British Columbia

GREENHOUSE GAS INVENTORY REPORT

2012

BRITISH COLUMBIA
Ministry of Environment

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TABLE OF CONTENTS

List of Tables

List of Figures

1. PURPOSE AND SCOPE OF THE REPORT

1.1 Purpose of the Report

The *British Columbia Greenhouse Gas Inventory Report 2012* (B.C. GHG inventory report or Provincial Inventory Report – PIR) has been prepared to provide sound, science-based, comparable and consistent reporting of GHG sources and sinks in British Columbia – in support of section 4(a) of the *Greenhouse Gas Reductions Target Act*[1] (GGRTA), as well as national and international reporting processes and related initiatives. A GHG sources and sinks inventory is a comprehensive account of emission releases from anthropogenic sources (e.g., fuel combustion, industrial processes) and removals[2] by sinks (e.g., growing plants and trees) for a defined area (such as a nation or province) over a specified period of time.

The GGRTA establishes legislated targets for reducing British Columbia's GHG emissions. As compared to 2007 levels, emissions must be reduced by a minimum of 33% by 2020 and 80% by 2050. Interim reduction targets of 6% by 2012 and 18% by 2016 have also been set by Ministerial Order. The Ministry of Environment (the ministry) has prepared a B.C. GHG inventory report for every even year subsequent to the 2007 baseline (i.e., 2008, 2010 and 2012). Inventory totals are a contributor, but not the complete emissions total, used to assess progress made toward greenhouse gas targets.

Further Information
A separate summary of this B.C. GHG inventory report, as well as additional information, is available at: www.env.gov.bc.ca/cas/climate/ghg-inventory/index.htm.

Comments or questions regarding the report can be sent to: ghgreporting@gov.bc.ca.

B.C. GHG Emissions and the Progress to Targets Report

The Progress to Targets Report[3] is published by the Ministry of Environment in parallel with the Provincial Inventory Report (PIR). The PIR addresses the legal requirement in section 4(a) of the *Greenhouse Gas Reduction Targets Act* to determine provincial emission levels. The Progress to Targets Report documents the progress made toward achieving the targets, actions that have been taken to achieve that progress and the plans to further that progress (requirements under sections 4(b), (c) and (d) of the *Act*).

In 2007, the base year for calculation of B.C. GHG emissions targets established under the provincial *Greenhouse Gas Reductions Target Act*, GHG emissions were 64.3 Mt CO_2e. Total greenhouse gas emissions in British Columbia in 2012 were 61.5 Mt megatonnes (Mt) CO_2e.[4] This is 4.4% lower than 2007 emissions, but does not include emissions reductions from memo item emissions sources (forest carbon – see section 2.3).

Under international protocols, GHG emissions estimates are reviewed and revised to incorporate methodological refinements and improved data. The 2012 GHG emissions estimate (as well as all figures used in calculating trends and changes in emissions from previous years) in this report reflects the revised emissions estimates determined and reported by Environment Canada in the National Inventory Report.

[1] See: www.env.gov.bc.ca/cas/codes/ggrta
[2] The term "removal" is used to describe the removal of CO_2 from the atmosphere (e.g., through storage of carbon by vegetation or physical processes). Processes that remove more carbon dioxide from the atmosphere than they release, as part of the carbon cycle, are often referred to as carbon sinks. For example, forests and oceans can act as carbon sinks.
[3] See: www.env.gov.bc.ca/cas/pdfs/2014-Progress-to-Targets.pdf
[4] One megatonne (1 Mt) is one million tonnes. One kilotonne (1 kt) is one thousand tonnes. Note also that totals and percentages in figures and tables of this report may not sum due to rounding protocols.

1.2 Scope and Structure of the Report

The B.C. GHG inventory report (PIR) is structured using the same categorical breakdown of GHG sources and sinks presented in Environment Canada's *National Inventory Report on Greenhouse Gases and Sinks in Canada* (National Inventory Report – NIR), grouped in the following "sector" and "sub-sector" headings:

- *Energy* – stationary combustion sources, transportation and fugitive sources
- *Industrial processes* – mineral products, chemical industry, metal production, consumption of halocarbons and SF_6, and other and undifferentiated production
- *Solvent and other product use*
- *Agriculture* – enteric fermentation, manure management and agricultural soils
- *Waste* – solid waste disposal on land, wastewater handling and waste incineration
- *Land Use, Land-use Change and Forestry* – afforestation, deforestation, forest land, cropland and wetlands

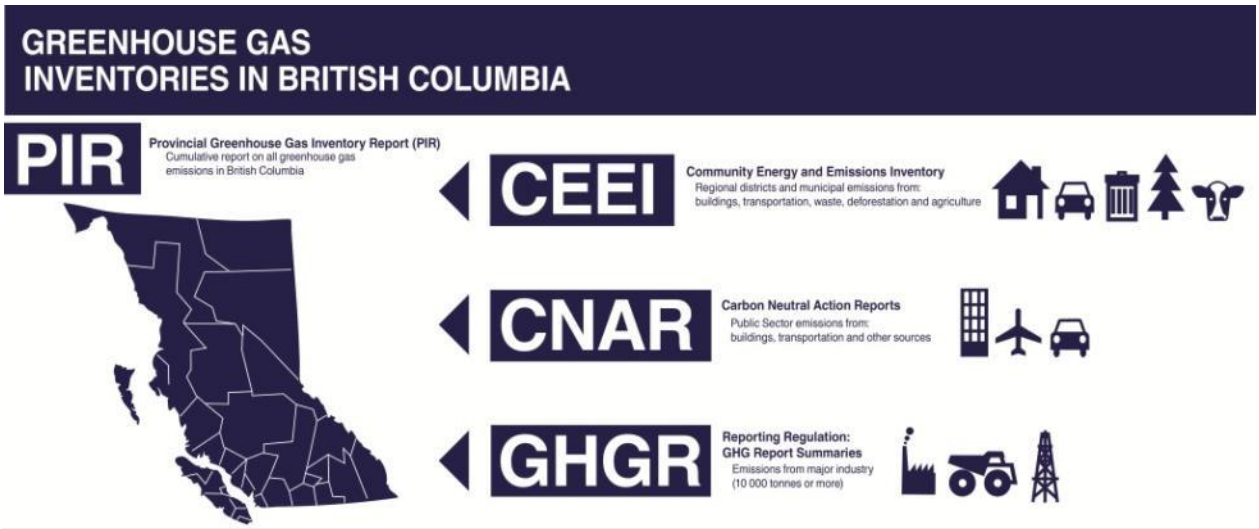


Figure 1: Related British Columbia GHG Inventories

British Columbia has developed and maintained four provincial-level greenhouse gas inventories, each serving a different purpose (see figure 1). Together the inventories provide a comprehensive view of the sources of provincial emissions. Insights gained through the collection of data for facility-specific reporting and the Community Energy and Emissions Inventory (CEEI) may be used to refine (where applicable) the GHG quantification methodologies used in the NIR and consequently also the B.C. GHG inventory report.

Provincial Greenhouse Gas Inventory Report (PIR)

The Provincial Greenhouse Gas Inventory Report (PIR) is the top-down (see section 10.4), aggregate report on all greenhouse gas emissions occurring within the geographic boundaries of British Columbia. The PIR is the foundation on which progress towards the legislated *Greenhouse Gas Reduction Targets Act* (GGRTA)[5] targets is measured and provides a high-level view of emissions for the province, for each sector, as well as emissions factors and background information.

Note: Continued on next page

[5] http://www.leg.bc.ca/38th3rd/1st_read/gov44-1.htm

Community Energy and Emissions Inventory (CEEI)

The Community Energy Emissions Inventory[6] (CEEI) supports tracking and reporting of energy use and GHG emissions at a community level in order to improve community-level understanding and decision making. The reports provide buildings, transportation and waste emissions profiles for the entire geographic area of the 162 municipalities and 28 regional districts within British Columbia. Deforestation and agricultural emissions data is also reported at the regional district level.

Carbon Neutral Action Reports

Carbon Neutral Action Reports[7] comply with GGRTA obligations for B.C. to document buildings, fleet and paper emissions from crown corporations, post-secondary institutions, school districts and health authorities and "Core Government" (government ministries and agencies). Core Government also reports on business travel.

Reporting Regulation Greenhouse Gas Emissions Report Summaries

The Reporting Regulation Greenhouse Gas Emissions Report Summaries[8] document emissions and geographic location for each industrial facility emitting 10,000 tonnes or more of greenhouse gas emissions within British Columbia, as well as the aggregate of all oil and gas and electricity transmission emissions for facilities with emissions less than 10,000 tonnes that are owned or operated by the same company. Given that the Reporting Regulation data provide a complete or near-complete profile of greenhouse gas emissions for some industrial sectors (e.g., oil and gas, most industrial process emissions, electricity generation), the Province is considering using the data to refine some of the coarser estimates in Canada's National Inventory Report. Reporting regulation data was used to help cross-check (but not as the direct source for) the re-estimate of oil and gas fugitive emissions this year. Reporting Regulation data is only available for 2010 to 2012 at present, an insufficient number of years on which to base the inventory estimates.

[6] http://www.env.gov.bc.ca/cas/mitigation/ceei/index.html
[7] http://www.livesmartbc.ca/government/carbon_neutral/neutral_action_reports.html
[8] http://www.env.gov.bc.ca/cas/mitigation/ggrcta/reporting-regulation/2010-emissions-reports.html

2. REPORTING METHODOLOGY

2.1 Preparing the Provincial Inventory Report

This report has been prepared by the Ministry of Environment (the ministry), working with staff in other provincial ministries and with federal counterparts, to determine and report the 2012 GHG emissions level for B.C. In keeping with national and international GHG inventory procedures it is expected that GHG estimates, including the 2007 baseline, will continue to be updated annually or periodically to reflect resolution of data anomalies and improved quantification methods and input data.

The ministry supports federal agencies responsible for preparation of the NIR to develop current and scientifically rigorous best practices and methodologies for GHG quantification, consistent with international standards and practices. The ministry also follows protocols established by Environment Canada to maintain confidentiality of data as and where appropriate.

Where needed to report emissions at a provincial scale, the B.C. GHG inventory report includes data provided to the ministry by the GHG Division of Environment Canada that is not published at the provincial level in the NIR (but that is included in NIR national totals). The ministry uses "memo item" categories to address important source and sink categories not included in national or provincial totals (see discussion under reporting of 'land use, land-use change and forestry' sector 'memo items' in section 2.3).

The ministry continues to use a Quality Assurance/Quality Control (QA/QC) process to ensure that the NIR data presented in the B.C. GHG inventory report is accurate and representative. Unless discrepancies in provincial data are noticed in QA/QC processes, the data presented in this report is provided entirely by Environment Canada and the Canadian Forest Service and is the same data presented in the NIR.

Readers wishing detailed information regarding methodologies and protocols for emissions reporting and recalculation – as well as QA/QC process, data sources and planned improvements – can refer to the extensive set of background and methodological documents provided on the Environment Canada GHG website.[9]

2.2 Canada's Inventory and Reporting System

Canada's national GHG emissions inventory system has been established under authority of the *Canadian Environmental Protection Act* (CEPA) and meets terms of the United Nations Framework Convention on Climate Change (UNFCCC).[10] The UNFCCC sets out reporting categories and methodologies for estimating emissions and removals of specified GHGs.

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

[9] See links under Environment Canada's "Climate Change" website: www.ec.gc.ca/cc
[10] See the "United Nations Framework Convention on Climate Change" website: http://unfccc.int

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. For example, future responsibility for harvested wood products will rest with the jurisdiction that produces rather than consumes the wood.

This approach keeps both reporting boundaries very clear and presumes that emissions are best counted at their source. 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 (purchasing) jurisdiction, rather than the home (producing) 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 (such as those under the Kyoto Protocol) may differ from inventory reporting rules and can allow for trade of emissions reductions, offsets and similar instruments across geographic borders.

B.C. is collecting GHG imported electricity emissions data as part of its standardized industry reporting system. Since this type of information is already publically available, a future PIR could include a summary as a memo item.

Differences in Reported Emissions – Canada and B.C.

The PIR (Provincial Inventory Report) includes British Columbia-specific emissions currently not reported at the provincial level in the NIR (National Inventory Report). These emission sources and sinks are reported under the "land use, land-use change and forestry" sector. Net deforestation and other land conversions from this category are included in B.C.'s emissions total, while forest, crop, wetland and grassland management are not but are reported separately for transparency. The PIR also includes a recalculation of: (i) oil and gas fugitives; and (ii) solid waste disposal on land – line items presented in the NIR. As a result, reported emissions are 1.4 Mt (2.3%) higher than the emissions of 60.1 Mt reported for B.C. in the NIR.

All facilities in Canada emitting over 50,000 tonnes of GHGs in a given year are required to report emissions to Environment Canada. Facility reporting is released as a companion to the NIR under Environment Canada's Greenhouse Gas Emissions Reporting program.[11] For the 2012 calendar year, 549 facilities across Canada reported their greenhouse gas (GHG) emissions to Environment Canada. Total reported emissions were 257 Mt CO_2e. This represents an increase of 1% from a 2011 total of 254 Mt. The GHG emissions data collected from facilities represent just over one-third (37%) of Canada's total GHG emissions. Generally, data reported under this system are not used in the NIR, with the exception of limited industrial process emissions data.

B.C. conducts its own industrial reporting for facilities and oil and gas companies 10,000 tonnes a year and larger under the British Columbia Reporting Regulation.[12] One hundred companies comprising 237 facilities reported emissions of 10,000 tonnes or more of GHGs in 2012. Total emissions from industrial operations over 10,000 tonnes were 19.0 megatonnes (Mt) of carbon dioxide equivalent (CO_2e), which is 31% of total provincial emissions. Emissions data by facility is made publicly available separately from the PIR.

[11] See links under Environment Canada's "Climate Change" website (www.ec.gc.ca/cc) for both a description of the reporting system and a link to the public data download site.
[12] See links in "Industrial Facilities Greenhouse Gas Reports" under B.C. Ministry of Environment's "Climate Change" webpage under "Reports and Data".

2.3 Reporting of Land Use, Land-Use Change and Forestry Sector Memo Items

The ministry uses "memo item" categories where needed to address important source and sink categories not otherwise included or cumulated into national totals. Reporting of emissions and removals under the "land use, land-use change and forestry" (LULUCF) sector is mandatory under greenhouse gas reporting protocols established by the United Nations Framework Convention on Climate Change (UNFCCC). Land-use and forestry emissions do not, however count towards national totals. The federal government reporting of GHG emissions in this sector however, only includes afforestation, deforestation and forestry (using the reference level approach) in its emissions target accounting.

The B.C. GHG inventory report includes emissions from the afforestation and deforestation components of the LULUCF sector towards provincial GHG emission totals for the following reasons:

- Afforestation and deforestation in B.C. are quantified using accounting protocols that do not introduce bias into reported emission levels.
- There is greater anthropogenic control over afforestation and deforestation than other sources and sinks in this sector.
- Reporting of net afforestation and deforestation emissions are in accordance with the "net-zero deforestation" policy outlined in B.C.'s Climate Action Plan.

Emissions designated as "memo items" in the LULUCF sector are included in this report under the categories of "forest land remaining forest land", "cropland remaining cropland", "wetlands remaining wetlands" and "grassland remaining grassland" – in accordance with international inventory protocols. These categories are sometimes referred to as forest land, cropland, wetlands, and grasslands respectively. See section 9 for additional detail and description of categories and associated emissions and removals.

Forestry Inventory and Accounting Updates

Starting with the submission of 1990-2013 national inventory reports, the UNFCCC requires use of updated harvested wood products methodologies for the forestry sector. This change addresses a key inventory estimation issue by more accurately reflecting actual emissions from harvested wood. The following changes result:

1. The end use type and timeframe for use of wood products will now have an impact on carbon emissions amounts and the year to which they are attributed. Carbon in harvested wood is no longer deemed to be immediately emitted to the atmosphere. Instead, emissions will be accounted for as they occur – carbon stored in harvested wood products will be reported as it is emitted (not at the time of harvest) while wood used for bioenergy will be treated as an immediate emission.
2. The source of wood (green, standing dead or waste) for any use becomes important.

The current inclusion of natural disturbance impacts in the forest sector inventory estimates obscures the impacts of human activity. Adoption of newly emerging accounting methods supports better understanding of these impacts. The new accounting methods utilize inventory estimates and other information to estimate how changes in forest management over time contribute to achieving emission reductions. As a result:

1. 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. It is likely that natural disturbance emissions totals would be provided as an information item for transparency and completeness purposes.

Note: continued on next page

2. The forward-looking reference levels[13] (baseline) for forest management would ensure that the existing state of a jurisdiction's forest is factored into the accounting.

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

Beginning with the release of the 1990-2013 inventory tables in 2015, B.C. GHG inventory estimates will match Canada's production approach[14] to incorporating harvested wood product emissions estimates. B.C. is studying the international accounting method updates that would exclude the impact of natural disturbances and may incorporate these for the 1990-2013 (and subsequent) inventory and/or accounting year estimates.

2.4 Calculating Emissions

Global Warming Potentials of GHGs

There are four major gases or groups of gases[15] that are influenced by human activities that are of interest with respect to greenhouse gas emissions:

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)
- Synthetic (not naturally occurring) fluorinated gases – sulphur hexafluoride (SF_6), hydro-fluorocarbons (HFCs) and perfluorocarbons (PFCs)

The concept of "global warming potential" (GWP or CO_2e) has been developed to enable comparison of the ability of different GHGs to trap heat in the atmosphere (radiative forcing).[16] By definition, the GWP from the release of 1 kg of CO_2 is one, with the GWP of other GHGs stated relative to CO_2. 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. The following summary table lists the "100-Year GWP" for the major gases and groups of gases. A complete table with specific figures for each GHG is included in Annex 10.2 of this report.

[13] See: http://unfccc.int/files/kyoto_protocol/application/pdf/lulucf_-_canada_-_september_2009_informal_submission.pdf

[14] The 2015 inventory report will be the first report in which countries are required to include harvested wood product emissions in their inventory reporting. The specific tables that must be followed for this reporting can be found at: http://unfccc.int/files/national_reports/annex_i_ghg_inventories/reporting_requirements/application/vnd.openxmlformats-officedocument.spreadsheetml.sheet/set_2_afolu_final_16nov13.xlsx (see Tables 4.Gs1 and 4.Gs2).

[15] The ministry is following developments regarding emerging greenhouse gases such as nitrogen trifluoride (NF_3), trifluoromethyl sulphur pentafluoride (SF_5CF_3), fluorinated ethers, perfluoropolyethers, hydrocarbons (black carbon) and other compounds – and may also include these within the B.C. provincial GHG inventory report at the appropriate time. Further information can be found at: http://unfccc.int/national_reports/annex_i_ghg_inventories/items/4624.php and Environment Canada website: http://www.ec.gc.ca/ges-ghg/default.asp?lang=En&n=CAD07259-1.

[16] The term "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).

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

GHG	Current Year GWP 100-Year GWP (IPCC 2AR 1995)	Future GWP 100-Year GWP (IPCC 4AR 2007)
Carbon Dioxide (CO_2)	1	1
Methane (CH_4)	21	25
Nitrous Oxide (N_2O)	310	298
Nitrogen Trifluoride (NF_3)	-	17,200
Sulphur Hexafluoride (SF_6)	23,900	22,800
Hydrofluorocarbon - 23 (CHF_3)	11,700	14,800
Hydrofluorocarbon - 32 (CH_2F_2)	650	675
Perfluorocarbons – 116 (C_2F_6)	9,200	12,200

International Inventory and Global Warming Potential Updates

At the 17th United Nations Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP 17) in Durban, South Africa[17] the UNFCCC Reporting Guidelines for greenhouse gas inventories were released.[18] Revised guidelines contain updates in scope and methods, and incorporate recent science based on the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories.[19] The revisions will take effect internationally starting with the 2015 submission of 1990-2013 national inventory reports. All inventory years from 1990-2013 will be recalculated based on the new standards. Given the importance of international standardization, British Columbia will follow the same timeframe and approach.

The updates include the adoption of the IPCC 4th Assessment Report (4AR)[20] global warming potentials, reporting of emissions from wood products when they occur rather than immediately upon harvest and inclusion of new (mostly industrial) source and sink categories (e.g. NF_3). The most significant changes for B.C. are: (i) the 20% increase in the global warming potential of methane, which will raise the relative importance of fugitive oil and gas, coal mine and agricultural methane emissions in the inventory and; (ii) the time sensitive reporting of emissions from wood products which is expected to reduce emissions from logging by approximately 50%. As NF_3 primary use is in electronics manufacturing, its inclusion is likely insignificant in B.C.

Other chemical compounds, including short-lived climate forcers [21] such as black carbon (soot from forest fires, slash burning and diesel engines)[22], are known to have an impact on climate change. The ministry is tracking accounting and science developments related to these compounds and will consider incorporating them into its greenhouse gas inventory if international guidelines are updated and/or changes are adopted by sub-national governments.

[17] http://unfccc.int/meetings/durban_nov_2011/meeting/6245.php
[18] http://unfccc.int/national_reports/annex_i_ghg_inventories/reporting_requirements/items/2759.php
[19] http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html
[20] http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_synthesis_report.htm
[21] http://www.unep.org/dewa/Portals/67/pdf/SL_climateforcers_02.pdf
[22] http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-5-4.html

Emission Factors

GHG emissions are typically estimated using emission factors – metrics that relate quantity of emissions released to unit levels of activity data (e.g., 2.34 kg CO_2e emitted per litre gasoline burned for on road vehicles, 0.85 CO_2e kg per kg wood waste with 50% moisture content). Emission factors are determined using mass balance, fixed chemical equations or other relationships under average conditions. The factors can be averaged across various geographical ranges – nationally, provincially or even at a facility-specific level. Emission factors used in calculations for fuel combustion, industrial processes and electricity emissions are listed under separate tables in Annex 10.3 of this report.

