METHODOLOGY BOOK FOR THE BRITISH COLUMBIA PROVINCIAL GREENHOUSE GAS INVENTORY

Ministry of Environment and Climate Change Strategy

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TABLE OF CONTENTS

List of Tables

1. PURPOSE AND STRUCTURE

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 the *Climate Change Accountability Act* (CCAA)[1]. The Provincial Inventory is the foundation on which progress towards the legislated CCAA targets is measured.

This Provincial Inventory Methodology Book is intended to:
- Serve as a reference source for evaluation of GHG emissions in B.C. by providing foundational data for GHG analysis by sector, and over time;
- 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)* and used by B.C. for the line items in the B.C. Provincial Inventory that mirror the NIR;
- Explain the methodologies used for those emissions line items directly compiled by B.C.

The United Nations Framework Convention on Climate Change (UNFCCC)[2] sets out reporting categories and methodologies for estimating emissions and removals of specified GHGs and B.C. follows this reporting structure. The Provincial Inventory Methodology Book is grouped by sectors based on definitions laid out internationally, beginning with Energy in Section 3. 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 Provincial Inventory.

Where B.C. deviates from the NIR methodology for any line items, the differing methodology is outlined in the British Columbia Provincial Greenhouse Gas Inventory: Method Changes and Exceptions Table that is posted with each year's inventory and must be read together with this Methodology Book. Where a change in method is permanent, the appropriate section in this Methodology Book will be updated. This document makes no attempt to track method changes inside the NIR itself where the NIR remains the sole source of B.C. data for a given line item.

2. REPORTING METHODOLOGY

The main data source for B.C.'s Inventory is Canada's National Inventory Report.[3] Canada's National Inventory Report (NIR) is prepared and submitted annually by ECCC to the UNFCCC.

B.C. uses methodologies for the emissions sectors as described in Annex 3[4] in Part 2 of the NIR. The data and the methodology within the Provincial Inventory follow the NIR except where explicitly specified in this document.

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[1] http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/00_07042_01
[2] http://unfccc.int/
[3] The specific inventory data sources are listed in Part 1 of the NIR *GHG Sources and Sinks in Canada.*
[4] https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories-annex-i-parties/national-inventory-submissions-2019

B.C.'s Provincial Inventory deviates 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 in emissions totals for B.C.
- The Provincial Inventory breaks out the Forest Management category into sub-sectors.

The Provincial Inventory may also include calculations of certain line items based on B.C. specific data (see Method Changes and Exceptions Table). B.C. reviews the NIR data to ensure that the data presented is accurate. B.C. revises a given line item in the Provincial Inventory if: a discrepancy in the provincial NIR data relative to other data sources is identified for a specific line item; or in circumstances where B.C. believes more accurate data is available. The Provincial Inventory Methodology Book and the annual Method Changes and Exceptions Table issued with the B.C. Inventory explain the data source and methodology used where it deviates, temporarily or permanently, from the NIR.

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.

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.

2.1   Calculating Emissions

Emission Factors

GHG emissions are typically estimated using emission factors, metrics that relate quantity of emissions released per unit level of activity data. The emission factors are determined using mass balance, fixed chemical equations or other relationships under average conditions. The average emission factors for many inventory categories are developed 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 calculated at a 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 B.C.'s Provincial Inventory are listed by sector in [Annex 6][5], Part 2 of the NIR.

Global Warming Potentials of GHGs

Greenhouse gas emissions that are influenced by human activities and that are of primary concern for GHG abatement policy and activities are listed in Table 1. 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). 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. Table 1 lists the "100-Year GWP" for the major gases and groups of gases (GWP values for other GHGs are listed under [Table 1-1][6] in Part 1 of the NIR).

Table 1: GHGs and their Global Warming Potential (GWP)

GHG	100-Year GWP (IPCC AR 4 2007)
Carbon Dioxide (CO_2)	1
Methane (CH_4)	25
Nitrous Oxide (N_2O)	298
Nitrogen Tri-fluoride (NF_3)	17,200
Sulphur Hexafluoride (SF_6)	22,800
Hydrofluorocarbon 23 (CHF_3)	14,800
Hydrofluorocarbon 32 (CH_2F_2)	675
Perfluorocarbons –Perfluoroethane (C_2F_6)	12,200

Quantification Approaches

Approaches used to produce GHG emissions data are categorized in one of three tiers. Tier 1 is a broad 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. The level of methodological accuracy increases when progressing from tiers 1 to 3, however the methodological complexity also increases. The NIR and the Provincial Inventory use methods across all three tiers.

