³ http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/9492.php

Territoriality and Reporting

The UNFCCC Reporting Guidelines use a strict geographic territoriality approach to reporting of greenhouse gas emissions. A jurisdiction is responsible to report only those emissions that occur within its boundaries. Emissions that occur within the source jurisdiction for imported products and emissions that occur within receiving jurisdictions from exported products are reported in the source and receiving jurisdiction, respectively.

This approach keeps both reporting boundaries very clear. However, geographic territoriality can simplify relationships when emissions in one jurisdiction may be considered the sole or primary responsibility of another jurisdiction. For example, the emissions associated with a thermal power plant supplying electricity to a neighbouring jurisdiction and having limited market or sales within its home jurisdiction. These emissions could theoretically be considered the responsibility of the neighbouring (receiving) jurisdiction, rather than the home (source) jurisdiction.

As there has to be one standardized method of reporting internationally on GHG emissions to avoid double-counting and missing some emissions completely, one cannot selectively choose to depart from the territorial principle for reporting of some products and not for others. Keeping strictly to the principle of territorial reporting (or territoriality) is powerful in aligning emissions with the jurisdiction that can do the most to manage and reduce those emissions. Accounting rules may differ from inventory reporting rules and can allow for trade of emissions reductions, offsets and similar instruments across geographic borders.

2.2 Provincial Inventory Methodology

The methodologies used by ECCC for the different sectors of the NIR are described in [Annex 3](#)⁴ in Part 2 of the NIR:

- A3.1. Methodology and Data for Estimating Emissions from Fossil Fuel Combustion
- A3.2. Methodology for Fugitive Emissions from Fossil Fuel Production, Processing, Transmission and Distribution
- A3.3. Methodology for Industrial Processes and Product Use
- A3.4. Methodology for the Agriculture Sector
- A3.5. Methodology for the Land Use, Land-Use Change and Forestry Sector
- A3.6. Methodology for Waste Sector

B.C. reviews the NIR data to ensure that the data presented is accurate. If a discrepancy in the provincial data relative to other data sources is identified for a specific line item, or in circumstances where B.C. believes more accurate data (derived using a tier 3 approach) is available, B.C. revises that line item in the Provincial Inventory. In these circumstances this Provincial Inventory Methodology document explains the data source and methodology used.

2.2.1 Methodology Specific to the 1990-2014 B.C. Provincial Inventory

The source data and methodology used by Statistics Canada and ECCC to estimate mining and upstream oil and gas production emissions have proven to be inconsistent for B.C.'s specific

⁴ http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/9492.php

circumstances over a number of years and led to misstated provincial emissions. For the 2014 Provincial Inventory, B.C. reviewed the NIR mining and upstream oil and gas line item and determined it to be an overestimate relative to other sources.

B.C. isolated the mining data from the NIR mining and upstream oil and gas line item by subtracting known mining emissions from the NIR line item total based on data from the B.C. Reporting Regulation. B.C. then used data from the studies⁵ conducted for ECCC by Clearstone Engineering Ltd. to extrapolate only the upstream oil and gas GHG emission values to 2014 from the 2011 values reported. The extrapolation was done using production and emissions intensity information from The Canadian Association of Petroleum Producers (CAPP). This amount was re-combined with the previously isolated NIR mining data to re-estimate the Provincial Inventory mining and upstream oil and gas production combustion emissions line item. To ensure accuracy the new estimate was cross-checked against bottom up data for stationary combustion in oil and gas from B.C.'s Reporting Regulation. The B.C. Reporting Regulation has been replaced by B.C.'s Greenhouse Gas Emission Reporting Regulation effective Jan, 2016.

2.3 Calculating Emissions

2.3.1 Emission Factors

GHG emissions are typically estimated using emission factors, metrics that relate quantity of emissions released per unit level of activity data. ECCC determines the emission factors using mass balance, fixed chemical equations or other relationships under average conditions. ECCC has developed average emission factors for many inventory categories in consultation with other government departments, industry associations and agencies, reflecting the most accurate available methodologies and international (Intergovernmental Panel on Climate Change (IPCC) and UNFCCC) standards and practices. The factors can be averaged across national, provincial or even at a facility-specific level.

These average emission factors are then combined with the activity data from the respective sectors to calculate the GHG emissions.

The emission factors used in the NIR and therefore in B.C.'s Provincial Inventory are listed in [Annex 6](#)⁶, Part 2 of the NIR by sector.

- Annex A6.1- Fuel Combustion Emission Factors.
- Annex A6.2 - Industrial Processes Emission Factors.
- Annex A6.3- Other Product Manufacture and Use Emission Factors.
- Annex A6.4- Agriculture Emission Factors.
- Annex A6.5- Land Use, Land-Use Change and Forestry Emission Factors.

⁵ *A National Inventory of Greenhouse Gas (GHG), Criteria Air Contaminant (CAC) and Hydrogen Sulphide (H2S) Emissions by the Upstream Oil and Gas Industry (CAPP 2005a)* and an update to the inventory that was completed in 2014

⁶ http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/9492.php

- Annex A6.6 - Biomass Combustion Emission Factors.
- Annex A6.7 - Waste Emission Factors.

2.3.2 Global Warming Potentials of GHGs

The groups of greenhouse gas emissions that are influenced by human activities and that are of primary concern for GHG abatement policy and activities are listed below:

- Carbon dioxide (CO₂).
- Methane (CH₄).
- Nitrous oxide (N₂O).
- Synthetic (not naturally occurring) fluorinated gases – sulphur hexafluoride (SF₆), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs); and
- Nitrogen Tri-fluoride (NF₃)⁷.