Recalculations and Changes in Prior Year GHG Emissions

Year to Year Changes in GHG Emissions

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 influences emissions.

Changes over three and ten year (or longer) periods provide a better indication of trends in emissions than annual differences.

Uncertainty in inventory estimates is inherent and the inventory should only be viewed as an approximation of total emissions.

In preparing each year's national inventory report submission, Environment Canada 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 (e.g., model artifacts) found when reviewing previous inventory reports; and (iii) updates to the source data used in the inventory calculations (e.g., regular updates to the Statistics Canada Report on Energy Supply and Demand). As a result of these recalculations, emissions estimates for any given past year will change when a new inventory report is submitted.

Between the 1990-2011 and 1990-2012 inventories, the following significant emissions adjustments were made by Environment Canada:

- The estimates for "Other and Undifferentiated Production" were re-estimated for the years 1995-2011, resulting in a downward adjustment of 630 kilotonnes in year 2007 for B.C.
- The estimate for "Fossil Fuel Production and Refining" was re-estimated for the 2011 year, resulting in a upward adjustment of 1,700 kilotonnes in year 2011 for B.C.

For the 1990-2012 inventory report, the ministry has, in addition to adjustments made by Environment Canada, incorporated the following changes:

- A significant re-estimate of oil and gas fugitive emissions based on a 2014 update to a 2000 study used to estimate these emissions.[23] To correct this major known issue, B.C. is incorporating this update within its 1990-2012 inventory report.
- An update to the Environment Canada landfill gas capture survey that collected data from 1990-2011. As significant landfill gas capture systems were installed at British Columbia landfills in 2012 to meet compliance requirements under the Landfill Gas Management Regulation, B.C. is incorporating estimates of incremental 2012 landfill gas capture into its 1990-2012 inventory report.

For the 1990-2013 inventory report, the following updates are expected:

- Inclusion of additional deforestation mapping of B.C. municipalities. B.C. will be incorporating this update with the 1990-2013 inventory tables.
- B.C. is investigating the incorporation of the updated forest carbon accounting rules into the 1990-2013 inventory tables (see Sections 2.3 and 9). Given the substantive nature of the changes and potential data availability and interpretation issues, the first incorporation of this update may be as a revised memo item table rather than a full line item.

[23] "A National Inventory of Greenhouse Gas (GHG), Criteria Air Contaminant (CAC) and Hydrogen Sulphide (H_2S) Emissions by the Upstream Oil and Gas Industry" (2000). Unpublished study, Clearstone Engineering Ltd.

3. B.C. GHG EMISSIONS – 2012

3.1 B.C. GHG Emissions by Sector – 2012

GHG emissions are attributed to six defined sectors: energy; industrial processes; solvents and other product use; agriculture; waste; and afforestation and deforestation.

Total GHG emissions in 2012 from each of the sectors is shown in Figure 2. The figure also shows emissions from the three energy sub-sectors (stationary combustion sources, transport and fugitive sources) as a significant percentage of total emissions are attributed to these sub-sectors. A brief description of these sectors, their attributed GHG emissions and three and ten year trends in emissions is provided in Table 2. Figure 3 shows trends in emissions over time.

Note that emission percentages presented in tables and figures are rounded to the nearest tenth of a percent. Unless otherwise stated in the report, all emissions are presented in kilotonnes of carbon dioxide equivalent (kt CO_2e) rounded to the nearest whole number.

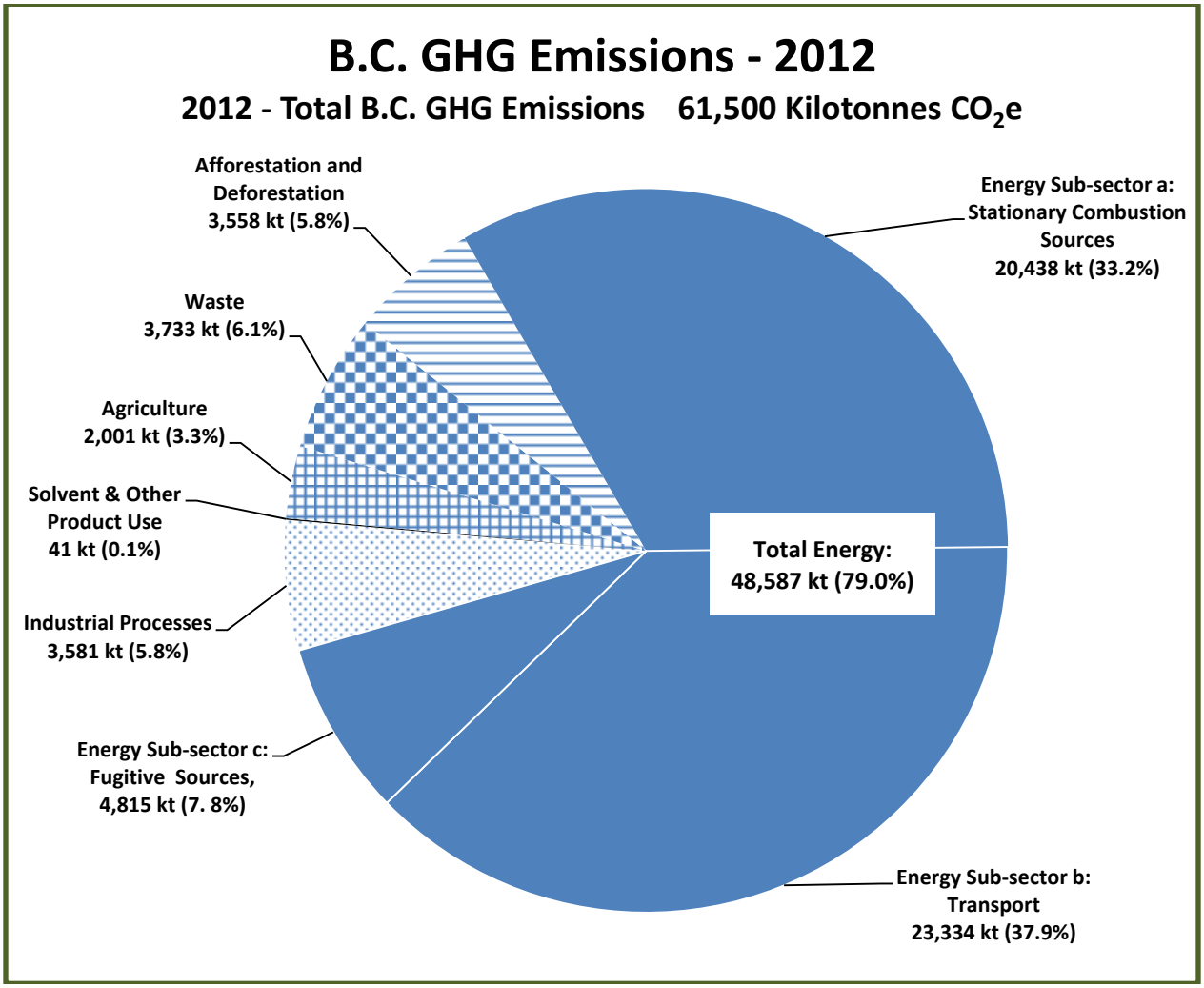


Figure 2: B.C. GHG Emissions – 2012

Table 2: Sector Descriptions and 2012 GHG Emissions

Sector	Description	Key Factors Influencing Changes in Emissions	3-Year Change (2009-2012)	10-Year Change (2002-2012)	GHG Emissions (kt CO_2e)	% of B.C. Emissions
ENERGY	Emissions from stationary and transport fuel combustion and fugitive emissions from the fossil fuel industry	Oil and gas extraction and processing activities,[1] use of natural gas for electricity generation,[1] use of heavy-duty diesel vehicles,[2] fugitive oil and natural gas emissions[3]	+1.5%	-5.2%	**48,587**	**79.0%**
INDUSTRIAL PROCESSES	Emissions from chemical reactions used in industry that physically or chemically transform materials	Closure of ammonia and methanol plants, use of improved control technology for PFC emissions in aluminum production[4]	-7.5%	-0.6%	**3,581**	**5.8%**
SOLVENT & OTHER PRODUCT USE	Nitrous oxide emissions when used as an anaesthetic or propellant	Use of nitrous oxide as anaesthetic and propellant[5]	+18.7%	-19.5%	**41**	**0.1%**
AGRICULTURE	Emissions from enteric fermentation, manure management and non-CO_2 emissions from agricultural soils	Cattle and hog populations, fertilizer use, soil management practices[6]	-5.7%	-20.0%	**2,001**	**3.3%**
WASTE	Emissions from solid waste disposal, wastewater treatment and waste incineration	Annual waste generated and quantities sent to landfills,[7] rates of diversion (i.e., recycling and composting),[7] capturing and flaring of CH_4 emissions from landfills	-7.9%	-5.8%	**3,733**	**6.1%**
AFFORESTATION & DEFORESTATION	Emissions from deforestation and removals from afforestation	Area of deforested land (i.e., conversion of forest land to settlement or cropland) and afforested land (e.g., conversion of cropland to forest land)[8]	+7.5%	-4.3%	**3,558**	**5.8%**
	TOTAL				**61,500**	

[1] Statistics Canada Report on Energy Supply and Demand in Canada

[2] Statistics Canada CANSIM Table 405-008: Canadian vehicle survey, vehicle-km, by type of vehicle, province and territory

[3] B.C. Reporting Regulation 2010 Facility GHG Emission Report Summaries

[4] Rio Tinto Alcan Primary Metal B.C. Operations Annual Performance Reports

[5] Statistics Canada International Merchandise Trade Database and Nitrous Oxide Canada

[6] Statistics Canada Census of Agriculture

[7] Statistics Canada Waste Management Industry Survey: Business and Government Sectors

[8] Refer to Annex 10.4 for detailed data

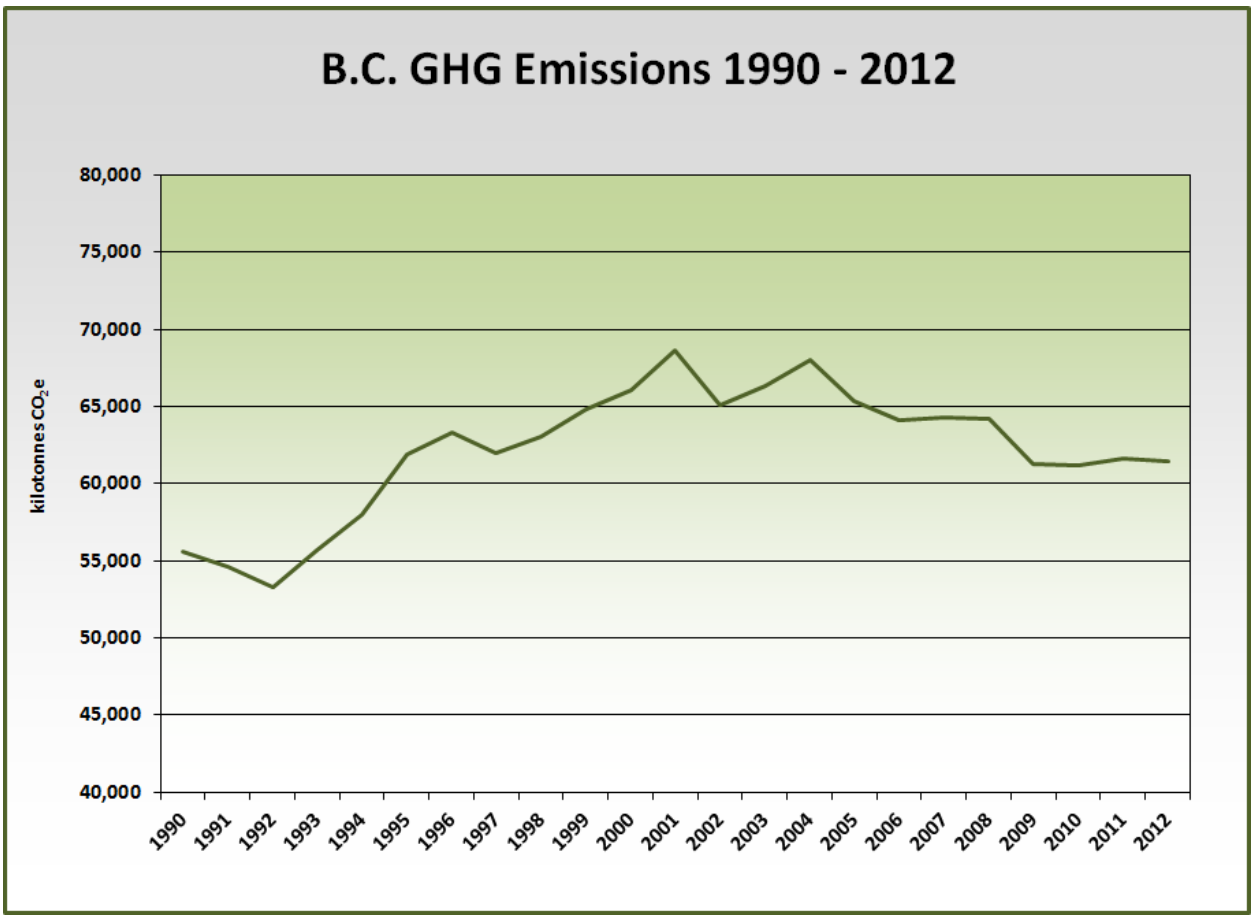


Figure 3: B.C. GHG Emissions – 1990-2012 Trends

3.2 B.C. GHG Emissions by Greenhouse Gas – 2012

Table 3 provides a summary of emissions by greenhouse gas (in kt and kt CO_2e) for each reporting category. Sub-sectors in the land use, land-use change and forestry (LULUCF) sector with emissions and removals for afforestation and deforestation are included in the provincial total. Forest land, cropland and wetlands management are reported as "memo items". Note that these memo item emissions do not contribute to the total emissions figure reported in the first row of the table (see section 2.3).

Table 3: B.C. Emissions by GHG and Reporting Category – 2012

Greenhouse Gas	CO_2	CH_4	CH_4	N_2O	N_2O	PFCs	HFCs and SF_6	TOTAL
Unit GHG Source Category	kt	kt	kt CO_2e	kt	kt CO_2e	kt CO_2e	kt CO_2e	kt CO_2e
TOTAL	**49,715 (80.8%)**	**375**	**7,869 (12.8%)**	**8**	**2,330 (3.8%)**	**444**	**1,143 (1.9%)**	**61,500**
ENERGY	**44,163**	**151**	**3,163**	**4**	**1,261**			**48,587**
a. Stationary Combustion Sources	**19,497**	**30**	**631**	**1**	**310**			20,438
Electricity and Heat Generation	487	0	2	0	4			494
Fossil Fuel Industries	6,101	17	360	0	53			6,514
Mining and Oil & Gas Extraction	1,749	0	1	0	10			1,759
Manufacturing Industries	3,847	1	14	1	157			4,018
Construction	188	0	0	0	1			189
Commercial & Institutional	2,785	0	1	0	17			2,804
Residential	3,960	12	252	0	64			4,276
Agriculture & Forestry	381	0	0	0	2			383
b. Transport	**22,315**	**3**	**68**	**3**	**951**			**23,334**
Domestic Aviation	1,038	0	1	0	9			1,048
Road Transportation	14,152	1	24	1	405			14,581
Light-Duty Gasoline Vehicles	3,466	0	6	0	123			3,595
Light-Duty Gasoline Trucks	3,982	0	7	0	150			4,140
Heavy-Duty Gasoline Vehicles	1,614	0	1	0	42			1,657
Motorcycles	26	0	0	0	0			27
Light-Duty Diesel Vehicles	82	0	0	0	2			84
Light-Duty Diesel Trucks	58	0	0	0	2			59
Heavy-Duty Diesel Vehicles	4,727	0	4	0	85			4,816
Propane & Natural Gas Vehicles	198	0	5	0	1			204
Railways	608	0	1	0	81			689
Domestic Marine	2,529	0	5	0	110			2,644
Other Transportation	3,988	2	37	1	346			4,371
Off-Road Gasoline	697	1	18	0	5			720
Off-Road Diesel	2,514	0	3	1	335			2,852
Pipelines	777	1	16	0	6			799
c. Fugitive Sources	**2,350**	**117**	**2,464**	**0**	**1**			**4,815**
Coal Mining		40	832					832
Oil and Natural Gas	2,350	78	1,632	0	1			3,983

Note: Table continued on next page

Greenhouse Gas	CO_2	CH_4	CH_4	N_2O	N_2O	PFCs	HFCs and SF_6	TOTAL
Unit	kt	kt	kt CO_2e	kt	kt CO_2e	kt CO_2e	kt CO_2e	kt CO_2e
GHG Source Category								
INDUSTRIAL PROCESSES	**1,994**					**444**	**1,143**	**3,581**
a. Mineral Products	**1,227**							**1,227**
Cement Production	1,028							1,028
Lime Production	173							173
Mineral Product Use	26							26
b. Chemical Industry								
Nitric Acid Production								
Adipic Acid Production								
c. Metal Production	**372**					**444**	**1**	**817**
Iron and Steel Production								
Aluminium Production	372					444		817
SF_6 Used in Magnesium Smelters and Casters							1	1
d. Consumption of Halocarbons and SF_6							**1,142**	**1,142**
e. Other & Undifferentiated Production	395							**395**
SOLVENT & OTHER PRODUCT USE					**41**			**41**
AGRICULTURE		**52**	**1,102**	**3**	**900**			**2,001**
a. Enteric Fermentation		44	933					**933**
b. Manure Management		8	169	1	172			**341**
c. Agriculture Soils				2	728			**728**
Direct Sources				1	307			307
Pasture, Range and Paddock Manure				1	167			167
Indirect Sources				1	254			254
Field Burning of Agricultural Residues								
WASTE	**73**	**169**	**3,559**	**0**	**101**			**3,733**
a. Solid Waste Disposal on Land		167	3,516					3,516
b. Wastewater Handling		2	44	0	89			133
c. Waste Incineration	73			0	11			84
AFFORESTATION & DEFORESTATION	**3,485**	**2**	**45**	**0**	**28**	**0**	**0**	**3,558**
a. Afforestation	-22[1]							-22
b. Deforestation	3,504	2	45	0	28			3,577
MEMO ITEMS	**(categories presented for information purposes but not included in B.C. total GHG emissions)**							**MEMO ITEMS**
OTHER LAND USE	***36,503***	***82***	***1,722***	***3***	***1,070***			***39,295***
a. Forest Management	*36,251*	*82*	*1,722*	*3*	*1,070*			*39,043*
b. Cropland Management	*212*							*212*
c. Wetlands Management	*40*							*40*
d. Grassland Management	*0*	*0*	*2*	*0*	*1*			*3*

Note: "0" indicates less than 0.6 kt or ktCO_2 emissions

[1] A negative number indicates that the estimate is a sink (i.e., the activity removes carbon from the atmosphere)

3.3 B.C. GHG Emissions by Sector – 1990 to 2012

Table 4: B.C. GHG Emissions 1990-2012

Year	1990	2002	2007	2008	2009	2010	2011	2012
GHG Source Categories	GHG Emissions (kt CO_2e)							
TOTAL (with afforestation and deforestation)	**55,569**	**65,068**	**64,318**	**64,255**	**61,277**	**61,216**	**61,618**	**61,500**
ENERGY	**41,233**	**51,234**	**50,276**	**50,663**	**47,886**	**48,127**	**48,722**	**48,587**
a. Stationary Combustion Sources	**18,958**	**22,160**	**20,871**	**20,807**	**20,455**	**19,936**	**21,430**	**20,438**
Electricity and Heat Generation	803	946	1,125	1,467	1,319	1,211	761	494
Fossil Fuel Industries	3,576	5,544	6,163	6,017	6,281	6,354	6,944	6,514
Mining & Oil and Gas Extraction	328	284	1,169	1,444	1,416	1,622	1,670	1,759
Manufacturing Industries	6,460	6,730	4,662	4,070	4,036	4,060	4,185	4,018
Construction	306	76	125	104	63	81	187	189
Commercial & Institutional	2,838	4,037	2,906	3,089	2,742	2,498	2,818	2,804
Residential	4,328	4,414	4,649	4,556	4,551	3,804	4,589	4,276
Agriculture & Forestry	321	130	71	60	46	305	277	383
b. Transportation	**18,609**	**23,743**	**24,859**	**25,304**	**23,166**	**23,713**	**22,323**	**23,334**
Domestic Aviation	1,285	1,340	1,422	1,331	1,202	1,156	1,087	1,048
Road Transportation	11,405	14,684	15,484	15,396	15,536	15,456	15,254	14,581
Light-Duty Gasoline Vehicles	3,735	4,281	4,059	4,023	4,094	3,928	3,632	3,595
Light-Duty Gasoline Trucks	2,134	4,618	4,635	4,603	4,694	4,509	4,171	4,140
Heavy-Duty Gasoline Vehicles	2,224	1,652	1,772	1,778	1,831	1,773	1,657	1,657
Motorcycles	19	21	29	29	30	29	27	27
Light-Duty Diesel Vehicles	34	54	66	71	78	83	81	84
Light-Duty Diesel Trucks	40	51	59	60	63	63	59	59
Heavy-Duty Diesel Vehicles	2,438	3,719	4,638	4,580	4,540	4,855	5,415	4,816
Propane & Natural Gas Vehicles	781	287	226	252	207	216	212	204
Railways	1,441	865	424	658	444	515	676	689
Domestic Marine	1,025	1,875	2,627	2,584	2,666	2,704	2,262	2,644
Others	3,453	4,979	4,901	5,336	3,318	3,882	3,044	4,371
Off Road (sum of gasoline and diesel below)	2,597	3,619	3,968	4,441	2,450	3,046	2,237	3,572
Off-Road Gasoline	350	429	442	351	255	345	423	720
Off-Road Diesel	2,247	3,190	3,526	4,090	2,195	2,701	1,814	2,852
Pipelines	856	1,360	933	895	868	836	806	799
c. Fugitive Sources	**3,666**	**5,330**	**4,546**	**4,552**	**4,265**	**4,479**	**4,969**	**4,815**
Coal Mining	686	666	728	701	621	764	758	832
Oil and Natural Gas	2,980	4,664	3,817	3,851	3,644	3,715	4,211	3,983
INDUSTRIAL PROCESSES	**2,674**	**3,601**	**4,009**	**4,011**	**3,871**	**3,696**	**3,476**	**3,581**
a. Mineral Products	**850**	**1,315**	**1,404**	**1,273**	**1,033**	**1,126**	**1,140**	**1,227**
Cement Production	613	1,065	1,186	1,069	857	932	939	1,028
Lime Production	162	201	162	157	137	165	172	173
Mineral Products Use	76	49	57	48	38	29	30	26