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[5] https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories-annex-i-parties/national-inventory-submissions-2019
[6] https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories-annex-i-parties/national-inventory-submissions-2019

Recalculations and Changes from Prior Year GHG Emissions

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, and it is what allows for the comparison of emissions across years.

3.   ENERGY SECTOR EMISSIONS

GHG emissions reported in the energy sector are from: (a) stationary combustion; (b) transport fuel combustion activities; (c) fugitive emissions from the fossil fuel and mining industries; and (d) CO_2 transport and storage.

B.C. relies on the NIR data from ECCC to estimate provincial emissions from the energy sector. ECCC uses Statistics Canada's *Report on Energy Supply and Demand in Canada* (RESD)[7] as the principal data source to estimate stationary combustion and transport emissions. The RESD 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.

Different approaches exist to calculate GHG emissions for energy sub-sectors[8]. References for data sources can be found in [Chapter 3](#)[9] in Part 1 of the NIR. Additional details on the methodologies can be found in [Annex 3.1 and 3.2](#)[10] in Part 2 of the NIR.

3.1   Stationary Combustion Sources Sub-Sector

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.

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[7] http://www5.statcan.gc.ca/olc-cel/olc.action?objId=57-003-X&objType=2&lang=en&limit=0
[8] The CO_2 pipelines in Canada are associated with the use of carbon dioxide in an enhanced oil recovery process. All CO_2 from this process is recovered for reuse and therefore no estimates are provided for emissions from storage.
[9] https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories-annex-i-parties/national-inventory-submissions-2019
[10] https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories-annex-i-parties/national-inventory-submissions-2019

Table 2: Stationary Combustion Sources Sub-Sector Description

Emission Category	Description
Public Electricity and Heat Generation	Production of electricity and useful heat in public or privately owned utility thermal power plants whose primary activity is supplying electricity to the public.
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.

Methodology

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. B.C. adopts ECCC data for most energy sector emissions.

3.2   Transport Sub-Sector

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, tracked-construction vehicles, mining vehicles, and off-road recreational vehicles.
Pipelines	Transportation and distribution of crude oil, natural gas and other products through a pipeline.

Methodology

NIR transport emissions estimates are used for the B.C. Inventory.

The methodology ECCC uses 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.

ECCC uses a Canadian-specific version of the US Environmental Protection Agency's (EPA) MOVES model, to allocate emissions in the transport sub-sector. The MOVES model is used to calculate energy consumption for the entire vehicle fleet, based on a range of distinct vehicle classes. ECCC uses a modified version of the U.S. EPA's NONROAD model for off-road emissions for reconciling bottom-up emissions estimates with top-down fuel availability. To do the same for the aviation sector it uses an Aviation Greenhouse Gas Emission Model (AGEM) and it uses RESD fuel reports for railway and navigation emissions.

3.3   Fugitive Sources Sub-Sector

Fugitive sources are intentional and 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, coal rubble 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; process vents include activities such as compressor start-up venting and purging of lines during maintenance.

Methodology

NIR fugitive emissions estimates are used for the B.C. Inventory.

The fugitive emission estimates for the oil and natural gas line item are based on studies[11] conducted by Clearstone Engineering Ltd. for ECCC. The fugitive emission estimates for coal mining are based on studies[12] conducted by King and Cheminfo Services Inc. and Clearstone Engineering Ltd.

3.4   CO$_2$ Transport and Storage Sub-Sector Description

This sub-sector involves the capture of anthropogenic CO_2 and its transport to a storage facility. The CO_2 pipelines in Canada are associated with the use of carbon dioxide in an enhanced oil recovery process. All CO_2 from this process is recovered for reuse and therefore no estimates are provided for emissions from storage.

4.   INDUSTRIAL PROCESSES AND PRODUCT USE SECTOR EMISSIONS

Industrial processes include activities that produce GHG emissions not from the combustion of a hydrocarbon fuel, but rather from a 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 described in Table 5.

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[11] *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
[12] 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.

4.1 Industrial Processes and Product Use

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 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_2CO_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_2O_3) with carbon-based anodes, pre-baking of carbon anodes and anode effects.
d. Production and Consumption of Halo-carbons, SF_6 and NF_3	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; the use of natural gas liquids and refinery output as feedstocks in the chemical industry and the use of lubricants such as engine oil and grease in transportation and industrial applications; 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 the use of SF_6 in electrical equipment; N_2O 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 CO_2 emissions from the use of urea in selective catalytic reduction.