The concept of global warming potential (GWP) has been developed to enable comparison of the ability of different GHGs to trap heat in the atmosphere (radiative forcing). By definition, the GWP from the release of 1 kg of CO₂ is one, with the GWP of other GHGs stated relative to CO₂. The GWP of a GHG accounts for both the immediate radiative forcing due to an increase in the concentration of the gas in the atmosphere, and the lifetime of the gas. GWP values are not static and underwent a major change in the IPCC 4th Assessment Report (AR). These changes were adopted by B.C. beginning with the 2013 Provincial Inventory.

The following summary table lists the “100-Year GWP” for the major gases and groups of gases. The GWP values for various other GHGs are listed under [Table 1-1](#)⁸ in Part 1 of the NIR.

Table 1: Global Warming Potential (GWP) for GHGs – Summary

GHG	100-Year GWP (IPCC AR 4 2007)
Carbon Dioxide (CO ₂)	1
Methane (CH ₄)	25
Nitrous Oxide (N ₂ O)	298
Nitrogen Tri-fluoride (NF ₃)	17,200
Sulphur Hexafluoride (SF ₆)	22,800
Hydrofluorocarbon 23 (CHF ₃)	14,800
Hydrofluorocarbon 32 (CH ₂ F ₂)	675
Perfluorocarbons –Perfluoroethane (C ₂ F ₆)	12,200

⁷ B.C. has negligible Nitrogen Tri-fluoride (NF₃) emissions but it is included here as it is reported at the national level.

⁸ http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/9492.php

2.3.3 Recalculations and Changes from Prior Year GHG Emissions

The NIR outlines detailed information on methodologies and protocols for emissions reporting and recalculation, as well as quality assurance/quality control (QA/QC) processes, data sources and planned improvements.

In preparing each year's NIR submission, ECCC recalculates the inventory estimates for each province for each data year reported, including prior years. Recalculations are based on: (i) changes to inventory methods (following science updates or the availability of new foundational reports and survey information); (ii) correction of inaccuracies found when reviewing previous inventory reports; and (iii) updates to the source data in the inventory calculations (e.g., regular updates to Statistics Canada's Report on Energy Supply and Demand). As a result of these recalculations, emissions estimates for any given past year may change when a new inventory is submitted. This process is commonly referred to as back-casting.

3. ENERGY SECTOR EMISSIONS

GHG emissions reported in the energy sector are: (a) stationary combustion; (b) transport fuel combustion activities; (c) fugitive emissions from the fossil fuel and mining industries; and (d) CO₂ transport and storage. Historically, the sector has accounted for the majority of emissions in B.C.

3.1 Energy Sub-Sectors Description

3.1.1 Stationary Combustion Sources Sub-Sector Description

Stationary combustion sources are emissions from stationary devices that combust solid, liquid or gaseous fuel in order to generate useful heat, cooling or electricity. Sources include boilers, combustion turbines, engines, incinerators and process heaters. Devices used to transport oil and gas through pipelines are not included in this sub-sector.

Table 2: Stationary Combustion Sources Sub-Sector Description

Emission Category	Description
Public Electricity and Heat Generation	Production of electricity and useful heat in public utility thermal power plants.
Petroleum Refining Industries	Petroleum refineries; direct emissions from the production of petroleum products from a raw feedstock.
Mining and Upstream Oil and Gas Production	Metal and non-metal mines, stone quarries and gravel pits, mineral exploration and contract drilling operations; natural gas and conventional oil production facilities.
Manufacturing Industries	Production of iron and steel, non-ferrous metals, pulp and paper, chemicals, and other non-metallic mineral products.
Construction	Building and road construction, and other construction activities.
Commercial and Institutional	Emissions primarily from the combustion of fuel to heat the buildings, excluding electricity. Fuel used by service industries related to mining, wholesale and retail trade, finance and business services, education, health and social services.
Residential	Personal residences including homes, apartment hotels, condominiums and farm-houses.
Agriculture and Forestry	Forestry, logging service, agricultural industry activities; on-site machinery operation and from space heating.

3.1.2 Transport Sub-Sector Description

The transport sub-sector within the energy sector includes emissions from mobile devices that combust liquid or gaseous fuels for the purpose of generating useful energy for propulsion. Sources include road vehicle, marine and jet engines. Emissions from stationary combustion devices used to transport oil and gas through pipelines are also included in this sub-sector.

Table 3: Transport Sub-Sector Description

Emission Category	Description
Domestic Aviation	Canadian registered airlines flying domestically within Canada and originating in B.C., including commercial, private, and agricultural flights.
Road Transportation (On-road Vehicles)	Vehicles in B.C. licensed to operate on roads.
Railways	Locomotives operating in B.C.
Domestic Navigation	Canadian registered marine vessels fuelled domestically in B.C.
Off-road Vehicles (Gasoline and Diesel)	Vehicles in B.C. not licensed to operate on roads or highways, including farm tractors, logging skidders, tracked-construction vehicles and mining vehicles as well as off-road recreational vehicles.
Pipelines	Transportation and distribution of crude oil, natural gas and other products through a pipeline.

3.1.3 Fugitive Sources Sub-Sector Description

Fugitive sources are unintentional emissions from the production, processing, transmission, storage and delivery of fossil fuels, as well as the intentional combustion of fossil fuels not used to generate useful heat or electricity.