Note: Table continued on next page

Year	1990	2002	2007	2008	2009	2010	2011	2012
GHG Source Categories	GHG Emissions (kt CO_2e)							
b. Chemical Industry								
Nitric Acid Production								
Adipic Acid Production								
Petrochemical Production								
c. Metal Production	1,507	**1,064**	**1,102**	**1,153**	**1,149**	**785**	**785**	**817**
Iron and Steel Production								
Aluminium Production	1,507	1,062	1,101	1,150	1,148	785	785	817
SF_6 Used in Magnesium Smelters and Casters		2	1	2	1	1	1	1
SF_6 used in electrical equipment	60	40	49	66	61	61	28	47
Consumption of Halocarbons and SF_6		527	781	800	916	1,016	1,077	1,096
d. Total Consumption of HFC and SF_6	**60**	**566**	**831**	**865**	**977**	**1,077**	**1,105**	**1,142**
e. Other & Undifferentiated Production	**257**	**656**	**672**	**719**	**713**	**708**	**445**	**395**
SOLVENT & OTHER PRODUCT USE	**21**	**50**	**43**	**45**	**34**	**32**	**32**	**41**
AGRICULTURE	**2,146**	**2,503**	**2,356**	**2,273**	**2,123**	**2,090**	**2,005**	**2,001**
a. Enteric Fermentation	**976**	**1,231**	**1,120**	**1,068**	**986**	**943**	**918**	**933**
b. Manure Management	**315**	**394**	**369**	**362**	**350**	**345**	**341**	**341**
c. Agriculture Soils	**855**	**878**	**867**	**843**	**787**	**802**	**746**	**728**
Direct Sources	394	339	357	351	333	352	325	307
Pasture, Range and Paddock Manure	168	239	213	200	180	169	160	167
Indirect Sources	292	300	298	291	274	280	261	254
Field Burning of Agricultural Residues								
WASTE	**3,340**	**3,964**	**4,001**	**4,008**	**4,054**	**3,968**	**3,953**	**3,733**
a. Solid Waste Disposal on Land	3,166	3,755	3,788	3,795	3,840	3,753	3,737	3,516
b. Wastewater Handling	92	124	129	129	130	131	132	133
c. Waste Incineration	81	86	85	85	84	84	84	84
AFFORESTATION AND DEFORESTATION	**6,155**	**3,716**	**3,634**	**3,256**	**3,308**	**3,302**	**3,429**	**3,558**
Afforestation		-5	-13	-14	-16	-18	-21	-22
Deforestation	6,140	3,721	3,647	3,270	3,325	3,319	3,447	3,576
Grassland conversion	3					1	2	3
Conversion to Wetlands	12							
OTHER LAND USE (Not included in total B.C. emissions)	***-21,232***	***-24,801***	***38,703***	***22,612***	***49,490***	***86,146***	***27,048***	***39,297***
Forest Management	*-21,420*	*-25,088*	*38,418*	*22,273*	*49,217*	*85,875*	*26,779*	*39,043*
Cropland Management	*84*	*214*	*233*	*232*	*227*	*222*	*218*	*212*
Wetlands Management	*104*	*68*	*51*	*48*	*46*	*44*	*42*	*40*
Grassland Management		*4*		*58*	-	*5*	*10*	*2*

[1] A negative number indicates that the estimate is a sink (i.e., the activity removes carbon from the atmosphere)

3.4 Emissions per Capita, per Unit of Economic Activity and Energy Use

Table 5: GHG Emission Trends – per Person and per Unit GDP

Period	GHG per Capita (tonnes CO_2 e/person)	GHG per GDP (tonnes CO_2e/$ million GDP)	GHG per Energy Use (tonnes CO_2e/TJ energy use)
2012	**13.5**	**294.3**	**72.0**
2009	13.9	315.5	74.2
2002	15.9	396.5	73.1
3-Year Trend (2009 to 2012)	-2.5%	-6.6%	-2.8%
10-Year Trend (2002 to 2012)	-14.6%	-25.7%	-1.4%

Figure 4 shows the trends in these indicators from 1990 to 2012. Data points are indexed to a starting point of 100 at 1990, with cumulative increases or decreases for each year plotted as a percentage of the 1990 figure for each indicator.

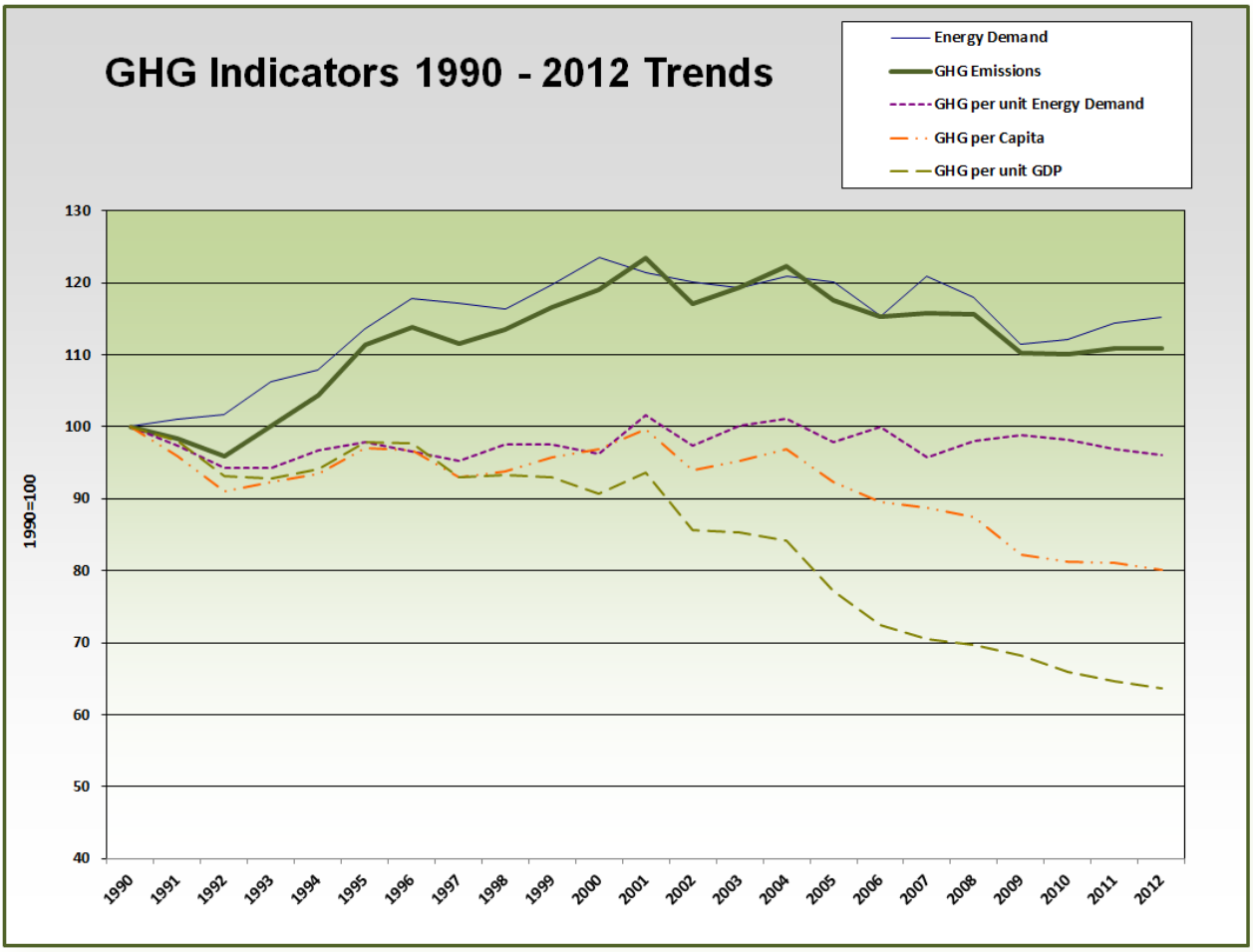


Figure 4: GHG Indicators – 1990-2012 Trends

4. ENERGY SECTOR EMISSIONS

The energy sector is subdivided into three sub-sectors – stationary combustion, transport and fugitive emissions.

Emissions by sub-sector and category relative to total B.C. emissions are shown in Figure 5. Sub-sector descriptions, the percentage change in emissions over three and ten years, and the key factors influencing changes in emissions for each of the sub-sectors are provided in Table 6. Trends from 1990-2012 are shown in Figure 6.

Data and analyses of emissions and trends for each of the energy sub-sectors are provided in Sections 4.1 through 4.3. Data sources are provided in Annex 10.4.

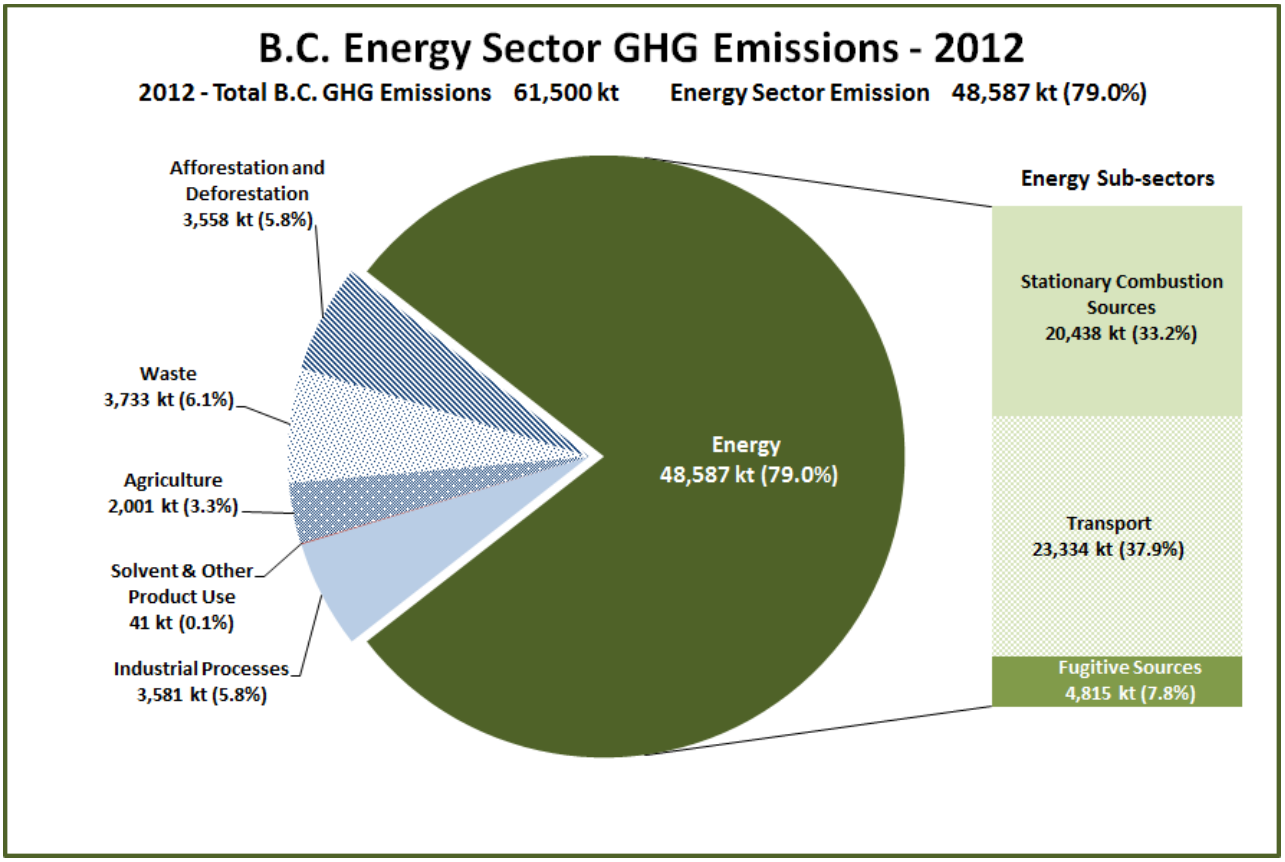


Figure 5: Energy Sector GHG Emissions – 2012

Table 6: Energy Sub-sector Descriptions

Sub-sector	3-Year Trend	10-Year Trend	Description
a. Stationary Combustion Sources	-0.1%	-7.8%	Emissions from stationary devices that combust solid, liquid or gaseous fuel in order to generate useful heat 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.
b. Transport	+0.7%	-1.7%	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.
c. Fugitive Emissions	+12.9%	-9.7%	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.

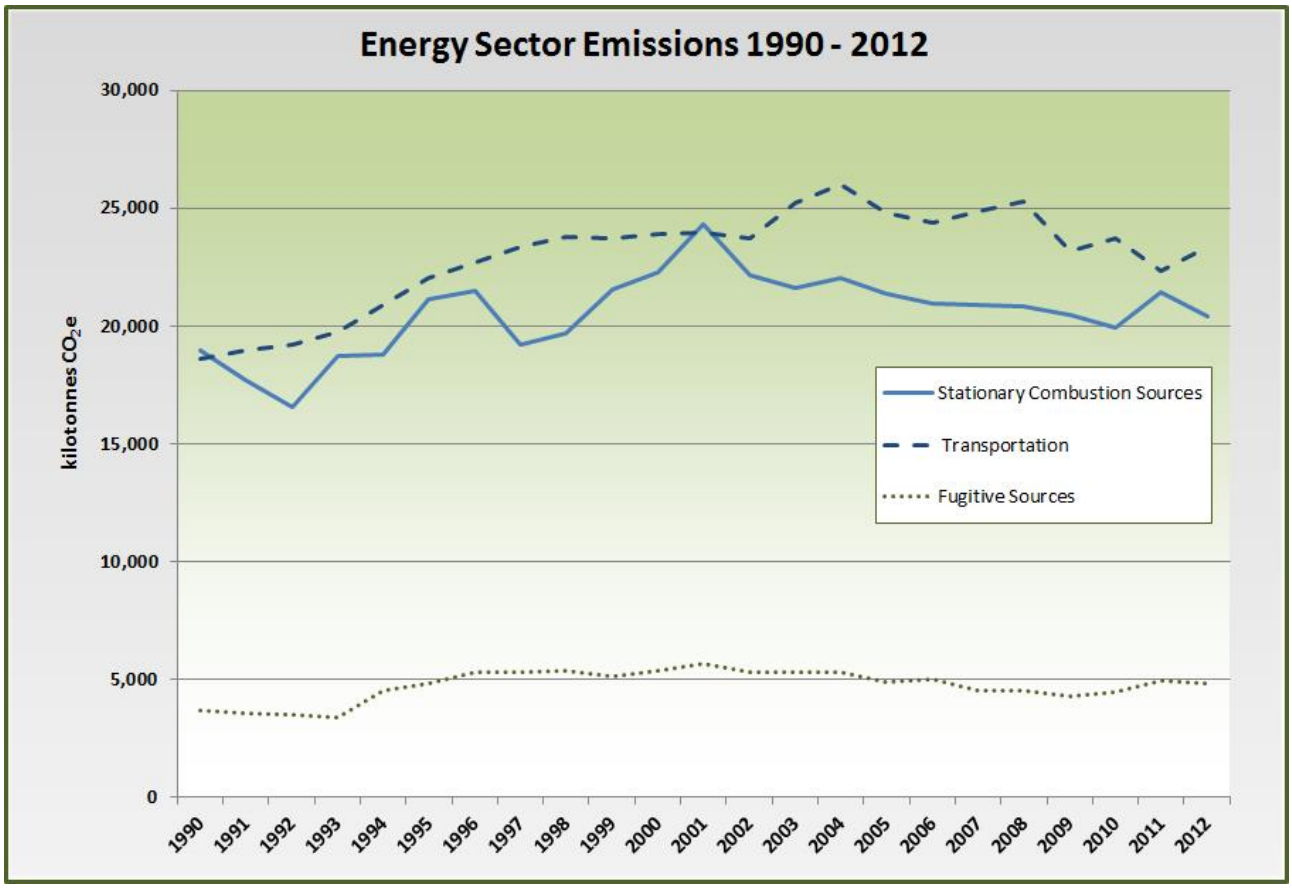


Figure 6: Energy Sector Emissions – 1990-2012 Trends

4.1 Energy Sub-sector a: Stationary Combustion Sources

Stationary combustion sources are emissions from stationary devices that combust solid, liquid or gaseous fuel in order to generate useful heat 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.

Emissions by category in the stationary combustion sources sub-sector are shown in Figure 7. Category descriptions, the percentage change in emissions over three and ten years, and the key factors influencing changes in emissions, for each of the categories are provided in Table 7.

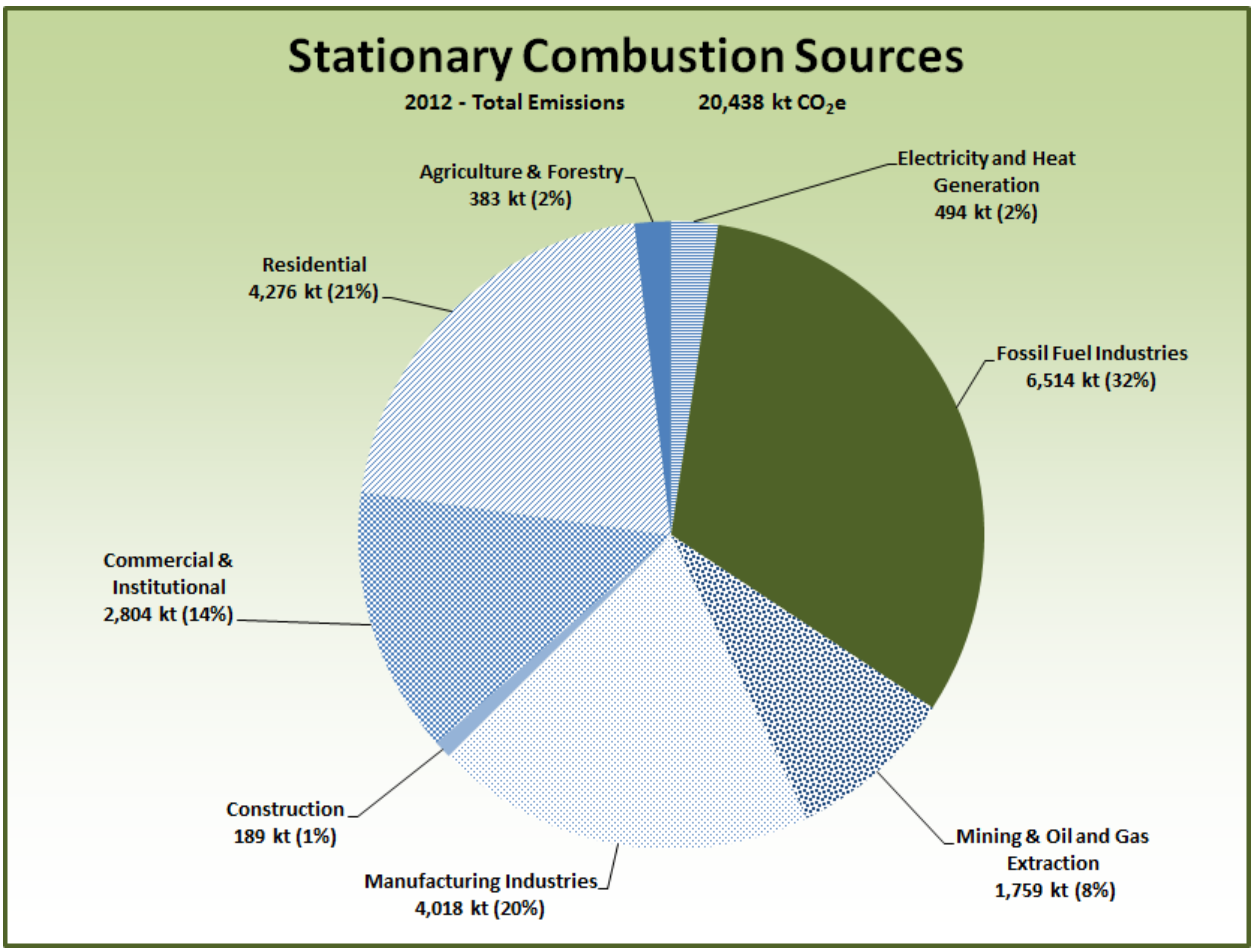


Figure 7: Stationary Combustion Sub-sector GHG Emissions by Category – 2012

Table 7: Stationary Combustion Description, Trends and Key Drivers

Emission Category	2012 Emissions	3-Year Trend	10-Year Trend	Description	Key Factors Influencing Changes in Emissions
STATIONARY COMBUSTION SUB-SECTOR	**20,438 (kt CO_2e)**	**-0.1%**	**-7.8%**		
Electricity and Heat Generation	494	-62.5%	-47.8%	Production of electricity and useful heat in thermal power plants in both the public and private sector	Demand for electricity,[1] precipitation,[2] variation in relative amounts of hydro-generated and fossil fuel-generated electricity[1]
Fossil Fuel Industries	6,514	+3.7%	+17.5%	Petroleum refineries, and natural gas and conventional oil production facilities	Production volumes of refined petroleum products and natural gas[1]
Mining and Oil and Gas Extraction	1,759	+24.2%	+520.0%	Metal and non-metal mines, stone quarries and gravel pits, oil and gas extraction facilities, mineral exploration and contract drilling operations	Extraction of coal, metals and natural gas[1]
Manufacturing Industries	4,018	-0.5%	-40.3%	Production of non-ferrous metals (e.g., aluminium, lead, zinc, copper), pulp and paper, cement, lime and other non-metallic mineral products	Production from manufacturing industries,[3] fuel sources (e.g., use of biomass rather than fossil fuel sources[1])
Construction	189	+202.3%	+150.8%	Building and road construction, and other construction activities	Number of annual housing starts and commercial/ institutional starts requiring fossil fuel and electricity use in construction[4,5,6]
Commercial and Institutional	2,804	+2.2%	-30.5%	Service industries related to mining, communication, wholesale and retail trade, finance and insurance, real estate, education, etc.; government establishments; National Defence and Canadian Coast Guard; train stations, airports; buildings and warehouses	Area of floor space requiring heating and electric loads,[5] mitigated by energy efficiency actions,[5] temperature[2]
Residential	4,276	-6.0%	-3.1%	Personal residences including homes, apartment hotels, condominiums and farm-houses	Area of floor space requiring heating and electric loads,[6] mitigated by energy efficiency actions,[6] temperature[2]
Agriculture and Forestry	383	+724.9%	+193.8%	Forestry, logging service, agricultural, hunting and trapping industry activities (excluding food processing and farm machinery manufacturing and repair)	Production in forestry sector,[3] fuel sources (e.g., switching to biomass)[1]