Methodology

B.C. relies on the NIR data from ECCC to estimate provincial emissions from industrial processes and product use.

To estimate B.C.'s GHG emissions, ECCC uses Statistics Canada's RESD and an "*Annual Industrial Consumption of Energy*" survey[13]. 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

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[13] https://www.statcan.gc.ca/eng/survey/business/5047

Natural Resource Canada (NRCan). The references for the data sources can be found in Chapter 4[14] in Part 1 of the NIR.

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. Additional details on the methodologies can be found in Annex 3.3[15] in Part 2 of the NIR.

5. AGRICULTURE SECTOR EMISSIONS

GHG emissions reported in the agriculture sector include five sub-sectors as described in Table 6. 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.

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_2O.
	Factors impacting the production of CH_4 and N_2O include manure characteristics and the aeration levels in various types of manure management systems.
c. Agriculture Soils	
Direct Sources	Direct sources of N_2O emissions include application of synthetic and manure-based fertilizers, decomposition of crop residue, irrigation, losses of soil organic matter through mineralization, cultivation of organic soils 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_2O 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.

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[14] https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories-annex-i-parties/national-inventory-submissions-2019
[15] https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories-annex-i-parties/national-inventory-submissions-2019

Methodology

The B.C. Inventory relies on NIR data from ECCC to estimate provincial emissions from agriculture. 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[16] in Part 1 of the NIR.

Agriculture sector emissions are calculated by multiplying activity data (e.g., number of heads of livestock) by the appropriate emission factor and use a combination of the 3 tiers. Annex 3.4[17] 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.

6. WASTE SECTOR EMISSIONS

GHG emissions from the waste sector are related to the treatment and disposal of solid waste and wastewater (see Table 7). Waste sector emissions are influenced by the quantity of waste sent to, as well as the amount of CH_4 captured from landfills.

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 and anaerobic digestion at biogas facilities of solid waste (CH_4 and N_2O emissions).
c. Wastewater treatment and discharge	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_2O emissions from municipal wastewater treatment operations.
d. Incineration and open burning of waste	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_2O 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.

Data sources for the waste sector vary by sub-sector. The references for the data sources can be found in Chapter 7[18] in Part 1 of the NIR.

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[16] https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories-annex-i-parties/national-inventory-submissions-2019
[17] https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories-annex-i-parties/national-inventory-submissions-2019
[18] https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories-annex-i-parties/national-inventory-submissions-2019

Solid Waste Sub-Sector :

To estimate B.C.'s GHG emissions, 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. Municipal sold 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 by ECCC[19]. The wood waste disposal estimate is based on an extrapolation from the 3 nationally available data points (1990, 1998, and 2004) from the National Wood Residue Data Base (NRCan survey).

Wastewater Treatment Sub-Sector :

To estimate B.C.'s GHG emissions, ECCC calculates emissions 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.

Waste Incineration Sub-Sector :

To estimate B.C.'s GHG emissions, ECCC determines the amount of waste incinerated each year from studies[20], 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.

Methodology

Methodologies used by ECCC to estimate GHG emissions from waste vary by type of waste. 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 model[21]. 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 estimate decomposition and related CH_4 emissions. Emissions from Biological Treatment of Solid Waste are estimating by ECCC using a composting model that is based on IPCC 2006 GL T_1 method[22]. Additional details on the methodologies can be found in Annex 3.6[23] in Part 2 of the NIR.

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

[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] The Scholl Canyon model uses the most recent first-order decay equation (IPCC) to estimate Canada's CH_4 emissions from landfills and has been validated independently through a study conducted by the University of Manitoba (Thompson et al. 2006).

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

[23] https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories-annex-i-parties/national-inventory-submissions-2019

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

The LULUCF sector consists of two categories of emissions: Afforestation and Deforestation; and Other Land Use. The Other Land Use category includes the management of forestlands, croplands, wetlands, grasslands, and settlements.

B.C. accounts for these two categories differently in its Provincial Inventory. Afforestation and Deforestation are subject to anthropogenic control and counted towards B.C. GHG emissions totals and included within the Provincial Inventory totals. Emissions associated with the Other Land Use category are important sources and sinks 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 in accordance with international practice. Emissions from Other Land Use are published as "Memo Items" in the Provincial Inventory for transparency purposes.