Table 4: Fugitive Sources Sub-Sector Description

Emission Category	Description
Coal Mining	Releases from exposed coal surfaces, and venting within coal deposits; and post-mining activities including preparation, transportation, storage and final processing.
Oil and Natural Gas	
Conventional Crude Oil Processing	Releases from wells, flow lines and batteries; venting of casing and solution gas; and evaporative losses from storage facilities.
Natural Gas Processing	Releases from wells, gathering systems, field facilities and gas batteries; seal leaks; line cleaning operations; formation CO ₂ removal; and pneumatic devices.
Natural Gas Transmission	Equipment leaks; compressor start-up venting and purging of lines during maintenance.

3.1.4 CO₂ Transport and Storage Sub-Sector Description

This sub-sector involves the capture of anthropogenic CO₂ and its transport to a storage facility.

3.2 Energy Sector Data Sources

In producing the NIR, ECCC uses Statistics Canada's *Report on Energy Supply and Demand in Canada* (RES⁹) as the principal data source to estimate stationary combustion and transport emissions. The report is a compilation of activity data from fuel producers and consumers drawn from annual and monthly censuses and surveys from industries, federal agencies and provincial energy departments. The data provides estimates of the supply of and demand for energy in Canada separated into categories such as import/export, producer consumption and final demand. Data are also disaggregated into broad industrial sectors and transport types (e.g., manufacturing, mining, airlines, and road transportation).

ECCC uses Canada's Mobile Greenhouse Gas Emission Model (MGEM)¹⁰ and Aviation Greenhouse Gas Emission Model (AGEM)¹⁰ to allocate emissions in the transport sub-sector. The models disaggregate reported fuel consumption into vehicle categories based on model year, fuel, and vehicle type.

Fugitive source emissions are more difficult to estimate than combustion emissions. ECCC utilizes numerous reports from government organizations and industry groups described in [section 3.3.3](#) in the development of fugitive emissions estimates.

The references for the data sources can be found in [Chapter 3](#)¹¹ in Part 1 of the NIR.

3.3 Energy Sector Methodology

The energy sub-sectors use different approaches to calculate the GHG emissions as described below.

3.3.1 Stationary Fuel Combustion Sub-Sector

The methodology to estimate stationary combustion GHG emissions is consistent with the IPCC Tier 2 sectoral approach, along with emission factors as outlined in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The emissions are calculated based on nationally reported activity data, except when emission factors are available at the provincial/territorial level. In these instances, the provincial/territorial emissions are aggregated to a national total.

3.3.2 Transportation Sub-Sector

The methodology to estimate road transportation GHG emissions follows a detailed IPCC Tier 3 approach (except for propane and natural gas vehicles that uses Tier 1 and 2) that involves using the activity data (vehicle populations, fuel consumption ratios, kilometre accumulation rates, aircraft movements, and flight path length) and estimation of fuel consumption. Emissions are then estimated based on fuel type, total fuel consumed and the appropriate emission factor.

⁹ <http://www5.statcan.gc.ca/olc-cel/olc.action?objId=57-003-X&objType=2&lang=en&limit=0>

¹⁰ MGEM and AGEM models incorporate a version of the IPCC-recommended methodology for vehicle modelling (IPCC 2006) and are used to calculate all transport emissions with the exception of those associated with pipelines.

¹¹ http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/9492.php

3.3.3 Fugitive Sub-Sector

The fugitive emission estimates for the oil and natural gas line item are based on studies¹² conducted by Clearstone Engineering Ltd. The fugitive emission estimates for coal mining are based on studies¹³ conducted by King and Cheminfo Services Inc. and Clearstone Engineering Ltd.

3.3.4 CO₂ Transport and Storage Sub-Sector

The CO₂ pipelines in Canada are associated with the use of carbon dioxide in an enhanced oil recovery process. All CO₂ from this process is recovered for reuse and therefore no estimates are provided for emissions from storage.

Additional details on the methodologies can be found in [Annex 3.1 and 3.2](#)¹⁴ in Part 2 of the NIR.

¹² *A National Inventory of Greenhouse Gas (GHG), Criteria Air Contaminant (CAC) and Hydrogen Sulphide (H₂S) Emissions by the Upstream Oil and Gas Industry (CAPP 2005a)* and an update to the inventory that was completed in 2014

¹³ Studies: *Management of Methane Emissions from Coal Mines: Environmental, Engineering, Economic and Institutional Implications of Options*, prepared by B. King for Neill and Gunter Ltd, and *Compilation of a National Inventory of Greenhouse Gas and Fugitive VOC Emissions by the Canadian Coal Mining Industry*, prepared by Cheminfo Services Inc. and Clearstone Engineering Ltd.

¹⁴ http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/9492.php

4. INDUSTRIAL PROCESSES AND PRODUCT USE SECTOR EMISSIONS

Industrial processes include GHG emissions from industrial activities which do not derive from the combustion of a hydrocarbon fuel, but rather from a different type of reaction which chemically or physically transforms materials (i.e. non-energy related GHG emissions from manufacturing processes and use of products).

This sector includes six sub-sectors: (a) mineral products (including cement and lime production, and soda ash, limestone and dolomite production and use); (b) chemical industry; (c) metal production; (d) production and consumption of halocarbons, SF₆ and NF₃; (e) Non-energy products from fuels and solvent use; and (f) other product manufacture and use.