[1] Statistics Canada Report on Energy Supply and Demand in Canada

[2] Weather data – Environment Canada and B.C. River Forecast Centre (snowpack)

[3] Statistics Canada CANSIM Table 304-0015: Manufacturing sales, by North American Industry Classification System (NAICS) and province, monthly (dollars)

[4] B.C. Stats – British Columbia Building Permits, Housing Starts and Sales

[5] NRCan Office of Energy Efficiency National Energy Use Database: Commercial/Institutional Sector British Columbia : Secondary Energy Use and GHG Emissions by End-Use

[6] NRCan Office of Energy Efficiency National Energy Use Database: Residential Sector British Columbia : Secondary Energy Use and GHG Emissions by End-Use

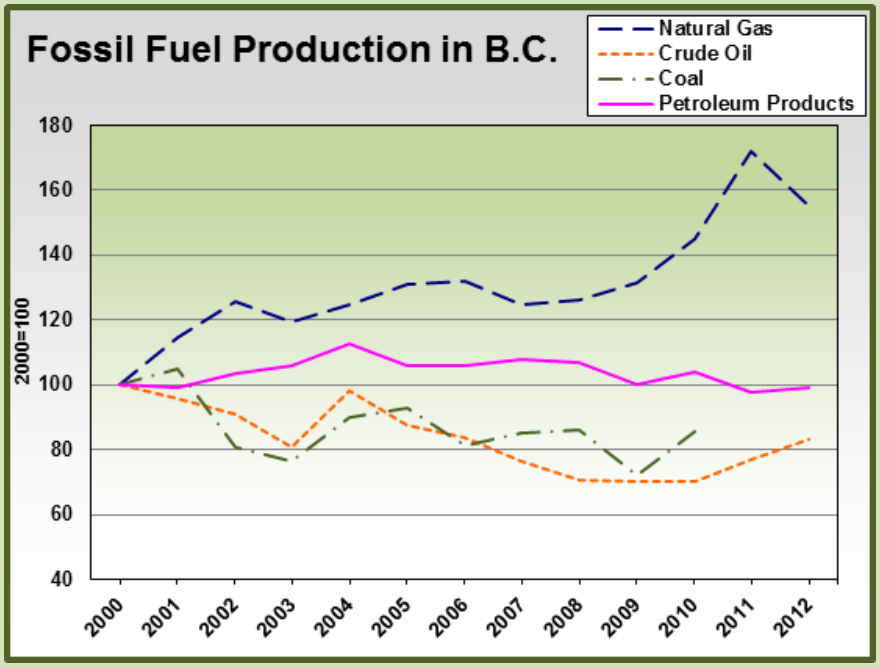
Understanding trends in energy sector emissions – fossil fuel production in B.C.

GHG emissions are associated with the production (as well as the consumption) of fossil fuels. Emissions associated with fossil fuel production depend on:

- Volume of fuel produced (e.g., tonnes of coal)
- Type of production (e.g., underground/surface mining, conventional natural gas/shale gas)
- Carbon dioxide (for natural gas) or methane (for coal) content of fuel produced
- Production equipment (e.g., mining haulers)
- Associated secondary emissions (e.g., fugitive emissions from exposed coal mine faces)
- Emissions control measures

Figure 8 shows that from 2000 to 2012, production of crude oil in B.C. decreased considerably until 2010, followed by a sharp increase. Petroleum product production decreased slightly (0.7% over the period) and natural gas production increased by about 55% from 2000 to 2012.[1]

Exports of natural gas amount to approximately 74% of B.C. production.[2] Emissions related to consumption of any fossil fuel are allocated to the jurisdiction of consumption (not of production).



Control measures available to reduce emissions related to fossil fuel production include:

- Carbon capture and sequestration
- Capture and beneficial use of methane from coal mines and faces
- Reducing flaring and fugitive emissions from oil and gas production equipment
- Electrification of equipment

Figure 8: Fossil Fuel Production in B.C.

B.C.'s coal production volume has generally been trending downward since 2000. Inter-annual fluctuations can be attributed largely to export market conditions, as B.C. consumption represents a very low proportion of total production (2.5% of total coal produced in 2009).[1] No coal data is available for 2011 and 2012 from Statistics Canada as they are suppressed to meet confidentiality requirements of the *Statistics Act*. Emissions associated with coal production are related to energy consumption for extraction, drying and transportation and fugitive emissions. Fugitive emissions from coal mining have increased by 16% in the years between 1998 and 2012 (see Table 9). Transportation emissions associated with the mining of coal are a portion of the 2.85 Mt reported in the off-road diesel subcategory.

[1] Statistics Canada Report on Energy Supply and Demand in Canada (RESD) – Table 2-12 Primary and secondary energy, terajoules – British Columbia

[2] Cansim table 128-0016 and 128-0002

Understanding trends in energy sector emissions – heating residential buildings

GHG emissions in the energy sector generally depend on three factors:

- Activity level (e.g., quantity of cement produced, number of vehicle-kilometres travelled)
- Energy efficiency (e.g., natural gas combusted per unit mass cement produced, electricity use per unit floor space, gasoline combusted per kilometre travelled)
- GHG intensity of fuels used (e.g., mass of CO_2e per unit volume of natural gas or gasoline, per kWh of electricity)

Examining the energy use associated with heating residential buildings illustrates the interplay of these three factors. Figure 9 shows that between 1990 and 2011, residential floor space in B.C. increased by 67% while annual energy demand to heat residential buildings has increased by only 15.4% over the same time period. The increased energy efficiency of residential buildings is attributed to more efficient heating systems and additional thermal insulation in building envelopes.

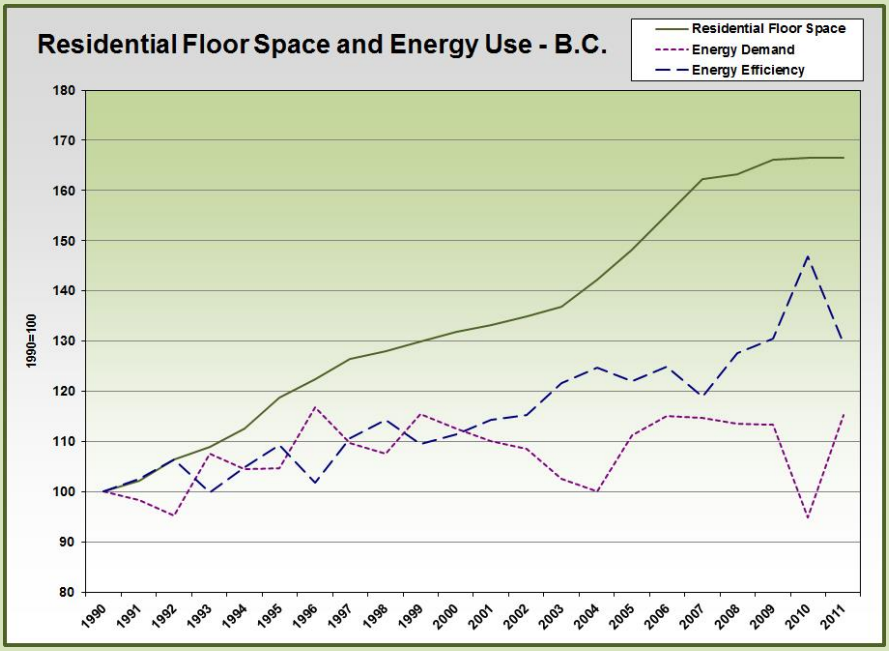


Figure 9: Residential Floor Space and Energy Use – B.C. Trends

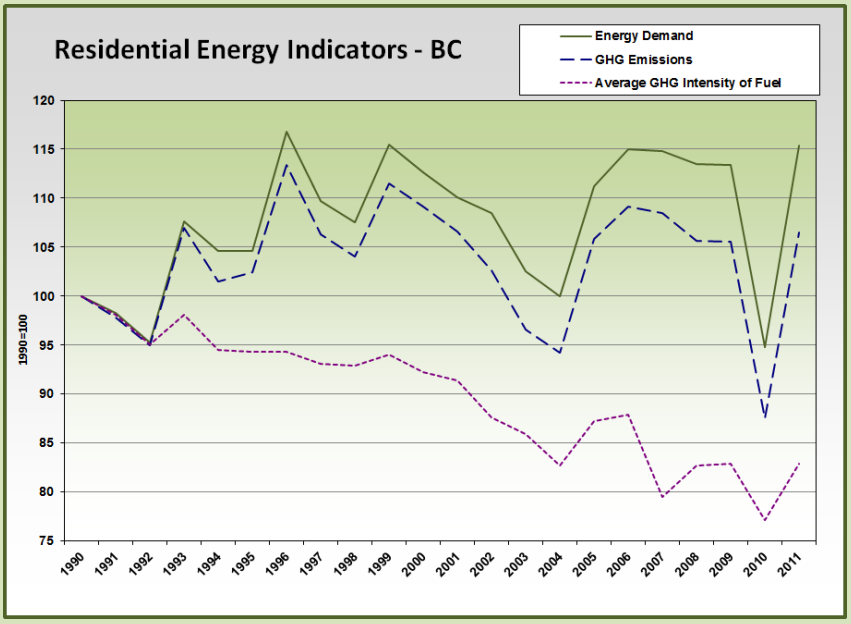


Figure 10: Residential Energy Indicators – B.C. Trends

Figure 10 illustrates the linkages between energy demand, fuel types and GHG emissions. Between 1990 and 2011, for example, the GHG intensity of fuels used to heat residential buildings has notably decreased, resulting in a steadily widening difference between energy demand and GHG emissions. The reduction in GHG intensity has been attributed to fuel switching from GHG-intensive fuels such as heating oil, coal and propane towards less intensive fuels such as natural gas and wood. Between 1990 and 2011 fuel switching has decreased the average GHG intensity of residential fuels per unit energy by about 17%.

Notes:

The above graphs (figures 9 and 10) suggest the possibility of data anomalies in 2010.

Electricity use is not considered in this analysis as related GHGs are reported under the "electricity and heat generation" rather than the "residential building" category in the NIR. Consequently, such activities as air-conditioning are not included.

Fluctuations in annual energy demand are reflective of average annual outdoor temperatures (e.g., a lower average annual temperature generally results in a higher annual energy use).

Data source for Figure 9 and Figure 10: NRCan Office of Energy Efficiency: Residential Sector British Columbia Table 2: Secondary Energy Use and GHG Emissions by End-Use.

4.2 Energy Sub-sector b: Transport

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.

Emissions by category in the transport sub-sector are shown in Figure 11. Category descriptions, the percentage change in emissions over three and ten years, and the key factors influencing changes in emissions, for each of the categories are provided in Table 8.

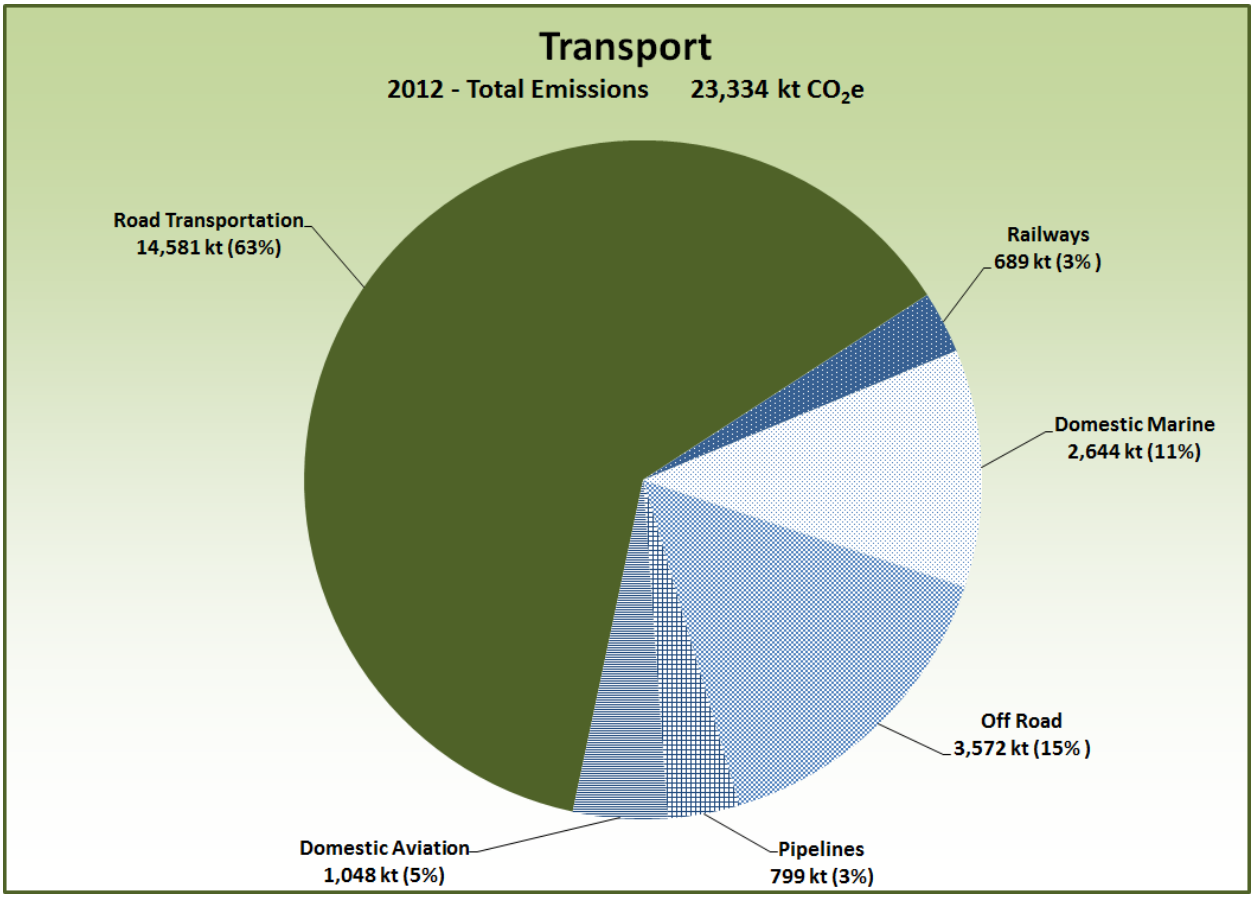


Figure 11: Transport Sub-sector GHG Emissions by Category – 2012

Table 8: Transport Category Descriptions

Emission Category	2012 Emissions (kt CO_2e)	3-Year Trend	10-Year Trend	Description	Key Factors Influencing Changes in Emissions
TRANSPORT SUB-SECTOR	**23,334**	**0.7%**	**-1.7%**		
Domestic Aviation	1,048	-12.8%	-21.7%	Canadian registered airlines flying domestically within Canada and originating in B.C., including commercial, private, military, and agricultural flights	Weight of freight transported, passenger loads and distance traveled[1]
Road Transportation (On-road Vehicles)	14,581	-6.1%	-0.7%	Vehicles in B.C. licensed to operate on roads	Number of vehicles on road and distance travelled,[2] average fuel efficiency of vehicles[3]
Railways	689	+55.4%	-20.3%	Locomotives operating in B.C.	Passenger ridership, freight shipped by locomotive of major B.C. products (coal, wood chips and wood pulp), trans-continental freight shipped by locomotive through B.C.[4]
Domestic Marine	2,644	-0.8%	+41.0%	Canadian registered marine vessels fuelled domestically in B.C.	Volume of import and export between international trading partners[5] (e.g., wood product and coal exports)
Off-road Vehicles (Gasoline and Diesel)	3,572	+45.8%	-1.3%	Vehicles in B.C. not licensed to operate on roads, including farm tractors, logging skidders, tracked-construction vehicles and mining vehicles	Forest, mining and agriculture off-road vehicle activity
Pipelines	799	-7.9%	-41.2%	Transportation and distribution of crude oil, natural gas and other products through a pipeline	Throughput,[6] equipment efficiency, computer automation, matching of throughput to pipeline capacity

[1] Statistics Canada CANSIM Table 401-0001: Operating and financial statistics of major Canadian airlines, monthly

[2] Statistics Canada CANSIM Table 405-0008: Canadian vehicle survey, vehicle-km, by type of vehicle, province and territory, quarterly

[3] NRCan Office of Energy Efficiency National Energy Use Database: Transportation Sector British Columbia and Territories: Road Transportation Secondary Energy Use and GHG Emissions by Energy Source

[4] Statistics Canada Catalogue 52-216-X: Rail in Canada

[5] B.C. STATS: B.C. International and Interprovincial Trade Flows

[6] Statistics Canada CANSIM Table 133-0003: Summary of Pipeline Movements, monthly

Road Transportation Emissions

As the road transportation category accounted for a significant proportion (23.7%) of 2012 total B.C. emissions and almost two-thirds of total transportation sub-sector emissions, additional "sub-category" level information for road transportation is provided in Figure 12.