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 Description

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 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.

Land Type Category	Description
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.

Table 9: Afforestation and Deforestation LULUCF Sector Categories (Included in inventory totals)

Emissions 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 Harvested Wood Products (HWP)	The estimate of CO_2 emissions associated with the use and disposal of 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 (Conversion 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 was minimal.

Table 10: Memo Item LULUCF Sector Categories (Not included in inventory totals)

Emissions 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. Includes emissions from the decomposition of HWP from harvest.
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_2O.
Settlements Remaining Settlements **(Settlement Management)**	Estimates of carbon sequestration by urban trees.

7.2 LULUCF Sector Methodology

B.C. obtains the provincial LULUCF data from ECCC. ECCC publishes LULUCF information at the national level but does not publish provincial-level data. The references for the data sources can be found in Chapter 6[24] in Part 1 of the NIR.

Estimation of GHG emissions in the LULUCF sector requires extensive modeling developed from a wide range of data sources. 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. Experts in the B.C. government collaborate with CFS to compile the activity data from the National Forest Carbon Monitoring, Accounting and Reporting System (NFCMARS). The detailed description of methodology can be found in Annex A3.5[26] in Part 2 of the NIR.

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[24] https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories-annex-i-parties/national-inventory-submissions-2019
[25] http://www.nrcan.gc.ca/forests/climate-change/carbon-accounting/13107
[26] https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories-annex-i-parties/national-inventory-submissions-2019

B.C.'s provincial level LULUCF emissions data are estimated by ECCC using the same methodology used to generate national estimates published in the NIR (see Table 11), drawing data from the same source, but publishing at a level of regional disaggregation unavailable elsewhere.

B.C. reports based on the following aggregations of the data in the CFS dataset, composed of sub-processes as follows:

Table 11: Methodologies for Calculating Afforestation and Deforestation Emissions

Category	Methodology
Deforestation	Sum of 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	Sum of all of the emissions data that represent all other land type categories converted to Forestland.
Grassland converted to cropland	Sum of all emissions data for Grassland converted to Cropland.
Other land converted to wetlands	Sum of all emissions data for other land type categories converted to Wetland.

Table 12: Methodologies for Calculating GHG Emissions for Other Land Use

Category	Methodology
Forestland Management	Sum of Forest Growth minus Decay, Slash Pile Burning, Wildfires and Decomposition of Harvested Wood Products.
Cropland Management	Cropland remaining Cropland.
Wetland Management	Wetlands remaining Wetlands.
Grassland Management	Grassland remaining Grassland.
Settlement Management	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.

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.

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).

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.

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.

Grassland:
Grassland includes unimproved pasture or range land that is only used for grazing domestic livestock and 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.

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).

Removals[27]:
Means either of the following:
a) An amount of GHG removed from the atmosphere using and 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

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.

Sink:
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 Burning[28]:
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.

Tier[29]:
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.

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[27] Greenhouse Gas Emission Control Regulation
[28] http://www2.gov.bc.ca/gov/content/environment/air-land-water/air/air-pollution/smoke-burning/industrial
[29] IPCC 2006 guidelines: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/1_Volume1/V1_1_Ch1_Introduction.pdf

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.

8.2 Abbreviations, Acronyms and Measures

Table 13: Abbreviations, Acronyms and Measures

Abbreviation, Acronym or Measure	Definition
AGEM	Aviation Greenhouse Gas Emission Model
AR	Assessment Report
Al_2O_3	Alumina
B.C.	British Columbia
CCAA	Climate Change Accountability Act
CBM	Carbon Budget Model
CFCs	Chlorofluorocarbons
CFS	Canadian Forest Service
CH_4	Methane
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent – 1 CO_2e is the GWP from the release of 1 kg of CO_2
ECCC	Environment and Climate Change Canada
e.g.	for example
EPA	Environmental Protection Agency
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
MOVES	Motor Vehicle Emissions Simulator
NFCMARS	National Forest Carbon Monitoring, Accounting and Reporting System
NF_3	Nitrogen trifluoride
NIR	National Inventory Report
N_2O	Nitrous oxide
NRCan	Natural Resources Canada
PFCs	Perfluorocarbons
QA/QC	Quality assurance/quality control
RESD	Report on Energy Supply and Demand in Canada
SF_6	Sulphur hexafluoride
UNFCCC	United Nations Framework Convention on Climate Change
VOC	Volatile organic compound