In the NIR and therefore in B.C.'s Provincial Inventory, industrial process emissions from aluminium production are reported under the Metal Production sub-sector. The Other Product Manufacture and Use sub-sector includes:

- emissions from the use of SF₆ in electrical equipment,
- emissions of N₂O from medical applications and use as a propellant,
- PFC emissions from other contained product uses which are not ozone-depleting substances substitutes or electronics industry-related, and
- CO₂ emissions from the use of urea in selective catalytic reduction.

Due to the small number of emitters in certain subsectors ECCC aggregates emissions that are listed across the ammonia, nitric acid and petrochemical production sub-categories to protect commercial confidentiality.

4.1 Industrial Processes and Product Use Sub-Sector Description

Table 5: Industrial Processes and Product Use Sub-Sector Description

Emission Category	Description
a. Mineral Products	
Cement Production	Estimate process-related CO ₂ emissions from the calcination of raw materials by either based on the amount and chemical composition of the products (clinker plus dust leaving the kiln system) or based on the amount and composition of the raw materials entering the kiln.
Lime Production	Emissions from dolomitic lime and high-calcium lime production. Lime is formed by the heating of limestone to decompose carbonates through calcination, which releases CO ₂ .
Mineral Products Use	Calcination of limestone or dolomite into lime for purposes other than cement or lime production – these include glass manufacturing and non-ferrous metal production, pulp and paper production, flue gas desulphurization and wastewater treatment/neutralization. CO ₂ is released during the decomposition of soda ash (Na ₂ CO ₃), used in glass manufacturing, chemical production, pulp and paper manufacturing and wastewater treatment.
b. Chemical Industry	Emissions from ammonia and petrochemical production.
c. Metal Production	GHG emissions include PFCs, as well as CO ₂ , formed during the aluminium smelting process – including electrolytic reduction of alumina (Al ₂ O ₃) with carbon-based anodes, pre-baking of carbon anodes and anode effects.
d. Production and Consumption of Halocarbons, SF₆ and NF₃	Fugitive releases of HFCs used in refrigeration and air conditioning, fire suppression, aerosols, solvent cleaning, foam blowing, and other applications – also includes emissions of SF ₆ from electrical generation, transmission and distribution equipment and magnesium casting.
e. Non-energy Products from Fuels and Solvent Use	CO ₂ emissions from the feedstock use of waxes, paraffin and unfinished petrochemical derivatives; residual and non-residual non-energy use of petroleum products coming out of the oil refineries; CO ₂ emissions from non-energy use of hydrocarbons or fossil fuels that are not reported elsewhere in the inventory.
f. Other Product Manufacture and Use	GHG emissions from electrical equipment, medical applications, propellant and use of urea in selective catalytic reduction vehicles.

4.2 Industrial Processes and Product Use Data Sources

ECCC uses Statistics Canada's RESD and an "*Annual Industrial Consumption of Energy*" survey¹⁵ to estimate the GHG emissions used in the NIR. Other data sources are specific to the sub-sector and include the Cement Association of Canada, Canadian Minerals Yearbook, the Aluminum Association of Canada, and Natural Resource Canada (NRCan). The NIR data sources for emission factors and activity data for each emission category are found in section 2.3.1 and section 2.1 in this report.

The references for the data sources can be found in [Chapter 4](#)¹⁶ in Part 1 of the NIR.

¹⁵ http://www23.statcan.gc.ca/imdb/p25v.pl?Function=getSurvey&SDDS=5047&Item_Id=44545&lang=en

¹⁶ http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/9492.php

4.3 Industrial Process and Product Use Sector Methodology

In general, industrial process emissions are calculated by multiplying activity data (e.g., quantity of the product produced) by the appropriate emission factor. However, there are more complex categories such as aluminum production which necessitate use of more elaborate formulae.

SF₆ emissions from the production of Aluminium are included under SF₆ used in magnesium smelters and casters due to confidentiality reasons.

Additional details on the methodologies can be found in [Annex 3.3](#)¹⁷ in Part 2 of the NIR.

¹⁷ http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/9492.php

5. AGRICULTURE SECTOR EMISSIONS

GHG emissions reported in the agriculture sector are: (a) CH₄ emissions from enteric fermentation; (b) CH₄ and N₂O emission from manure management; (c) N₂O emissions from agricultural soils (including direct and indirect sources, pasture, range and paddock manure); (d) field burning of agricultural residues; and (e) liming, urea application and other carbon containing fertilizers. Emissions associated with stationary farm equipment (e.g. heating greenhouses), and on-farm transportation (e.g. tractors), are included in the stationary combustion and transport sections respectively.

5.1 Agriculture Sub-Sector Description

Table 6: Agriculture Sub-Sector Description

Emission Category	Description
a. Enteric Fermentation	The digestive process of ruminant animals (such as cattle) involves microbial fermentation in the rumen, which produces CH ₄ emissions as a by-product.
b. Manure Management	The decomposition of manure by microbial organisms produces CH ₄ emissions as a by-product. The nitrification and denitrification of nitrogen-containing compounds in manure results in the production of N ₂ O. Factors impacting the production of CH ₄ and N ₂ O include manure characteristics and the aeration levels in various types of manure management systems.
c. Agriculture Soils	
Direct Sources	Direct sources of N ₂ O emissions include application of synthetic and manure-based fertilizers, decomposition of crop residue, irrigation, cultivation of histosols and changes to tillage practices and summer fallow.
Indirect Sources	Nitrogen present in crop residue and in synthetic and organic fertilizers (e.g., manure) applied to agricultural fields may be transported off-site through the air with subsequent re-deposition, or by leaching, erosion or runoff. A portion of this nitrogen may undergo nitrification and denitrification, producing N ₂ O emissions.
d. Field Burning of Agricultural Residues	The burning of crop residues as a matter of convenience and for the purpose of disease control through residue removals.
e. Liming, Urea Application and Other Carbon-containing Fertilizers	Includes a portion of dolomite contained in the lime consumption data; amount and composition of the urea or urea-based fertilizers applied annually, and the quantity of carbon contained in the urea that is released as CO ₂ after hydrolysis.