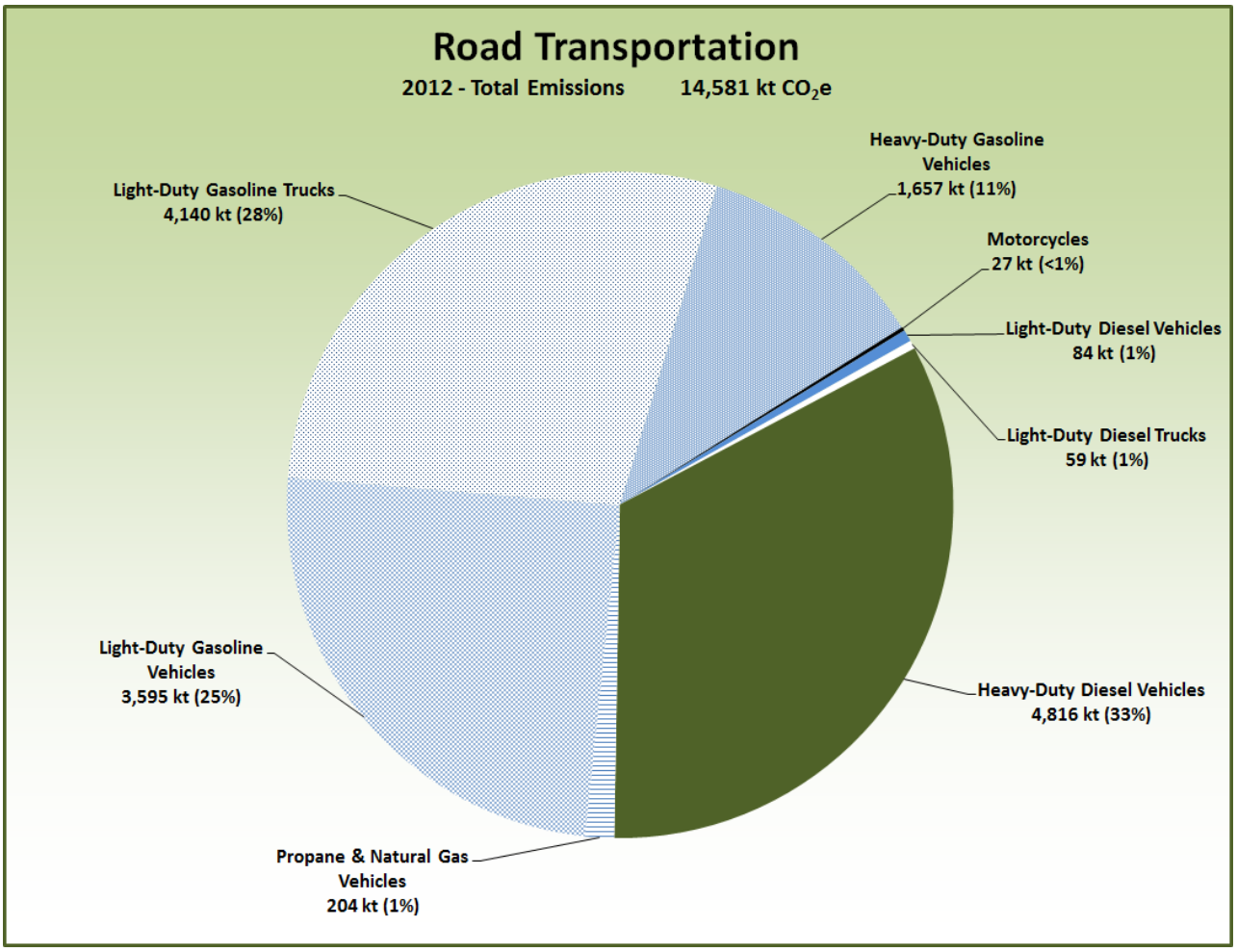


Figure 12: Road Transportation Category and Sub-category GHG Emissions – 2012

Understanding trends in road transportation emissions

Trends in road transportation emissions are influenced by kilometres travelled (i.e., activity level), engine efficiency and fuel type.

Figure 13 shows trends since 1990 in passenger-kilometres (Pkm)[1] traveled and engine efficiencies for passenger and freight road transportation. While energy intensity for both passenger and freight transportation has decreased between 1990 and 2011, passenger kilometres and GHG emissions have both increased over this period. Note that there has been a small decrease in passenger energy intensity (from 89% of 1990 levels to 82% of 1990 levels from 1995 to 2011) due to increases in fuel efficiency offset by an increase in average vehicle size.[2]

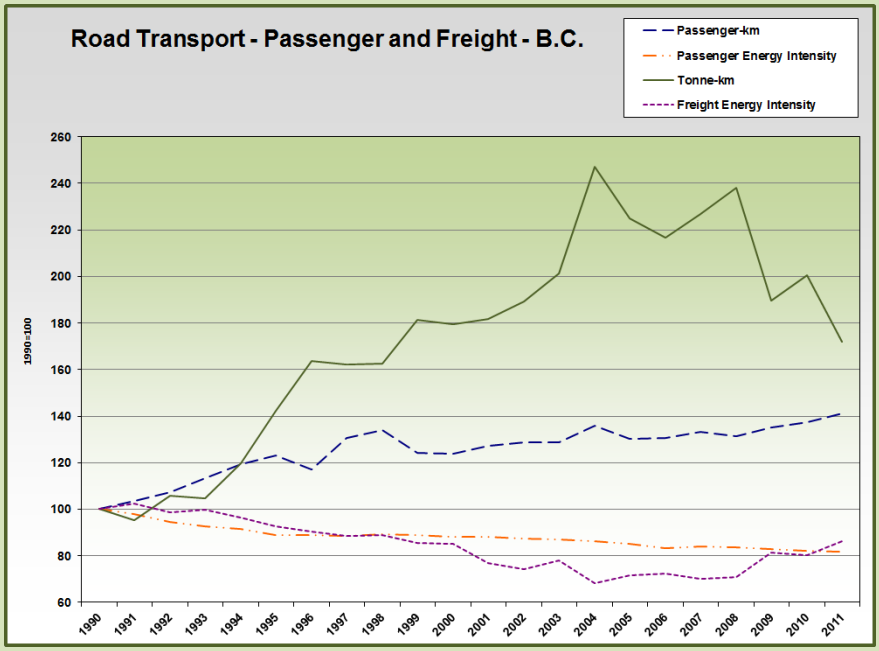


Figure 13: Road Transportation – Passenger and Freight – B.C. Trends

[1] Number of passengers in a vehicle multiplied by the number of kilometres travelled.

[2] Refer to Statistics Canada CANSIM Table 079-0003: New Motor Vehicle Sales, Canada, provinces and territories, monthly.

4.3 Energy Sub-sector c: Fugitive Sources

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.

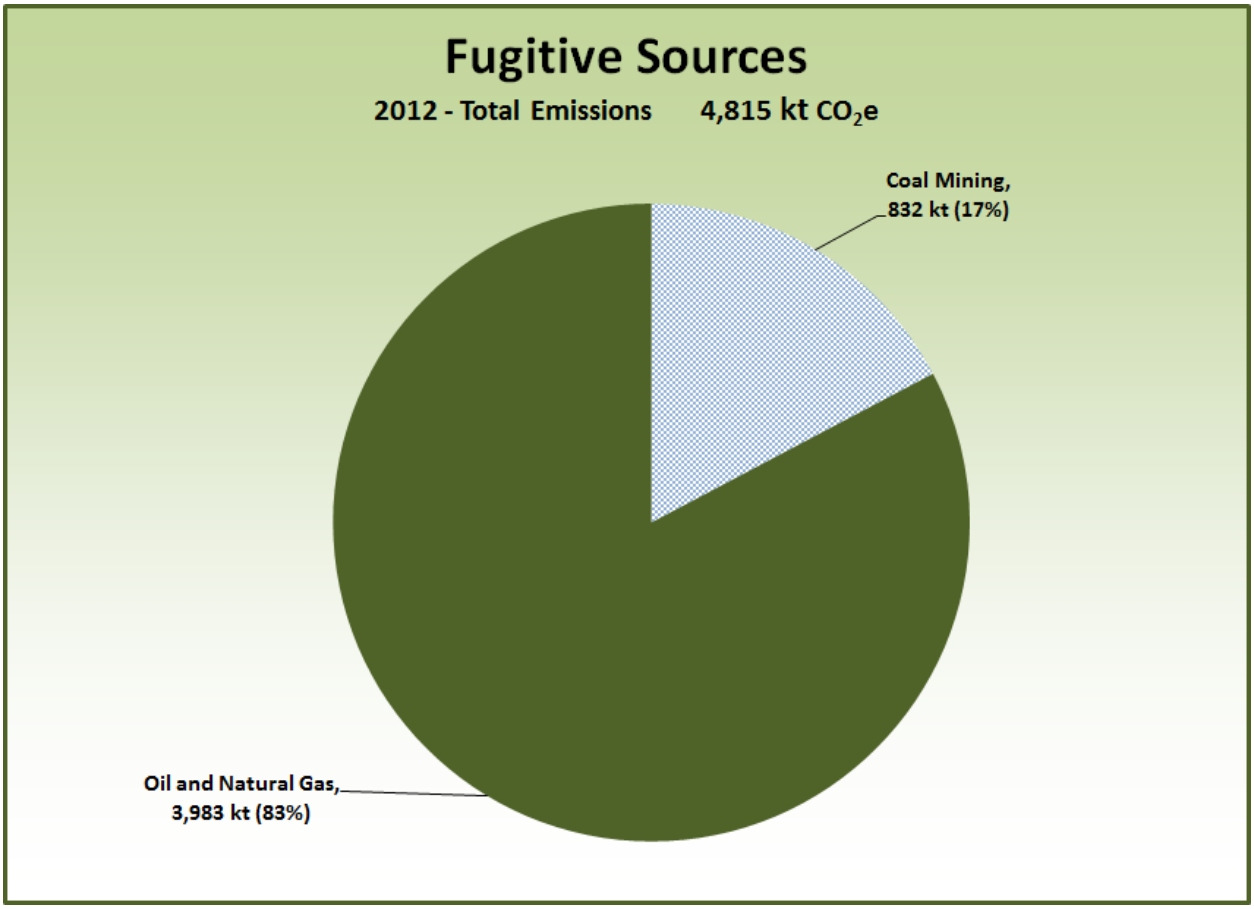


Figure 14: Fugitive Sources Category and Sub-category GHG Emissions – 2012

Table 9: Fugitive Sources Sub-sector Descriptions and Trends

Emission Category	2012 Emissions	3-Year Trend	10-Year Trend	Description	Key Factors Influencing Changes in Emissions
FUGITIVE SOURCES SUB-SECTOR	**4,815 (kt CO_2e)**	**+12.9%**	**-9.7%**		
Coal Mining	832	+33.9%	+24.8%	Releases from exposed coal surfaces, coal rubble and venting within coal deposits; and post-mining activities including preparation, transportation, storage and final processing	Annual production of coal,[1] methane content in active coal mines Coal mine production
Oil and Natural Gas	3,983	+9.3%	-14.6%		
Conventional Crude Oil Extraction and Processing				Releases from wells, flow lines and batteries; venting of casing and solution gas; and evaporative losses from storage facilities	Natural gas production[1] Annual crude oil production[1]
Natural Gas Extraction and Processing				Releases from wells, gathering systems, field facilities and gas batteries; seal leaks; line cleaning operations; formation CO_2 removal and pneumatic devices	Annual natural gas production[1]
Petroleum Refining				Equipment leaks, wastewater treatment, cooling towers, storage tanks and loading operations; and flaring of excess gas	Annual production of refined petroleum products[2]
Natural Gas Transmission				Equipment leaks, compressor start-up venting and purging of lines during maintenance	Annual natural gas throughput in pipelines[5] and energy efficiency of equipment
Oil Transmission in Pipelines				Loading and unloading of tankers, storage losses, equipment leaks and process venting	Annual crude oil throughput through pipelines[3] and energy efficiency of equipment

[1] Statistics Canada Report on Energy Supply and Demand in Canada

[2] CANSIM Table 134-0004 – Supply and Disposition of Refined Petroleum Products[4] Statistics Canada CANSIM Table 131-0001: Supply and Disposition of Natural Gas

[5] Statistics Canada CANSIM Table 133-0003: Summary of Pipeline Movements, monthly

B.C. undertook a significant re-estimate of oil and gas fugitive emissions relative to the figure published in the NIR for B.C. The NIR estimates were based on a 2000 study of practices in the sector, and does not consider significant GHG mitigation efforts that have taken place since then. Based on a 2014 update to the 2000 study[24], B.C. has re-estimated the oil and gas fugitives line item in the 1990-2012 provincial inventory. It is expected that the 1990-2013 NIR will include the information from the 2014 study update and undertake appropriate revisions to prior year provincial level emissions.

[24] See discussion and footnote in section 2.4 (Recalculations and Changes in Prior Year GHG Emissions)

5. INDUSTRIAL PROCESSES 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 transform materials. This sector of emissions includes five sub-sectors: (a) mineral products (including cement and lime production, and soda ash, limestone and dolomite production and use); (b) chemical industry (for which there are no BC emissions); (c) metal production;[25] (d) consumption of halocarbons; and (e) SF_6 and "other and undifferentiated production" (including lead and zinc production).

Emissions by sub-sector and category relative to total B.C. emissions are shown in Figure 15. Category descriptions, the percentage change in emissions over three and ten years, and the key factors influencing changes in emissions, for each of the categories are provided in Table 10.

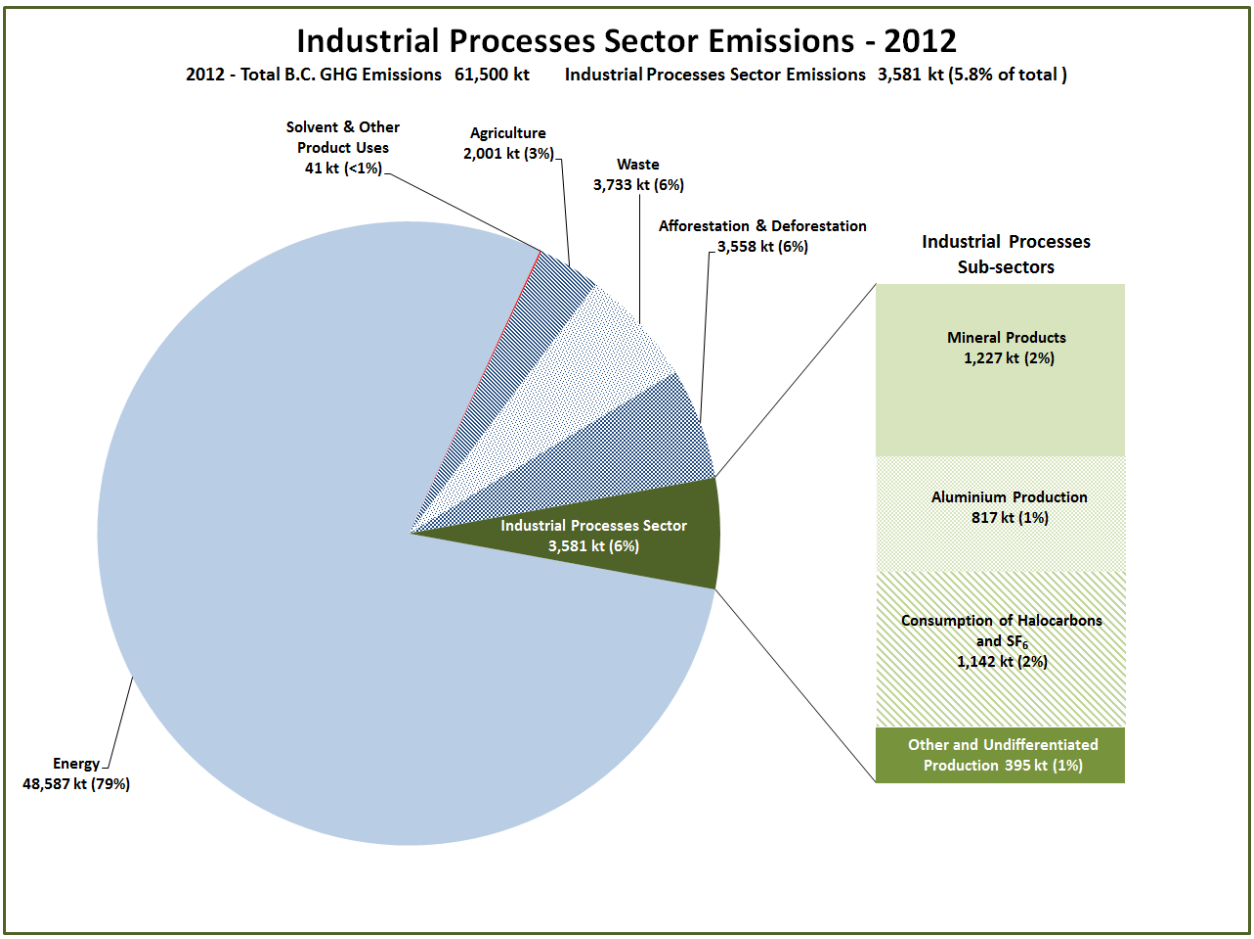


Figure 15: Industrial Processes GHG Emissions by Category – 2012

[25] Aluminium, lead, zinc, copper and molybdenum are produced in B.C. Industrial process emissions from aluminium production are reported individually under the "Metal Production" sub-sector. Industrial process emissions from lead, zinc and copper relate to the use of fossil fuel as reducing agents and are aggregated under the "Other and Undifferentiated Production" sub-sector. There are no industrial process emissions associated with molybdenum production.

Table 10: Industrial Processes Sub-sector and Category Descriptions

Emission Source	2012 Emissions (kt CO_2e)	3-Year Trend	10-Year Trend	Description	Key Factors Influencing Changes in Emissions
INDUSTRIAL PROCESSES SECTOR	**3,581**	**-7.5%**	**-0.6%**		
a. Mineral Products	**1,227**	**+18.8%**	**-6.7%**		
Cement Production	1,028	+19.9%	-3.4%	Lime (used in cement clinker) is formed by the heating of limestone to decompose carbonates through calcination, which releases CO_2	Annual cement production[1]
Lime Production	173	+25.8%	-13.8%	Lime is formed by the heating of limestone to decompose carbonates through calcination, which releases CO_2	Annual lime production[2]
Mineral Products Use	26	-31.8%	-47.2%	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	Annual pulp and paper production[3]
b. Chemical Industry				There are no B.C. industrial process emissions sources under this category	
c. Metal Production Aluminium Production	**817**	**-28.9%**	**-23.2%**	All B.C. emissions in this sub-sector are associated with aluminium production – SF_6 emissions from magnesium casting are included under "Consumption of Halocarbons and SF_6" due to confidentiality reasons GHG emissions include CF_4 and C_2F_6 (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	Control measures to reduce PFC emissions from anode effects[4]

Note: Table continued on next page

d. Consumption of Halocarbons and SF_6	**1,142**	**+16.9%**	**+101.6%**	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	Displacement of banned CFCs in 1996, demand for HFCs associated with building space[5,6] and vehicle-kilometres travelled; SF_6 used in electrical generation, transmission and distribution equipment
e. Other and Undifferentiated Production	**395**	**-44.6%**	**-39.8%**	GHG emissions from the non-energy use of fossil fuels, including the use of fossil fuels as a reducing agent in base metal smelting (i.e., lead and zinc), natural gas liquids in the chemical industry and the use of lubricants and engine oil	Closure of ammonia and methanol plants in Kitimat, lead and zinc production

[1] Cement Association of Canada
[2] NRCan Canadian Minerals Yearbook
[3] CANSIM Table 304-0015: Manufacturing sales, by North American Industry Classification System (NAICS) and province, monthly (dollars),
[4] Rio Tinto Alcan B.C. 2012 Sustainable Development Report
[5] NRCan Office of Energy Efficiency: Commercial/Institutional Sector British Columbia and Territories Secondary Energy Use and GHG Emissions by Activity Type
[6] NRCan Office of Energy Efficiency: Residential Sector B.C. Secondary Energy Use and GHG Emissions by End-Use

The trend in industrial processes sector GHG emissions between 1990 and 2012 is shown in Figure 16.

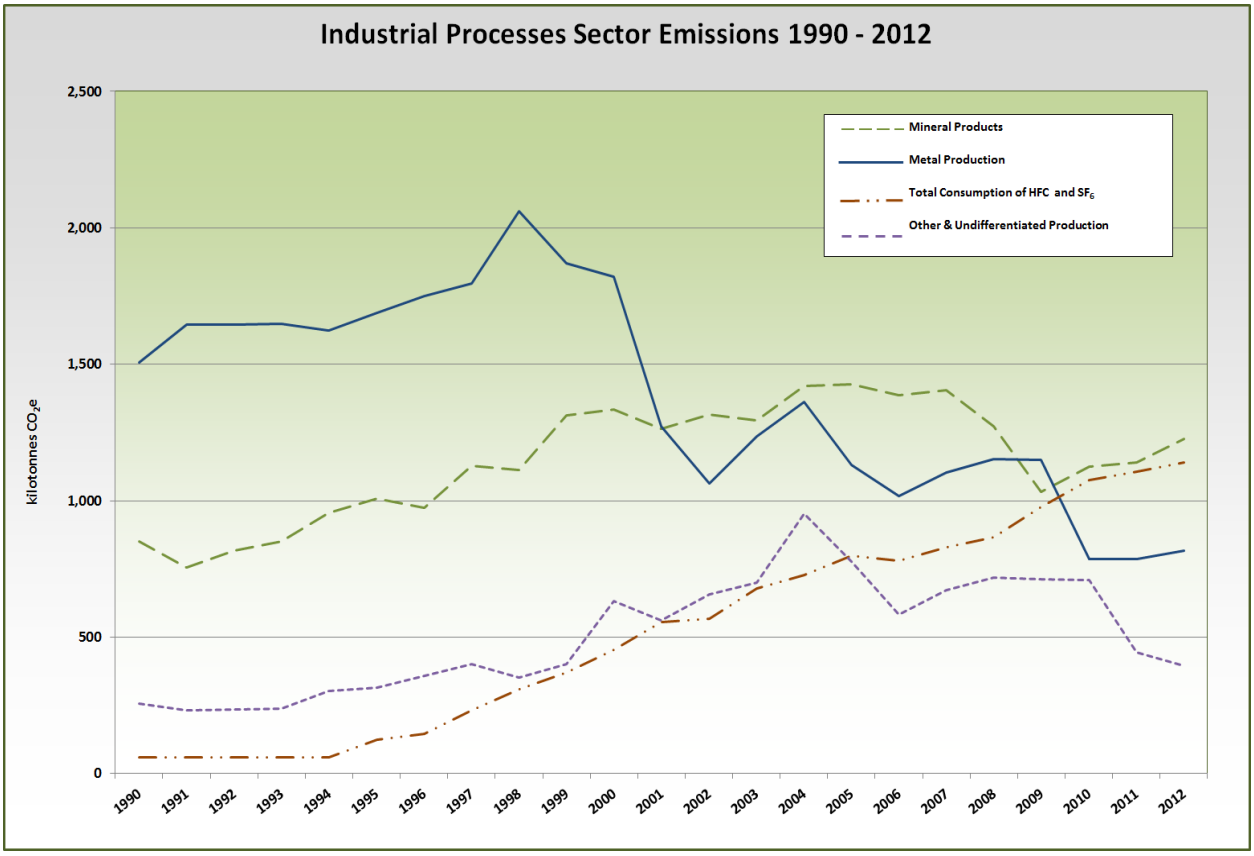


Figure 16: Industrial Processes Emissions – 1990-2012 Trends

Understanding trends in industrial emissions

Industrial process emissions[1] are primarily related to production levels, chemical relationships and efficiencies in production technologies.