5.2 Agriculture Data Sources

B.C. uses the data provided within the NIR. ECCC calculates the emissions published in the NIR from an estimation of annual livestock and poultry population data sources from Statistics Canada, the Census of Agriculture, and from Agriculture and Agri-Food Canada. Data are disaggregated at the provincial level by animal subcategory to develop estimates of GHG emissions. ECCC uses data from Statistics Canada on Agricultural Soils and Urea Application estimates, and data from Natural

Resources Canada's Canadian Minerals Yearbook and Canadian Fertilizer Institute for Liming estimates.

The references for the data sources can be found in [Chapter 5](#)¹⁸ in Part 1 of the NIR.

5.3 Agriculture Sector Methodology

Agriculture sector emissions are calculated by multiplying activity data (e.g., number of livestock) by the appropriate emission factor and use a combination of the 3 tiers.

[Annex 3.4](#)¹⁸ in Part 2 of the NIR describes the estimation methodologies, equations, activity data, emission factors and parameters that are used to estimate the GHG emissions.

¹⁸ http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/9492.php

6. WASTE SECTOR EMISSIONS

GHG emissions from the waste sector are related to the treatment and disposal of solid waste and wastewater. Emissions sources are: (a) CH₄ emissions from landfills; (b) CH₄ and N₂O emissions from biological treatment of solid waste; (c) CH₄ and N₂O emissions from wastewater handling; and (d) CO₂, CH₄ and N₂O emissions from waste incineration. Waste sector emissions are influenced by the quantity of waste sent to, as well as the amount of CH₄ captured from landfills.

6.1 Waste Sub-Sector Description

Table 7: Waste Category Sub-Sector Description

Emission Category	Description
a. Solid Waste Disposal on Land	Organic wastes sent to landfills are decomposed through anaerobic (i.e., without oxygen) digestion by bacteria and other microorganisms. By-products of this process include GHG emissions. This category includes CH ₄ emissions from municipal solid waste landfills and wood waste landfills.
b. Biological Treatment of Solid Waste	Composting of Solid Waste (CH ₄ and N ₂ O emissions).
c. Wastewater Handling	The amount of organic matter and microorganisms in wastewater is reduced through aerobic (i.e., “with oxygen”) and anaerobic digestion. Both methods involve addition of bacteria to wastewater to break down organic matter and microorganisms. By-products of this process include GHG emissions. This category includes CH ₄ and N ₂ O emissions from municipal wastewater treatment operations.
d. Waste Incineration	Some municipalities incinerate waste to reduce the amount of solid waste sent to landfills. By-products of incineration of bio-based and hydrocarbon-based wastes include GHG emissions. This category includes CO ₂ and N ₂ O emissions from waste incineration, excluding CO ₂ emissions from bio-based waste, which is considered carbon-neutral. CH ₄ emissions are not included due to lack of data.

6.2 Waste Data Sources

The data sources for the different sub-sectors are shown below:

6.2.1 Solid Waste Sub-Sector

B.C. uses the data provided within the NIR. ECCC calculates the emissions published in the NIR from an estimation of the GHG emissions from two types of landfills (municipal solid waste (MSW) landfills; and wood waste landfills). Waste disposal data are collected by ECCC from a Statistics Canada biennial waste survey. Landfill gas capture and flare data are collected directly from individual landfill operators for 1997-2003 by ECCC, through a study¹⁹ for 2005 and subsequent studies conducted by ECCC for other years.

¹⁹ *An Inventory of Landfill Gas Recovery and Utilization in Canada* for 2005 prepared for ECCC

6.2.2 Wastewater Treatment Sub-Sector

B.C. uses the data provided within the NIR. ECCC calculates the emissions published in the NIR from data obtained through in-house surveys of industrial facilities either known or likely to be employing anaerobic units to treat their effluent on-site.

6.2.3 Waste Incineration Sub-Sector

B.C. uses the data provided within the NIR. ECCC calculates the emissions published in the NIR by determining the amount of waste incinerated each year from studies²⁰ performed by A.J. Chandler & Associates Ltd. for ECCC and activity data obtained directly from facilities through surveys. The type of waste incinerated can include MSW, sewage sludge, hazardous waste, clinical waste, etc.

The references for the data sources can be found in [Chapter 7](#)²¹ in Part 1 of the NIR.

6.3 Waste Sector Methodology

Emissions from wastewater handling and waste incineration are estimated by multiplying the appropriate emission factor by relevant activity data (i.e., population and quantity of waste incinerated).

Emissions from solid waste disposal are estimated through modelling of decomposition of waste in landfills using the Scholl Canyon model²². The model uses relevant activity data and site characteristics (i.e., historical quantities of waste disposed in landfill, precipitation levels, landfill depth and other characteristics) to model the various stages of decomposition of solid waste in a landfill and thus estimate CH₄ emissions.

Emissions from Biological Treatment of Solid Waste are estimated by ECCC using a composting model that is based on IPCC 2006 GL T₁ method²³.

Additional details on the methodologies can be found in [Annex 3.6](#)²¹ in Part 2 of the NIR.

²⁰ The amount of MSW incinerated is estimated based on a study performed by the Hazardous Waste Branch of ECCC and the study *Municipal Solid Waste Incineration in Canada: An Update on Operations 1999-2001*, performed by A.J. Chandler & Associates Ltd. for ECCC with trend extrapolation performed for other years.

²¹ http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/9492.php

²² The Scholl Canyon model uses a first-order decay equation (IPCC 2000) to estimate Canada's CH₄ emissions from landfills and has been validated independently through a study conducted by the University of Manitoba (Thompson et al. 2006).

²³ http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_4_Ch4_Bio_Treat.pdf

7. LAND USE, LAND-USE CHANGE AND FORESTRY (LULUCF) SECTOR EMISSIONS

The LULUCF sector consists of two categories of emissions that B.C. treats differently.

A. Afforestation and Deforestation category, which is counted towards the B.C. GHG emissions totals, is made up of: a) deforestation; b) afforestation; c) grassland to cropland conversion; and d) other lands conversion to wetlands. These line items are subject to anthropogenic control and are therefore considered not to introduce undue bias into reported emissions levels.

B. Other Land Use category, which is not counted towards the B.C. GHG emissions totals, in accordance with international inventory protocols, is made up of: a) forestland remaining forestland; b) cropland remaining cropland; c) wetlands remaining wetlands; d) grassland remaining grassland; and e) settlements remaining settlements. These categories are sometimes referred to simply as forestland management, cropland management, wetlands management, grassland management, and settlement management respectively. These emissions are important source and sink categories but are more volatile and subject to natural factors outside of direct human control and so are not reported as part of B.C. GHG emissions totals but are included in the Provincial Inventory for transparency purposes, and are referred to as “Memo Items”.

Note that emission estimates for the LULUCF sector have a high degree of uncertainty relative to estimates in other sectors. Sources of uncertainty include the limited size of sampled land area relative to the total land area of the province and the difficulty in accounting for complex ecological processes such as carbon uptake by vegetation and carbon release through organic matter decomposition.

7.1 LULUCF Sub-Sectors Description

7.1.1 Definitions

Table 8: Definitions of the Individual Land Type Categories

Land Type Category	Description
Forestland	Forest land includes all land with woody vegetation consistent with the following thresholds used to define forest land in the NIR: (i) 1.0 ha minimum land area; (ii) tree crown cover (at maturity) of more than 25%; (iii) 5 metre minimum tree height (at maturity). These thresholds underestimate total afforestation and deforestation area. In particular, small linear land clearings from minor forest service roads and oil and gas right of ways and seismic lines will be excluded, as well as any deforestation event in itself less than 1 ha in size and similarly small afforestation events. Forest land also includes systems with vegetation that currently fall below, but are expected to exceed, the threshold of the forest land category.
Cropland	Cropland includes all lands in annual crops, summer fallow, and perennial crops (mostly forage, but also including berries, grapes, nursery crops, vegetables, and fruit trees and orchards). Cropland also includes non-forest pasture or rangeland used for grazing domestic livestock that does not meet the definition of grassland. Note that this definition of cropland is broader than some definitions in common use in B.C. due to the inclusion of non-forest land used for pasture and grazing.
Grassland	Grassland includes unimproved pasture or range land that is only used for grazing domestic livestock and

Land Type Category	Description
	occurs only in geographical areas where the grassland would not naturally re-grow to forest if unused. In addition, vegetated areas that do not and will not meet the definition of forest land or cropland are generally included in this category.
Wetlands	Wetlands are areas where permanent or recurrent saturated conditions allow the establishment of vegetation and soil development typical of these conditions and that are not already in forest land, cropland or agricultural grassland. Wetlands include reservoirs as a managed sub-division and natural rivers and lakes as unmanaged sub-divisions.
Settlements	Settlements include all built-up land: urban, rural residential, land devoted to industrial and recreational use; roads, rights-of-way and other transportation infrastructure; and resource exploration, extraction and distribution (mining, oil and gas); urban tree growth.

7.1.2 Afforestation and Deforestation LULUCF Sector Categories (included in B.C.'s Inventory totals)

Table 9: Afforestation and Deforestation LULUCF Sector Categories

LULUCF Category	Description
a. Deforestation	
Forestland converted to Cropland	The clearing of forest land for agricultural use results in GHG emissions from the removal of biomass, decay of dead organic matter, changes in soil composition and changes in soil management practices. In addition, the ability of the land area to remove CO ₂ from the atmosphere is diminished.
Forestland converted to Settlements	The clearing of forest land for transportation, energy infrastructure, municipal development, resource extraction activities and recreation results in GHG emissions from the removal of biomass and from the decay of dead organic matter. In addition, the ability of the land area to remove CO ₂ from the atmosphere is diminished.
Forestland converted to Wetlands	The clearing of forest land for hydroelectric or municipal reservoirs or peat harvesting results in GHG emissions from the decomposition of cleared biomass and the decomposition of submerged soils and organic matter. In addition, the ability of the land area to remove CO ₂ from the atmosphere is diminished. Emissions are reported in this category for 10 years following the year of flooding. Emissions occurring after 10 years are reported in the "Wetlands remaining Wetlands" category.
Forestland conversion associated with HWP	The estimate of the CO ₂ emissions associated with the use and disposal of Harvested Wood Products (HWP) manufactured from wood coming from forest harvest and forest conversion activities in B.C., and consumed either in B.C. or elsewhere in the world.
b. Afforestation	
Cropland converted to Forestland	The direct conversion by humans of unused cropland into forest land results in increased sequestration of CO ₂ and minor emissions of GHGs due to the decay of dead organic matter. Post-harvest tree planting and the natural growth of vegetation in unused cropland are not included in this category.
c. Grassland converted to cropland (Grassland Conversion)	The clearing of grassland for agricultural use may result in GHG emissions due to the decay of dead organic matter, changes in soil composition and changes in soil management practices. In addition, the ability of the land area to remove CO ₂ from the atmosphere may be increased or diminished.
d. Other land converted to wetlands	Non-forest land converted to peatland (for peat extraction) or flooded land (for hydro reservoirs). Owing to methodological limitations, this includes only large hydroelectric reservoirs created by land flooding. Existing water bodies dammed for water control or energy generation were not considered if flooding