Figure 17 illustrates the variation in production levels for several key B.C. commodities between 2000 and 2012. Over the time period, production of cement[2] increased by 16% (up to 2011 as 2012 data for cement is not available), down from a much higher peak in 2006. Aluminium production[3] decreased by around 32%. Over the time period (2000-2012), GHG emissions associated with cement production decreased by 2.4% and those associated with aluminium production decreased by 55.1%. For both industrial products – and aluminium in particular – emissions decreased by a relatively larger amount than production, indicating an increase in production efficiency (in relation to greenhouse gases). Efficiencies in aluminium production are in large part due to increased control measures to reduce PFC emissions from anode effects.

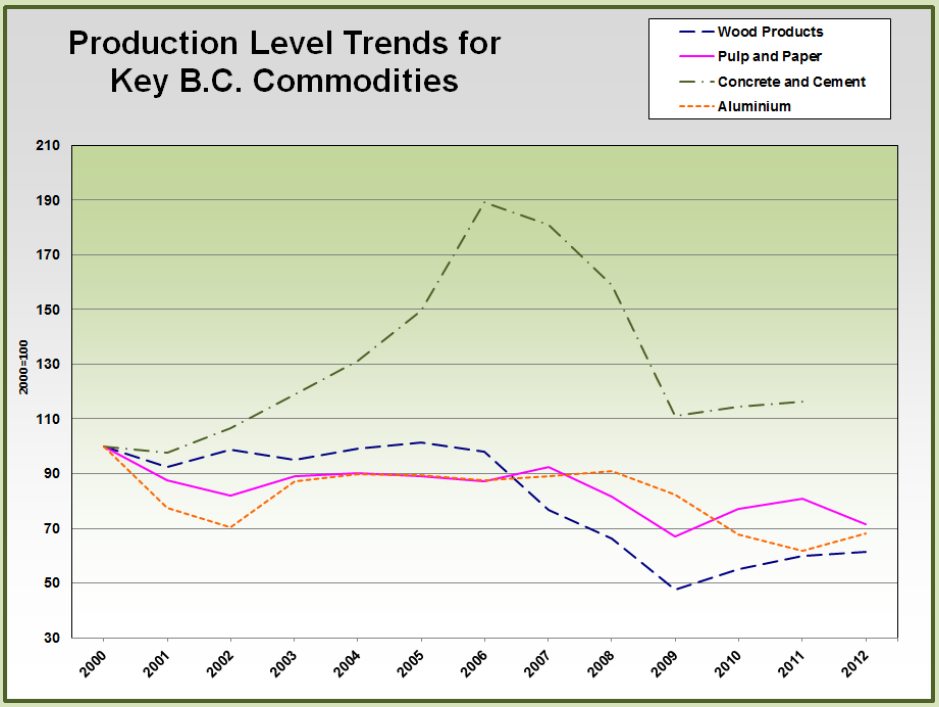


Figure 17: Production Level Trends for Key B.C. Commodities

The pulp and paper and wood products sectors are both cyclical industries – production varies with economic and market cycles. Production over the 2000-2012 period peaked in 2000 for pulp and paper[4] and in 2005 for wood products (manufacturing),[5] then dropped significantly, reaching a trough in 2009 before beginning to recover. Over the same time period, fuel switching from fossil fuels to biomass and increased production efficiencies have led to substantial decreases in greenhouse gas emissions for these sectors.[6]

[1] Although wood products manufacturing and pulp and paper are not considered "industrial processes" under reporting conventions, they are included in this figure to illustrate associations between production levels and GHG emissions.

[2] CANSIM table 304-0015: Manufacturing sales, by North American Industry Classification System; British Columbia; Sales of goods manufactured (shipments); Unadjusted; Cement and concrete product manufacturing [3273]. Concrete and Cement data for 2012 was suppressed by Statistics Canada to meet the confidentiality requirements of the *Statistics Act*.

[3] Alcan Performance Reports: www.riotintoalcaninbc.com/pages/media/performance-reports.php

[4] CANSIM Table 304-0015: Manufacturing sales, by North American Industry Classification System; British Columbia; Sales of goods manufactured (shipments)

[5] Statistics Canada Industry Price Indexes, March 2009 –Table 2-1 Industrial product price indexes, by commodity and commodity aggregations — Summary, and Table 3-8 Industrial product price indexes by industry and industry groups— Paper manufacturing

[6] See: www.statcan.gc.ca/pub/16-002-x/2009004/article/11030-eng.htm#a1 for more information.

6. SOLVENT AND OTHER PRODUCT USE SECTOR EMISSIONS

The solvent and other product use category encompasses emissions of N_2O used as an anaesthetic or as a propellant in pressure and aerosol products. Total emissions in this sector were 41 kilotonnes CO_2e in 2012, accounting for 0.1% of total emissions in the province.

Annual emissions for this sector increased by 25.1% between 2011 and 2012, by 18.7% between 2009 and 2012 and decreased by 19.5% between 2002 and 2012. Changes in emissions reflect differences in the amount of N_2O used for anaesthetic and as propellant.

7. AGRICULTURE SECTOR EMISSIONS

GHG emissions reported in the agriculture sector include: (a) CH_4 emissions from enteric fermentation; (b) CH_4 and N_2O emission from manure management; and (c) N_2O emissions from agricultural soils (including direct and indirect sources and pasture, range and paddock manure). 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.

Emissions by sub-sector and category relative to total B.C. emissions are shown in Figure 18. Table 11 provides category descriptions, the percentage change in emissions over three and ten years, and a summary of key factors influencing changes in emissions. Figure 19 depicts agriculture sub-sector emissions between 1990 and 2012.

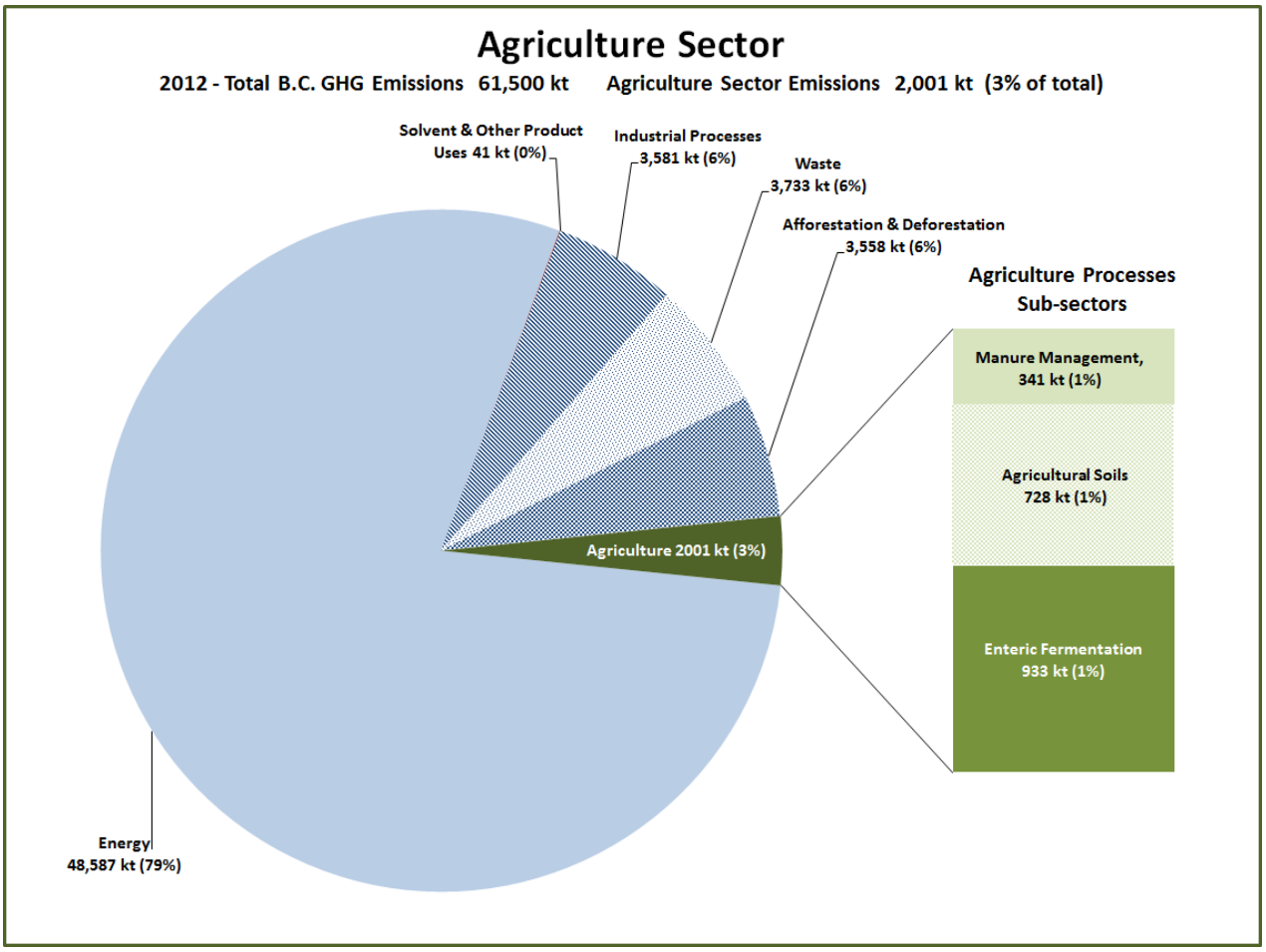


Figure 18: Agriculture Sector GHG Emissions by Category – 2012

Table 11: Agriculture Sub-sector and Category Descriptions

Emission Source	2012 Emissions (kt CO_2e)	3-Year Trend	10-Year Trend	Description	Key Factors Influencing Changes in Emissions
AGRICULTURE SECTOR EMISSIONS	**2,001**	**-5.7%**	**-20%**		
a. Enteric Fermentation	**933**	**-5.4%**	**-24.2%**	The digestive process of ruminant animals (such as cattle) involves microbial fermentation in the rumen, which produces CH_4 emissions as a by-product	Cattle populations[1]
b. Manure Management	**341**	**-2.6%**	**-13.5%**	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	Cattle populations,[1] hog populations[2]
c. Agriculture Soils	**728**	**-7.5%**	**-17.1%**		Cattle populations,[1] hog populations,[2] fertilizer use, soil management practices
Direct Sources	307	-7.9%	-9.5%	Direct sources of N_2O emissions include application of synthetic and manure-based fertilizers, decomposition of crop residue, irrigation, cultivation of hisotosols and changes to tillage practices and summer fallow	
Pasture, Range and Paddock	167	-7.4%	-30.2%	Grazing animals excrete manure on pastures, ranges and paddocks. Nitrification and denitrification of the manure produces N_2O emissions.	
Indirect Sources	254	-7.2%	-15.4%	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 redeposition, or by leaching, erosion or runoff. A portion of this nitrogen may undergo nitrification and denitrification, producing N_2O emissions	

[1] CANSIM Table 003-0032: Number of cattle, by class and farm type, annual (head)

[2] CANSIM Table 003-0004: Number of hogs on farms at end of quarter, quarterly (head)

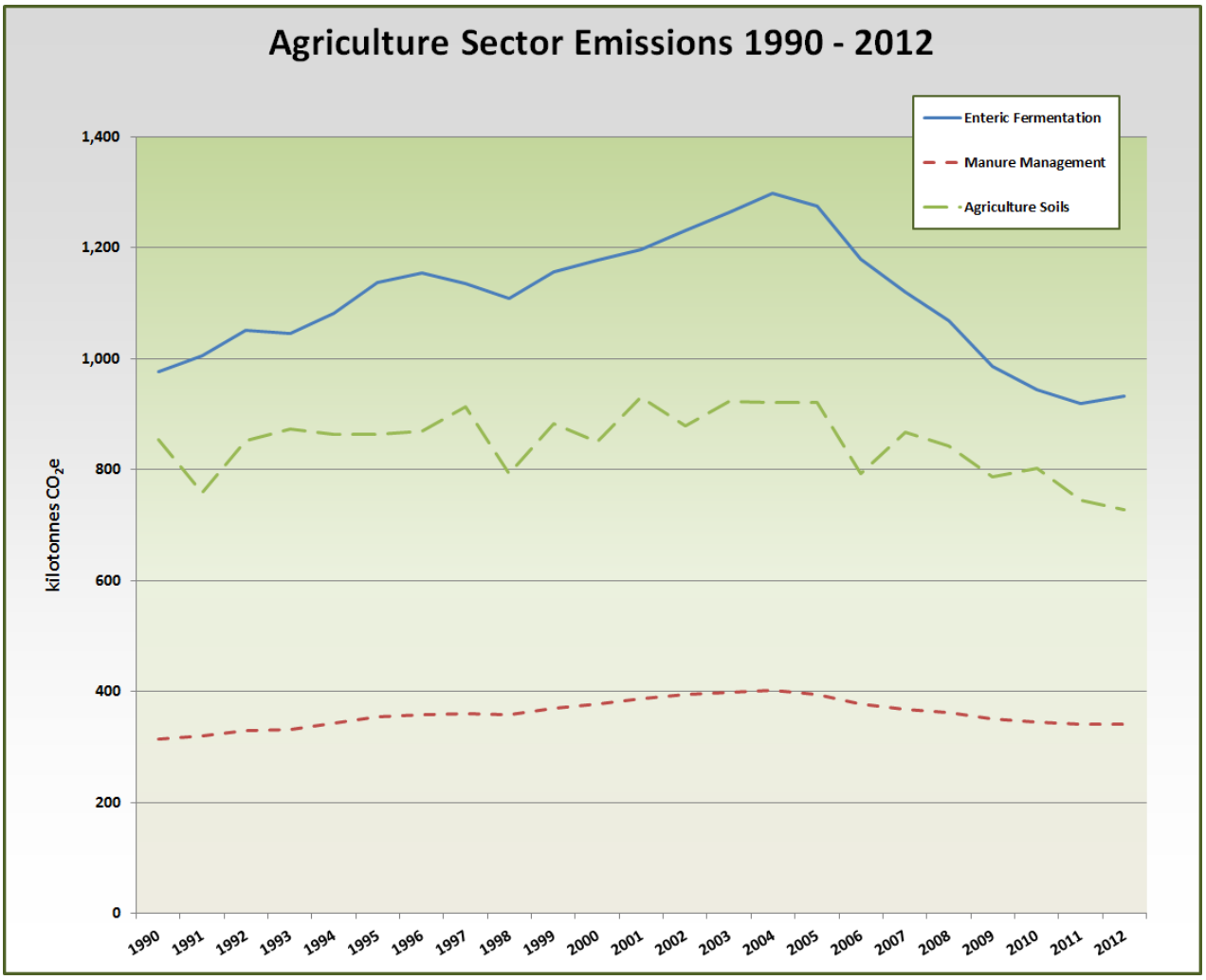


Figure 19: Agriculture Sector Emissions – 1990-2012 Trends

Understanding trends in agriculture emissions

Trends in agriculture emissions have been predominately influenced by cattle and hog populations. As Figure 20 shows, both hog and cattle populations[1] have been in decline since 2004, with hog populations trending downward since 1990.

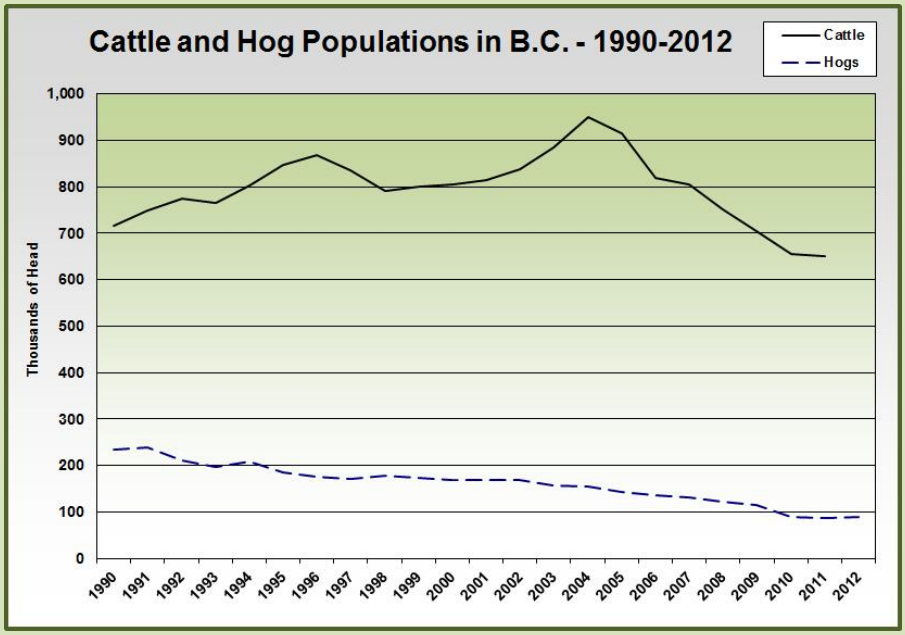


Figure 20: Cattle and Hog Populations – B.C. Trends

[1] Cattle data was not available for 2012

Data sources: CANSIM Tables 003-0032 and 003-0004

8. WASTE SECTOR EMISSIONS

GHG emissions from the waste sector are related to the treatment and disposal of solid waste and wastewater. Emissions sources include: (a) CH_4 emissions from landfills; (b) CH_4 and N_2O emissions from wastewater treatment; and (c) CO_2, CH_4 and N_2O emissions from waste incineration. CO_2 emissions of biogenic origin (i.e., wood, wood products and biomass-based wastes) are not included in this inventory category, and instead are currently reported as memo-items in the Land Use, Land Use Change and Forestry sector.

Emissions by sub-sector and category relative to total B.C. emissions are shown in Figure 21. Table 12 provides category descriptions, the percentage change in emissions over three and ten years, and the key factors influencing changes in emissions. Figure 22 shows emission trend information for the waste sector.

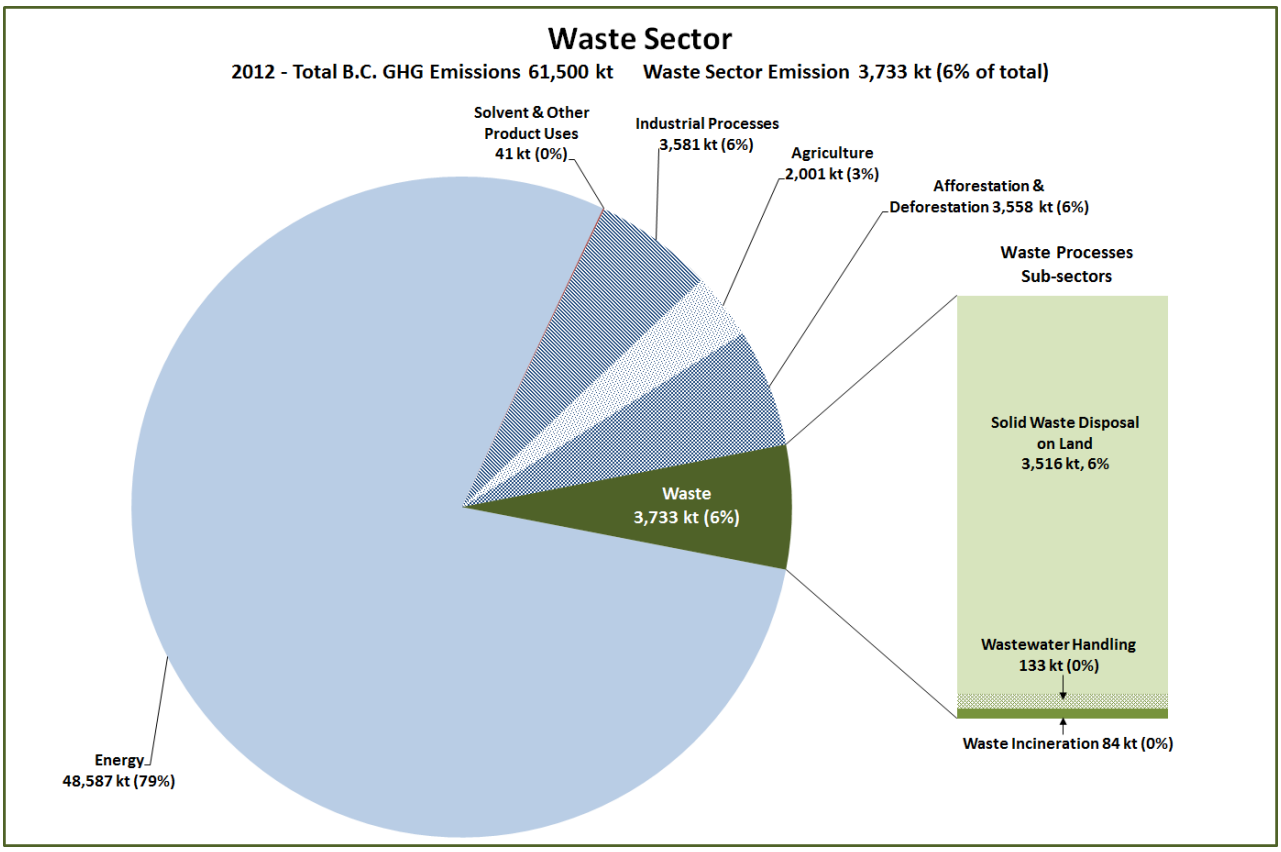


Figure 21: Waste Sector GHG Emissions – 2012

Table 12: Waste Category Sub-sector Descriptions

Emission Source	2012 Emissions (kt CO_2e)	3-Year Trend	10-Year Trend	Description	Key Factors Influencing Changes in Emissions
WASTE SECTOR EMISSIONS	**3,733**	**-7.9%**	**-5.8%**		
a. Solid Waste Disposal on Land	**3,516**	**-8.4%**	**-6.4%**	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	Annual quantity of solid waste generated,[1] quantity of waste sent to landfill,[1] diversion rates (i.e., recycling and composting),[1] capturing and flaring of CH_4 emissions from landfills[26]
b. Wastewater Handling	**133**	**+2.2%**	**+7.0%**	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	Population growth[2] and related water demand
c. Waste Incineration	**84**	**-0.5%**	**-1.7%**	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	Annual quantity of solid waste sent to landfill,[1] percentage of waste incinerated

[1] Statistics Canada Waste Management Industry Survey: Business and Government Sectors

[2] B.C. Stats: Population and Demographics

2012 NIR estimates of solid waste disposal on land emissions are based on a 2011 survey of practices at landfills. Since BC landfills are in the process of installing and improving landfill gas capture systems to comply with the Landfill Gas Management Regulation,[27] there were substantive changes to landfill gas capture amounts at major landfills that were implemented and functioning in 2012, but not in 2011. Since these emissions reductions are additional to the ones reflected in the NIR, BC has subtracted the known new 2012 capture amounts (amounting to

[26] CH_4 emissions from landfills can be captured through piping systems and sent to a stationary unit (e.g., flare, boiler, gas turbine) for combustion, often for the purposes of generating electricity. Combustion converts the CH_4 to CO_2, a less potent GHG, thus reducing overall GHG emissions from the landfill.