LULUCF Category	Description
(Conversion to Wetlands)	was minimal.

7.1.3 Memo Items LULUCF Sector Categories (not included in B.C.'s Inventory totals)

Table 10 provides a description of the categories and related GHG emissions sources and removals relating to the Memo Items.

Table 10: Memo Items LULUCF Sector Categories

LULUCF Category	Description
Forestland remaining Forestland (Forest Management)	The growth of biomass in forest land results in increased carbon sequestration in biomass and soils. Vegetation respiration, the decay of organic matter (natural or due to insect infestation) in biomass and soils, logging, controlled burning, and wildfires result in GHG emissions. In addition, the removal of biomass temporarily reduces the forest's capacity to remove CO ₂ from the atmosphere.
Cropland remaining Cropland (Cropland Management)	The amount of organic carbon retained in agricultural crops and soils is a balance between CO ₂ sequestration by crops, transfer and storage in soils and emissions through soil and crop decomposition. Factors that determine whether agricultural soils are a net source or sink of CO ₂ emissions include lime application, cultivation of organic soils, changes in the management of mineral soils and changes in woody biomass.
Wetlands remaining Wetlands (Wetland Management)	The residual decay of biomass cleared from the land, and the decomposition of soils in areas flooded for hydroelectric reservoirs and peat harvesting results in CO ₂ emissions. Emissions from residual decay of cleared biomass are reported in this category beginning 10 years after the year of flooding. Emissions occurring in the first 10 years are reported in the "Forestland Converted to Wetlands" category. Small hydroelectric reservoirs are not included in this category.
Grassland remaining Grassland (Grassland Management)	Managed grassland is sometimes burned naturally by lightning, by accidental ignition, as a management tool to control invasive plants and stimulate the growth of native species, or as part of military training exercises. Burning from managed grassland is a net source of CH ₄ , CO, NO _x and N ₂ O.
Settlements Remaining Settlements (Settlement Management)	Estimates of carbon sequestration by urban trees.

7.2 LULUCF Data Sources

ECCC publishes LULUCF information at the national level but does not publish provincial-level data publicly. ECCC does however provide B.C. with the provincial LULUCF data.

The references for the data sources can be found in [Chapter 6](#)²⁴ in Part 1 of the NIR.

7.3 LULUCF Sector Methodology

Estimation of GHG emissions in the LULUCF sector requires extensive modeling developed from a wide range of data sources. A description of modeling procedures and data sources is shown here.

NRCan uses version 3 of the Canadian Forest Service's (CFS) [Carbon Budget Model \(CBM\)](#)²⁵ to estimate GHG emissions and removals related to B.C.'s managed forests. This is a comprehensive modeling system that accounts for various activity data pertaining to managed forests.

CFS (part of NRCan) compiles the activity data from the National Forest Carbon Monitoring, Accounting and Reporting System (NFCMARS) in collaboration with experts in the B.C. government. Significant updates have been made to the NFCMARS through joint effort between the CFS and provincial and territorial Forestry, Environment and Agriculture ministries. CFS then shares the data with ECCC and the B.C. government.

The detailed description of methodology can be found in [Annex A3.5](#)²⁴ in Part 2 of the NIR.

7.3.1 Forest Inventory and Accounting Updates

Article 5 of the [Paris Agreement](#)²⁶ includes forests in climate actions. It states “parties should take action to conserve and enhance, as appropriate, sinks and reservoirs of greenhouse gases as referred to in Article 4, paragraph 1(d) of the Convention, including forests”.

The current inclusion of natural disturbance impacts in the forest sector inventory estimates obscures the impacts of human activity. New accounting methods are in development at NRCan/ECCC. They will be based on improved understanding of these impacts, and estimate how changes in forest management over time contribute to emissions and emission reductions. As a result, emissions from natural disturbances (such as insect outbreaks and wild fire) would be factored out of the accounting, ensuring that a jurisdiction is not unduly penalized by factors over which it has no, or little, control.

Overall, the incorporation of these updates is intended to provide better accounting for carbon flows and provide incentives for forest carbon management and greenhouse gas sequestration.

B.C. studies international accounting method revisions as they emerge, and may incorporate these updates in subsequent inventories.

²⁴ http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/9492.php

²⁵ <http://www.nrcan.gc.ca/forests/climate-change/carbon-accounting/13107>

²⁶ <https://unfccc.int/resource/docs/2015/cop21/eng/109r01.pdf>

7.3.2 Methodology to calculate GHG emissions for Afforestation, Deforestation and other Conversions

ECCC provides B.C. with provincial level LULUCF emissions data that is estimated using the same methodology used to generate national estimates published in the NIR, but with provincial breakdowns. This enables B.C. to publish the more detailed LULUCF emissions data at the provincial level than would otherwise be possible.

B.C. calculates deforestation by summing all of the emissions data for Forestland converted to other land type categories (i.e. Cropland, Grassland, Wetland and Settlements) and Forestland conversion associated with Harvested Wood Products emissions.

Afforestation is calculated by summing all of the emissions data that represent all other land type categories converted to Forestland.

Grassland converted to Cropland is calculated by summing of all emissions data for Grassland converted to Cropland.

Other Land converted to Wetlands is calculated by summing of all emissions data for other land type categories converted to Wetland.

7.3.3 Methodology to calculate GHG emissions for Other Land Use

The GHG emissions associated with the Other Land Use category (Memo Items) are calculated based on the data from CFS as stated above in [section 7.3](#).

B.C. calculates Forestland Management by summing all of the emissions data that represent Forest Growth minus Decay, Slash Pile Burning, Wildfires and Decomposition of Harvested Wood Products.

Cropland Management is calculated by summing of all emissions data for Cropland remaining Cropland.

Wetland Management is calculated by summing of all emissions data for Wetlands remaining Wetlands.

Grassland Management is calculated by summing of all emissions data for Grassland remaining Grassland.

Settlement Management is calculated by summing of all emissions data for Settlements Remaining Settlements.

8. APPENDICES

8.1 Glossary of Terms

Anthropogenic:

Anthropogenic emissions indicate the greenhouse gas emissions that occur as a result of human activities.

Afforestation:

Afforestation is defined in accordance with current international definitions as the “direct human-induced conversion of land that has not been forested since 31 December 1989 to forest land (e.g., through planting, seeding and/or the human-induced promotion of natural seed sources)”. Note that the international afforestation and reforestation definitions have been combined into the term “afforestation” for use in B.C. to avoid confusion with the conventional B.C. use of the term reforestation within a forest management context.

Deforestation:

Deforestation is defined as the “direct human-induced conversion of forest land to non-forest land”. Harvesting, when followed by regeneration, is not deforestation. Forestry operations can cause deforestation (e.g., when permanent roads and landings are established and conversion of land type category).

Forest Management:

A system of practices for stewardship and use of forest land aimed at fulfilling relevant ecological (including biological diversity), economic and social functions of the forest in a sustainable manner.

Managed Forest:

All forests subject to some kind of human interactions (notably commercial management, harvest of industrial round-wood (logs) and fuelwood, production and use of wood commodities, and forest managed for amenity value or environmental protection if specified by the country), with defined geographical boundaries.

Radiative Forcing:

Refers to the amount of heat-trapping potential for a GHG, measured in units of power per unit of area (watts per metre squared).

Removals²⁷:

Means either of the following:

- a) An amount of GHG removed from the atmosphere using an industrial or biological process;
- b) An amount of GHG that was not emitted into the atmosphere as a result of storage of those greenhouse gases or their components

Sink:

²⁷ [GG Emission Control Regulation](#)

A physical unit or process that removes a GHG from the atmosphere. Notation in the final stages of reporting is the negative (-) sign.

Slash Pile Burning²⁸:

Slash is the leftover tree limbs, tops and other residue left by logging activities. Slash pile burning is where the slash is piled together and burned during safe conditions, usually during the winter after it has been left to season (dry).

Source:

A physical unit or process that releases a GHG from the atmosphere. Notation in the final stages of reporting is the positive (+) sign.

Tier²⁹:

Tier represents a level of methodological complexity. Tier 1 is a top down approach that utilizes aggregated statistical data to estimate emissions; tier 2 is an intermediate level approach; and tier 3 is a bottom up approach such as site-specific quantification of emissions. As you go up through the tiers from 1 to 3 the level of accuracy increases, however the methodological complexity also increases.

²⁸ <http://www.bcairquality.ca/topics/slash-burning.html>

²⁹ IPCC 2006 guidelines:

http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/1_Volume1/V1_1_Ch1_Introduction.pdf

8.2 Abbreviations, Acronyms and Measures

Table 11: Abbreviations, Acronyms and Measures

Abbreviation, Acronym or Measure	Definition
AGEM	Aviation Greenhouse Gas Emission Model
AR	Assessment Report
Al ₂ O ₃	Alumina
B.C.	British Columbia
CBM	Carbon Budget Model
CFCs	Chlorofluorocarbons
CFS	Canadian Forest Service
CH ₄	Methane
CO ₂	Carbon dioxide
CO ₂ e	Carbon dioxide equivalent – 1 CO ₂ e is the GWP from the release of 1 kg of CO ₂
ECCC	Environment and Climate Change Canada
e.g.	for example
GGRTA	Greenhouse Gas Reductions Target Act
GHG	Greenhouse gas
GWP	Global warming potential
HFCs	Hydrofluorocarbons
i.e.	that is
IPCC	Intergovernmental Panel on Climate Change
LULUCF	Land Use, Land-Use Change and Forestry
MGEM	Mobile Greenhouse Gas Emission Model
NFCMARS	National Forest Carbon Monitoring, Accounting and Reporting System
NF ₃	Nitrogen trifluoride
NIR	National Inventory Report
N ₂ O	Nitrous oxide
NRCan	Natural Resources Canada
PFCs	Perfluorocarbons
QA/QC	Quality assurance/quality control
RESO	Report on Energy Supply and Demand in Canada
SF ₆	Sulphur hexafluoride
UNFCCC	United Nations Framework Convention on Climate Change
VOC	Volatile organic compound



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