[27] http://www.env.gov.bc.ca/epd/codes/landfill_gas/

203 kt) from the 1990-2012 NIR amounts. An updated survey of landfill practices that will reflect these emissions reductions in the 2012-2013 NIR is being conducted by Environment Canada.

Note that due to the large difference in emissions among categories for this sector, Figure 22 shows emissions for the solid waste disposal on land category on a separate scale (left side y-axis, blue solid trend line) than emissions for the wastewater handling and waste incineration categories (right side y-axis and dashed green trend lines).

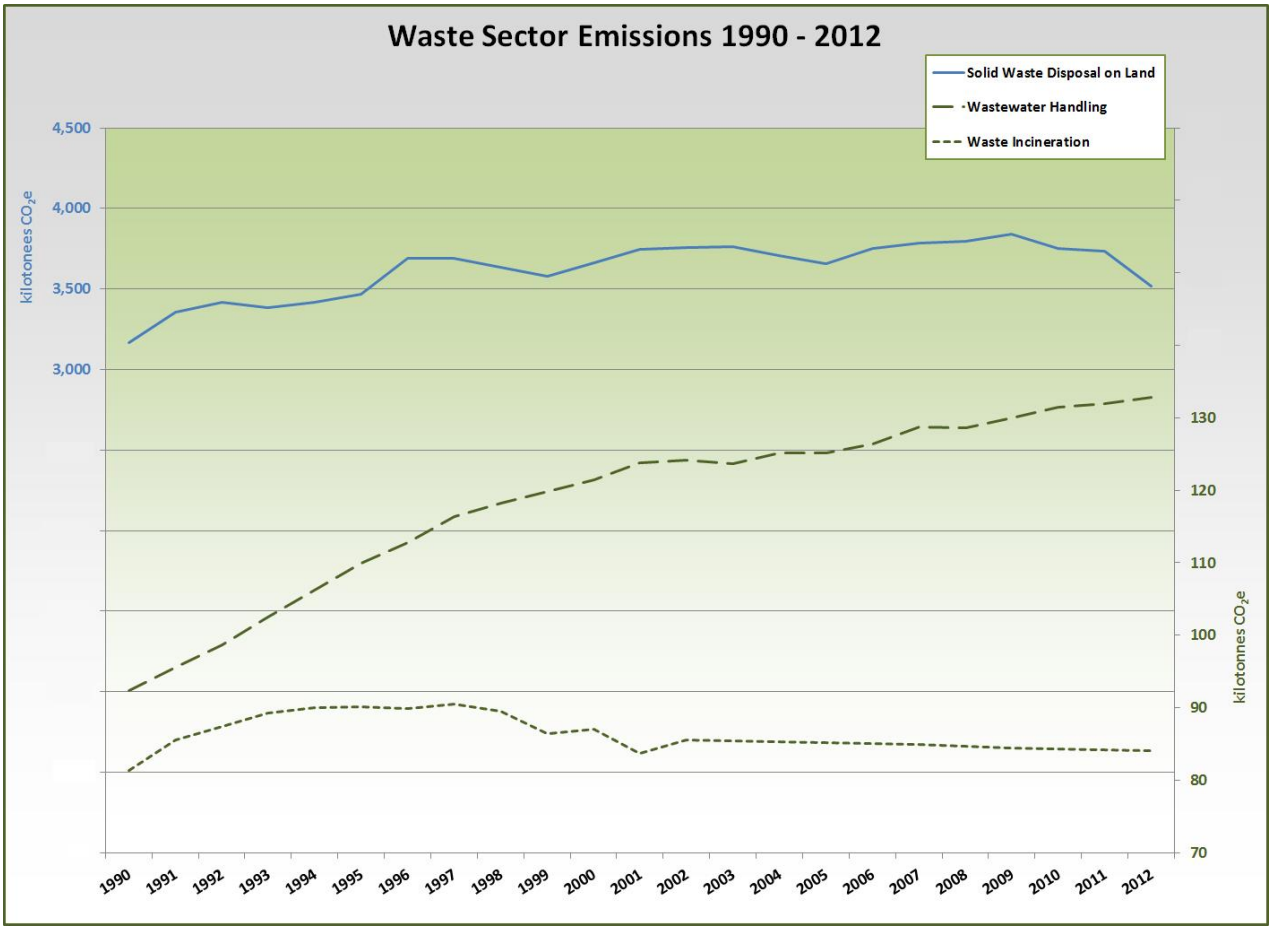


Figure 22: Waste Sector GHG Emissions – 1990-2012 Trends

Understanding trends in waste emissions

Waste sector emissions are influenced by the quantity of waste sent to, as well as the amount of methane gas captured from, landfills.

Figure 23 shows that although the amount of waste diverted (i.e., reused, recycled or composted) from landfills has increased slightly between 1998 and 2010, the total waste generated and disposed in landfills has also increased. Diversion has not reduced volumes destined for landfills sufficiently to counter level of waste generated by growth in population, consumption and associated generation of waste.

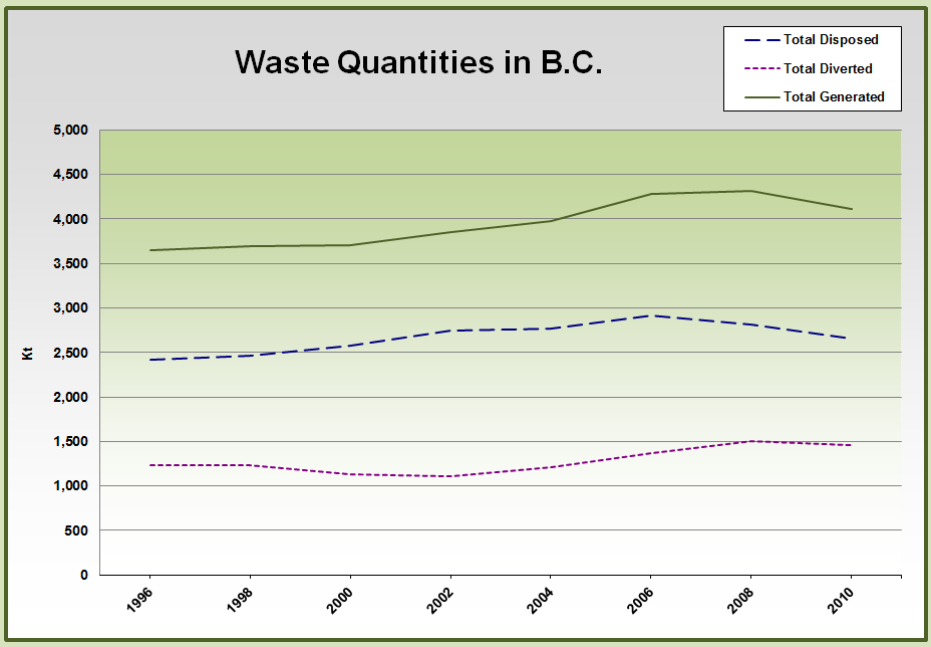


Figure 23: Waste Quantities in B.C.

Data Source: Statistics Canada Waste Management Industry Survey: Business and Government Sectors

9. LAND USE, LAND-USE CHANGE AND FORESTRY (LULUCF)

9.1 Categories and Estimating Emissions

Table 13 lists descriptions and notes for the categories of lands in this sector, consistent with definitions used in the National Inventory Report (NIR).[28]

Table 13: Land Categories and Descriptions

Land Category	Description and Notes
Forest Land	Forest land includes all land with woody vegetation consistent with the following thresholds used to define forest land in the NIR: (i) 1 ha minimum land area; (ii) 25% minimum tree crown cover (at maturity); (iii) 5 metre minimum tree height (at maturity); (iv) 20 metre minimum width (distance between trunks). 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-forested 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-forested 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. Note that this categorization of grassland differs from other definitions and uses of the term. Some studies classify grassland by vegetation while others characterize them by climate, soils and human use of the ecosystem.
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).

Changes to GHG emissions can arise from conversion from one type of land use to another, as well as from changes in the management or character of a particular land use.

Emission estimates for the land use, land-use change and forestry (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 (for deforestation) and the difficulty in accounting for complex ecological processes such as carbon uptake by vegetation and soil decomposition. Emission estimates presented in this report are approximate and, with improvements to accounting methodologies and increased sampling densities, will be subject to change in future years.

[28] For complete definitions, see IPCC Guidelines at: http://carbon.cfs.nrcan.gc.ca/ForestInventory_e.html and www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_files/Glossary_Acronyms_BasicInfo/Glossary.pdf

9.2 Afforestation, Deforestation and Other Land Use Conversions

Net GHG emissions from afforestation, deforestation and other land use conversions were approximately 3.6 megatonnes (Mt) CO_2e in 2012 – amounting to 5.8% of total B.C. emissions.

Afforestation, deforestation, grassland to cropland conversion and conversion to wetlands are the only categories in the land use, land use change and forestry (LULUCF) sector counted in B.C. emissions totals for 2012. 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 forested land through planting, seeding and/or the human-induced promotion of natural seed sources".[29] Deforestation is defined as the "direct human-induced conversion of forested land to non-forested land". Harvesting, when followed by regeneration, is not deforestation. Forestry operations however, can cause deforestation (e.g., when permanent roads and landings are established). Grassland conversion and other land conversion to wetlands (very small emissions sources) have not previously been reported as separate line items in the PIR. This reporting has been enabled by improvements in data availability from Environment Canada.

This report addresses land uses and land-use changes for which recognized NIR methodologies have been developed and that are estimated in the NIR. Table 14 provides a description of the categories and related GHG emissions (sources) and removals (sinks) relating to afforestation and deforestation. Figure 24 provides information on afforestation and deforestation trends.

Table 14: Afforestation and Deforestation LULUCF Sector Categories and GHG Emissions – 2012

LULUCF Category	Net GHG Emissions (kt CO_2e)	3-Year Trend	10-Year Trend	Description	Key Factors Influencing Changes in Emissions
AFFORESTATION & DEFORESTATION	**3,558**	**+7.5%**	**-4.3%**		
Cropland converted to Forest Land (Afforestation)	-22	+38%	+340%	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.	Afforestation rates on areas previously cropland
Forest Land converted to Cropland (Deforestation)	817	-6%	-19%	The clearing of forest land for agricultural use results in GHG emissions from the removal of biomass, 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 is diminished.	Clearing for annual crops, permanent tree clearing for pasture and rangeland, head of cattle, conversion of forest to vineyards and orchards, expansion of cleared areas within existing farms

Note: Table continued on next page

[29] See: http://unfccc.int/cop7/documents/accords_draft.pdf. 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.

LULUCF Category	Net GHG Emissions (kt CO_2e)	3-Year Trend	10-Year Trend	Description	Key Factors Influencing Changes in Emissions
Forest Land converted to Settlements (Deforestation)	2,759	+12%	+2%	The clearing of forest land for transportation and 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.	Expansion rates for transportation infrastructure (e.g., highways, logging roads, railways, airstrips), energy infrastructure (e.g., hydro line rights-of-way, hydro dams and earth fills, pipelines, well pads, seismic lines), municipal developments (e.g., urban and rural residential developments, open fields, gravel pits/quarries (and resource extraction activities), industry (e.g., industrial buildings/sites, shopping malls, prisons, schools, universities and similar infrastructure), mining (e.g., open pit coal, limestone and other mines. Infrastructure for underground mines) and recreation (e.g., campgrounds, golf courses, ski runs)
Forest Land converted to Wetlands (Deforestation)	0	No change	No change	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.	Flooded area and timber cleared for hydro dams and other reservoirs, peat production. Emissions zero since early 1990s because no new dams constructed.
Grassland converted to cropland (Grassland Conversion)	3	Emissions zero in 2009	Emissions zero in 2002	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.	Establishment of annual crops, pasture and rangeland, cattle, expansion of cleared areas within existing farms onto grassland
Other land converted to wetlands (Conversion to Wetlands)	0	No change	No change	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.	Mainly flooded area from hydro dam construction. Emissions zero since early 1990s because no new dams constructed

Note: A negative number indicates that the estimate is a sink (i.e., the activity removes carbon from the atmosphere)

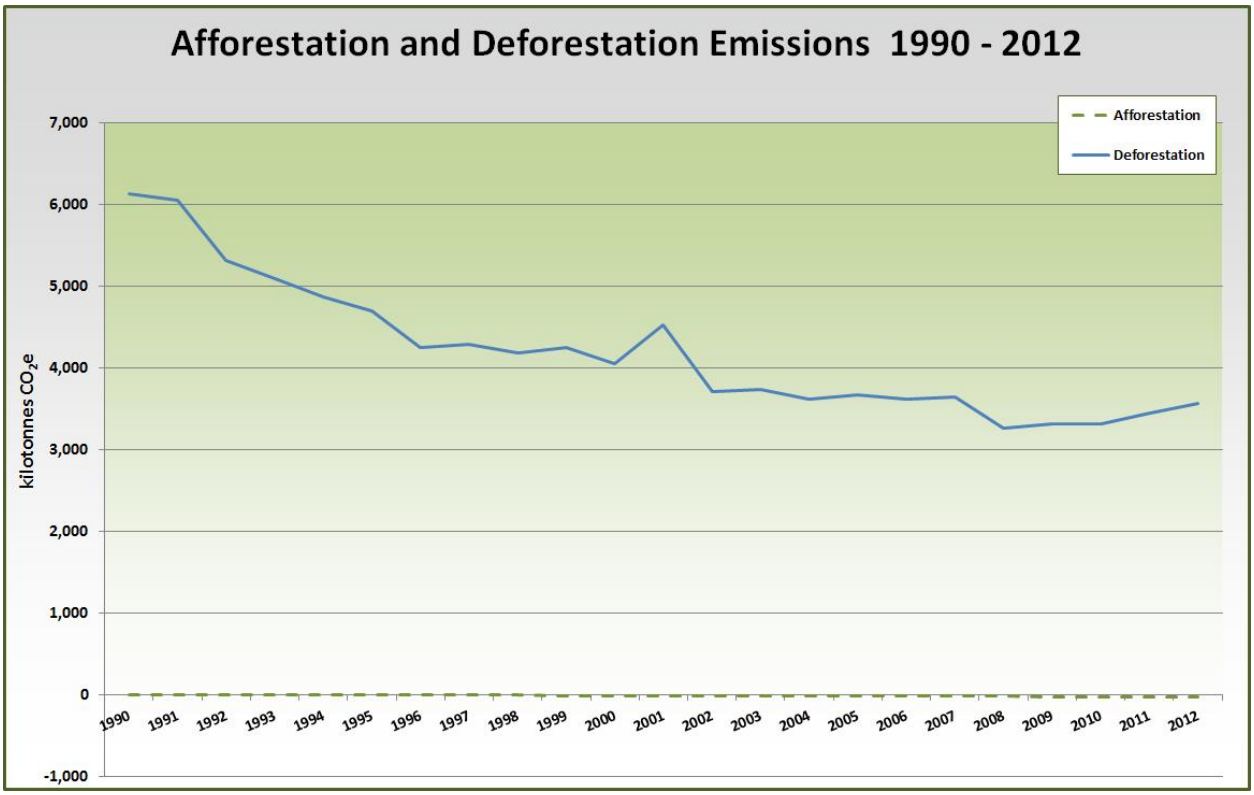


Figure 24: Afforestation and Deforestation Emission Trends

Approximately 5,114 hectares was deforested in 2012, a decrease of 26% from the 6,920 hectares in 2002. Deforested areas are not evenly distributed across the province but are concentrated in the lower mainland, east Vancouver Island (both in the Pacific Maritime ecozone), and north central/north-eastern B.C. (Boreal Cordillera, Montane Cordillera and Taiga Plains and Boreal Plains ecozones). These areas are subject to settlement growth, agricultural development or oil and gas activity. On average, across all terrestrial ecozones, 530 and 255 tonnes of greenhouse gases (for settlement and agriculture-related deforestation, respectively) are released from combined initial biomass removal and 20-year residual biomass decomposition from one hectare of deforestation in B.C.[30]

In 2008, the latest year for which complete afforestation data is available, approximately 1,004 hectares (primarily unused farmland) was afforested.[31] Between 2004 and 2008, an average of 472 ha per year was afforested in B.C. Carbon sequestration associated with afforested lands has been relatively low due to the young age of the new forests. As trees planted after 1990 mature however, the volume of carbon sequestered will increase substantially.

[30] Ministry of Forests, Lands and Natural Resource Operations.
[31] Historical afforestation data has not been collected on an annual basis – data is periodically collected and interpolated and extrapolated to appropriate years. Thus, year-to-year trends based on this data are not representative of true trends.

Annual rates of emissions associated with deforestation and removals from afforested land are in part influenced by the area of land involved (as well as by geographic location, growing conditions, tree species, density and age).[32] Area of land affected by deforestation for selected years are illustrated in Figure 25. In the figure, area affected by deforestation is grouped into specific "sectors of human activity" (described in the figure's legend).[33] Descriptions of these activities are provided in Table 15. Detailed trend information by industrial activity sector is provided in Table 28 in Annex 10.4.

Table 15: Activities Considered as Deforestation by Sector

Sector	Description of Activities Considered to be "Deforestation" of Forest Lands
Forestry	Construction of permanent forest roads and logging landings, forest road and human-induced rock slide scars
Hydro infrastructure	Clearing of hydro line right of ways, hydro dam and "earthfill" infrastructure
Industry	Light and heavy industrial buildings/sites, shopping malls, prisons, parking lots, schools, universities and similar infrastructure
Mining	Open pit coal, copper/molybdenum, limestone, zinc and other mines, as well as infrastructure for underground mines
Municipal	Urban and rural residential developments (including some roads), open fields, gravel pits/quarries
Oil and gas	Well pads, pipelines and seismic lines
Recreation	Campgrounds, golf courses, ski runs, etc.
Transportation	Highways, railways, airstrips, etc.
Agriculture	Conversion to croplands and cleared pasture

[32] For example, in the Pacific Maritime terrestrial ecozone (where there is relatively more settlement-related deforestation) the standing tree volume per unit hectare is higher than that in the Boreal Plains terrestrial ecozone (where there is relatively more agricultural-related deforestation), thus, emissions per hectare deforested are also higher. See Environment Canada's website for further information about Canada's terrestrial ecosystems and habitats.

[33] This figure uses sector category aggregations based on those used by the Canadian Forest Service in its estimation procedures. However, for international reporting, the categorical breakdown shown in Table 14 is used.

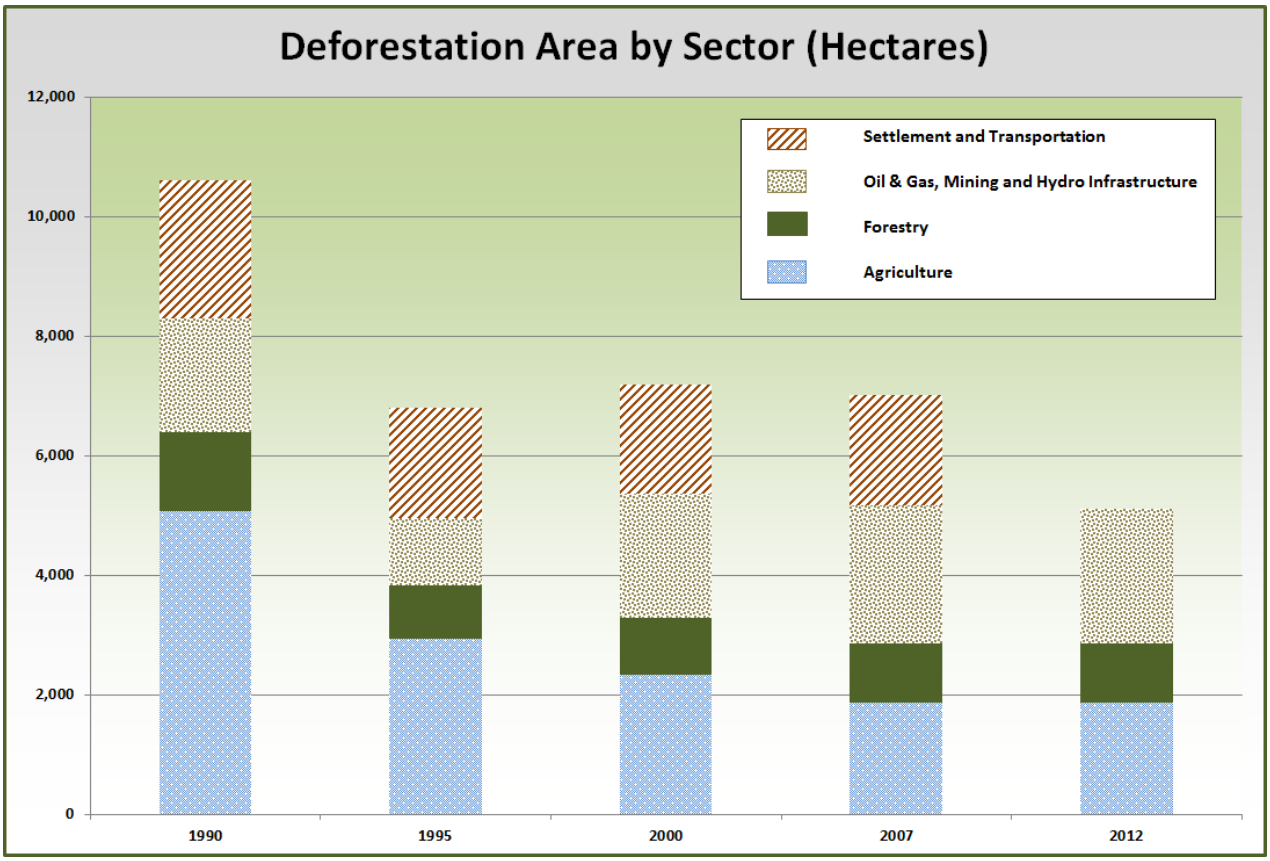


Figure 25: Deforestation Area by Sector of Human Activity

9.3 "Memo Item" Categories

"Memo items" (i.e., items not counted in emissions totals) are included in this report for transparency purposes).[34]

The memo items include emissions of approximately 39.0 Mt from forest land (i.e., "forest land remaining forest land"), 0.21 Mt from cropland (i.e., "cropland remaining cropland") 0.04 Mt from wetlands (i.e., "wetlands remaining wetlands"), and 0.002 Mt from grasslands ("grassland remaining grassland").

Table 16 provides a description of the categories and related GHG emissions and removals relating to memo item LULUCF categories (i.e., forest land, cropland, wetlands and grassland). Sources of emissions include biomass taken from managed lands,[35] biomass decomposition, biomass burning and changes in soil composition. Removals (of CO_2 from the atmosphere) include the uptake of CO_2 by vegetation through photosynthesis and subsequent storage of carbon in biomass and soils.

[34] See discussion of reporting land use, land-use change and forestry sector memo items in section 2.3 of this report.
[35] Under current international accounting protocols, all carbon stored in removed biomass (including harvested wood products) is considered to be converted to CO_2 and emitted to the atmosphere immediately.

Types of GHGs associated with emissions and removals in this sector include CO_2, CH_4, N_2O and CO emissions from burning, carbon stored in wood and soils (reported as CO_2) and CO_2 emissions from soils and biomass decomposition.

Table 16: "Memo Item" LULUCF Sector Categories and GHG Emissions – 2012

LULUCF Category	Description	Net GHG Emissions (kt CO_2e)
TOTAL "MEMO ITEM" LULUCF EMISSIONS (not included in Total Provincial GHG Emissions)		**39,297**
Forest Land remaining Forest Land	The growth of biomass in forest land results in increased CO_2 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.	39,043
Cropland remaining Cropland	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.	212
Wetlands remaining Wetlands	The burning of biomass prior to flooding, 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 "forest land converted to wetlands" category. Small hydroelectric reservoirs are not included in this category.	40
Grassland converted to Settlements[1]	The clearing of grassland for transportation and energy infrastructure, municipal development and resource extraction activities result in GHG emissions from the decay of dead organic matter. In addition, the ability of the land area to remove CO2 from the atmosphere is diminished.	2

[1] Not currently estimated in the NIR due to uncertainty in quantification methods

"Forest Land Remaining Forest Land" Category

Emissions from forest land (i.e., "forest land remaining forest land") were approximately 39.0 mega-tonnes (Mt) CO_2e in 2012. These emissions are being reported as a "memo item". Emissions in this category included net -49.2 Mt CO_2e sequestered through net primary production (NPP) and decay of dead organic matter,[36] 63.1 Mt CO_2e emitted due to harvesting,[37] 17.1 Mt CO_2e emitted due to wildfires and 8.0 Mt CO_2e emitted due to slash burning.[38,39]

[36] Net primary production (NPP) is a measurement of plant growth, calculated as the quantity of carbon dioxide absorbed from the atmosphere and stored as carbon by vegetation. NPP is equal to photosynthesis minus respiration and is measured in units of carbon per year. It is sometimes expressed in grams of carbon per square metre per year.
[37] All carbon stored in harvested wood products is assumed under current international accounting protocols to be converted to CO_2 and emitted immediately to the atmosphere. This is an overestimation of emissions since carbon embedded in wood products is sequestered for an extended period of time prior to the eventual decay of wood products and release of emissions. These protocols have been revised through international negotiation and will be incorporated into national inventories starting with the 1990-2013 inventories.
[38] The removal of biomass due to burning temporarily reduces the capacity of the forest to remove carbon dioxide from the atmosphere before regenerating trees grow to a significant size.

Trends in emissions from 1990 to 2012 are shown in Figure 26. From 1990 to 2002, British Columbia's managed forests were a net sink of GHGs – absorbing more GHGs than were emitted. Since 2002 managed forests have been net sources of GHGs. The transition from sink to source can be attributed in large part to the mountain pine beetle (MPB) outbreak,[40] wildfires and partly to increases in wood harvesting.[41]

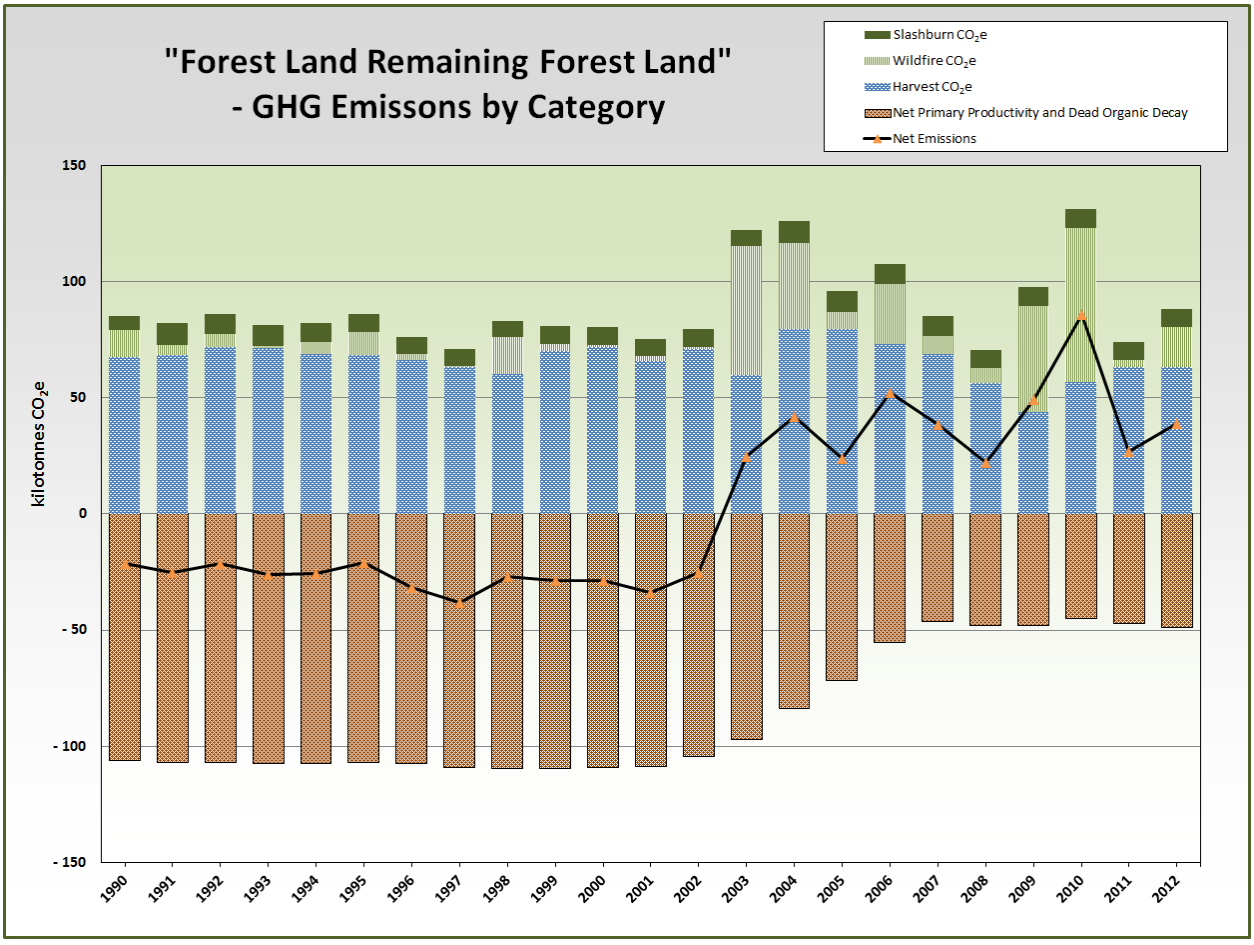


Figure 26: "Forest Land Remaining Forest Land" – GHG Emissions by Category

[39] Forest carbon accounting involves complex simulations. Research by the Canadian Forest Service and the Ministry of Forests, Lands and Natural Resource Operations indicates that greenhouse gas emissions from deforestation, harvesting, and wildfire may be overestimated in B.C. Scientific research is occurring to validate and implement the updates in the carbon accounting models.

[40] The mountain pine beetle infestation has resulted in dead pine trees, whose decomposition releases CO_2 emissions. In addition, the death of pine trees temporarily reduces the capacity of the forest to remove carbon dioxide from the atmosphere before new trees grow to a significant size. In the long term, as trees re-grow in mountain pine beetle affected areas, the forest's capacity to act as a GHG sink will increase and the rate of carbon sequestration could increase substantially. Hence, this change should not be considered as a "permanent" loss.

[41] In addition to removing stored carbon, the harvesting of woody biomass temporarily reduces the capacity of the forest to remove carbon dioxide from the atmosphere before regenerating trees grow to a significant size.

Table 17: Forest Land Remaining Forest Land Sector Categories and Key Drivers

Emission/Activity Data Category	Key Factors Influencing Changes in Emissions
FOREST LAND REMAINING FOREST LAND	
Net Primary Production and Decay of Dead Organic Matter (removal)	Growth of trees and other vegetation (including regeneration after harvesting, forest fires and insect/disease), decomposition of dead organic matter and intensity of insect and disease attack
Wildfires (emission)	Forest fire location and intensity – note that emissions due to wildfires vary greatly from year to year
Harvest (emission)	Amount of harvest
Slash Burning (emission)	Amount of slash pile burning

Area of forest land impacted by MPB, wildfires, thinning and clear-cutting from 1990 to 2012 is illustrated in Figure 27.[42] Area affected by MPB increased by two orders of magnitude between 1990 levels and peak years of 2005, 2006 and 2007. The area of land impacted by wildfires varies greatly from year to year, with significant spikes in 2003-2006, 2009 and 2010 and lows in 1993, 1997 and 2000-2002, and more recent low in 2011, relative to the high impact adjacent years.

[42] Detailed data on area affected by various factors can be found in Table 30.

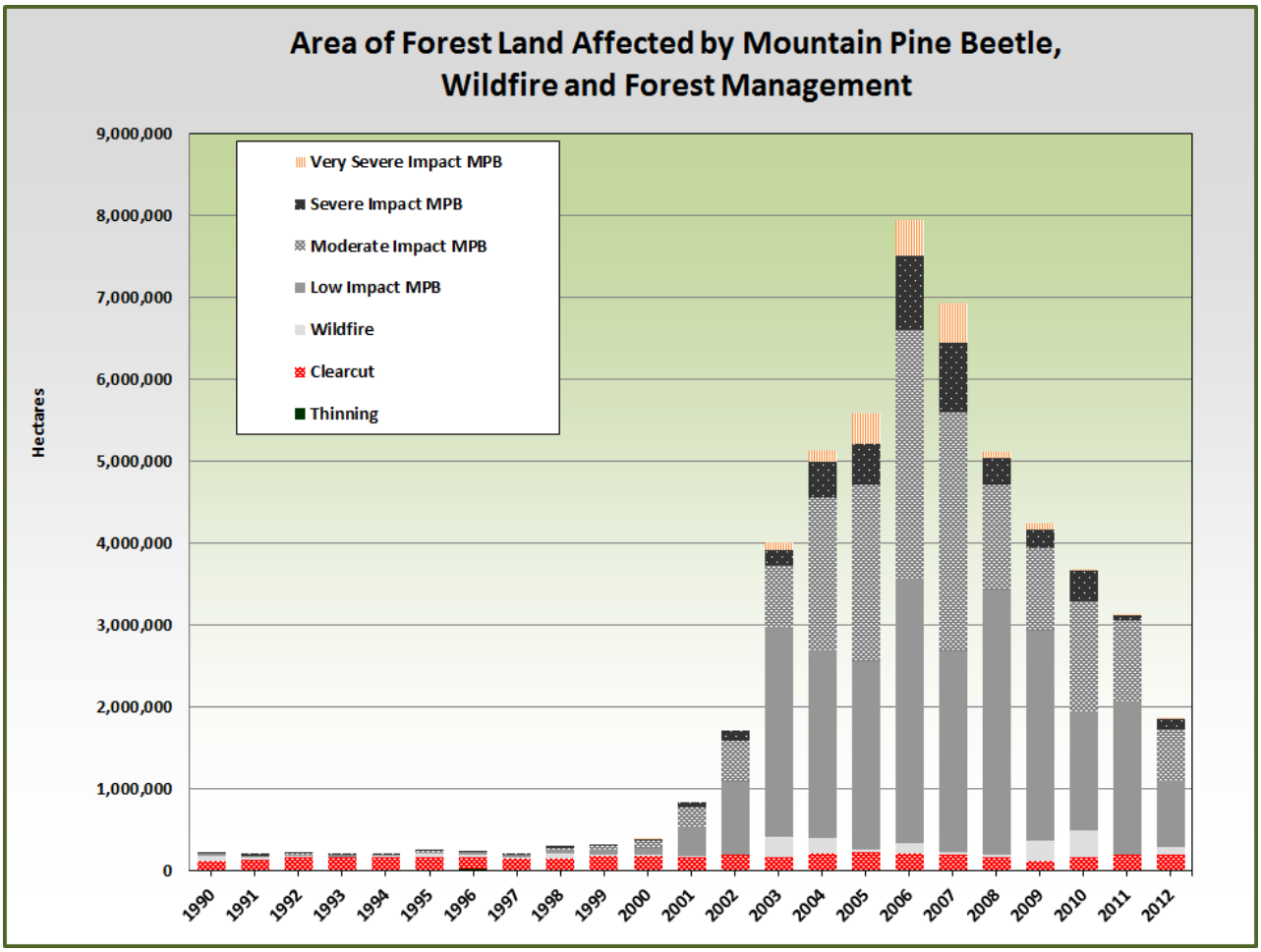


Figure 27: Area of Forest Land Affected by Mountain Pine Beetle, Wildfire and Forest Management

"Cropland Remaining Cropland" Category

Emissions from cropland (i.e., the "cropland remaining cropland" category) were 212 kilotonnes of CO_2e in 2012. These emissions are being reported as a "memo item". This is a decrease of 9.0% between 2007 and 2012 and a decrease of 1.0% from 2002 emissions. These changes can be attributed, in part, to changes in the area of cropland in the province. Total cropland area in 2012 (1,683,437 hectares) was 4.2% higher than in 2007, and 15.0% higher than in 2002. Trends in emissions and cropland area from 1990 to 2012 are shown in Figure 28: "Cropland Remaining Cropland" – Net GHG Emissions and Area. Other factors impacting emissions from cropland management include lime application, cultivation of organic soils, changes in the management of mineral soils and changes in woody biomass.[43]

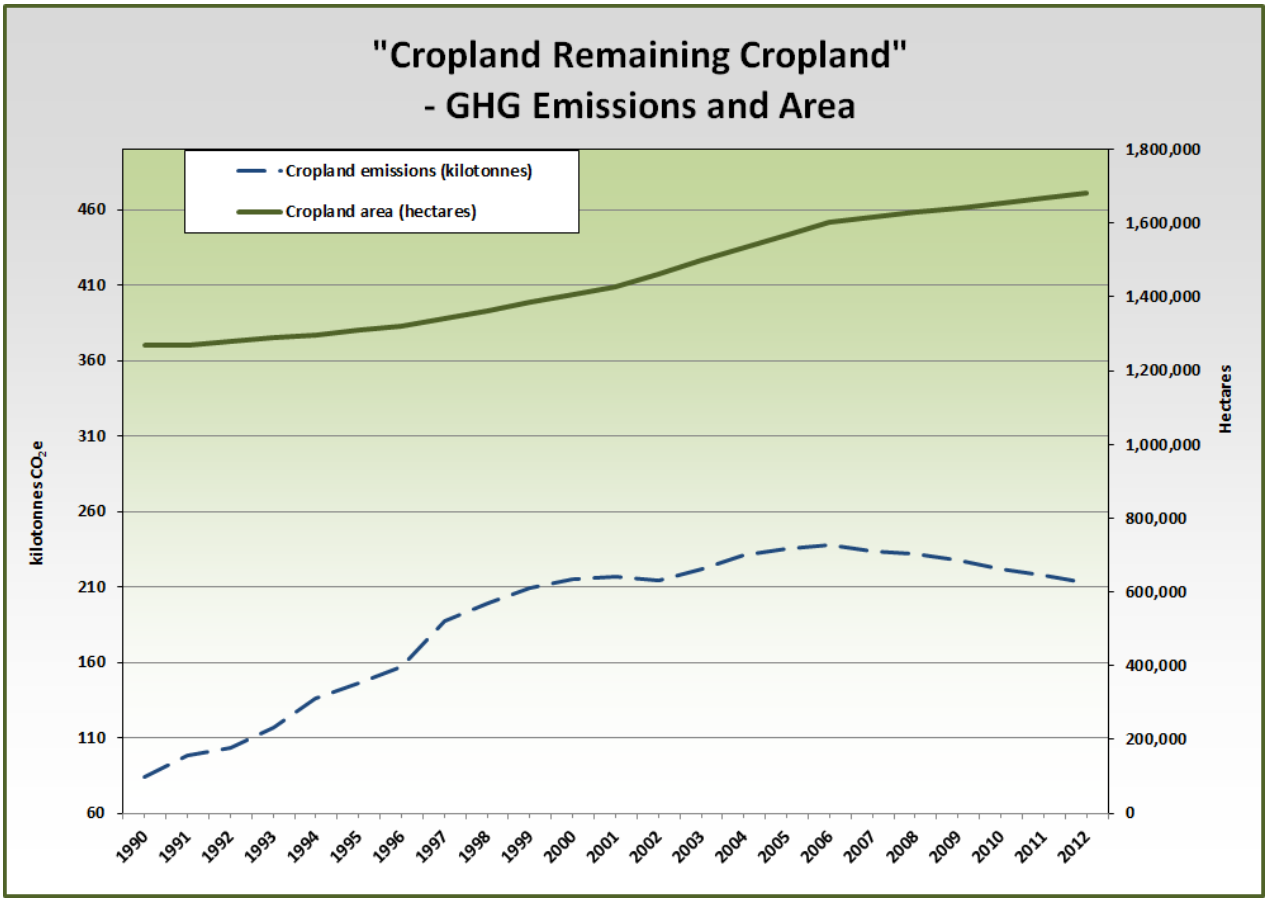


Figure 28: "Cropland Remaining Cropland" – Net GHG Emissions and Area

[43] Refer to the national inventory report for further description of these factors.

"Wetlands Remaining Wetlands" Category

Emissions from wetlands (i.e., the "wetlands remaining wetlands" category) were 40 kilotonnes CO_2e in 2012. These emissions are being reported as a "memo item". This is a 21.6% decrease from 2007 and a 41.1% decrease from 2002. The emissions trend for B.C. between 1990 and 2012 is shown in Figure 29. The steady decline in emissions is attributed to the fact that no new flooded area has been reported since 1993. As a result, there have been steady reductions in the residual decay of flooded biomass that was either cleared prior to reservoir flooding or left standing.

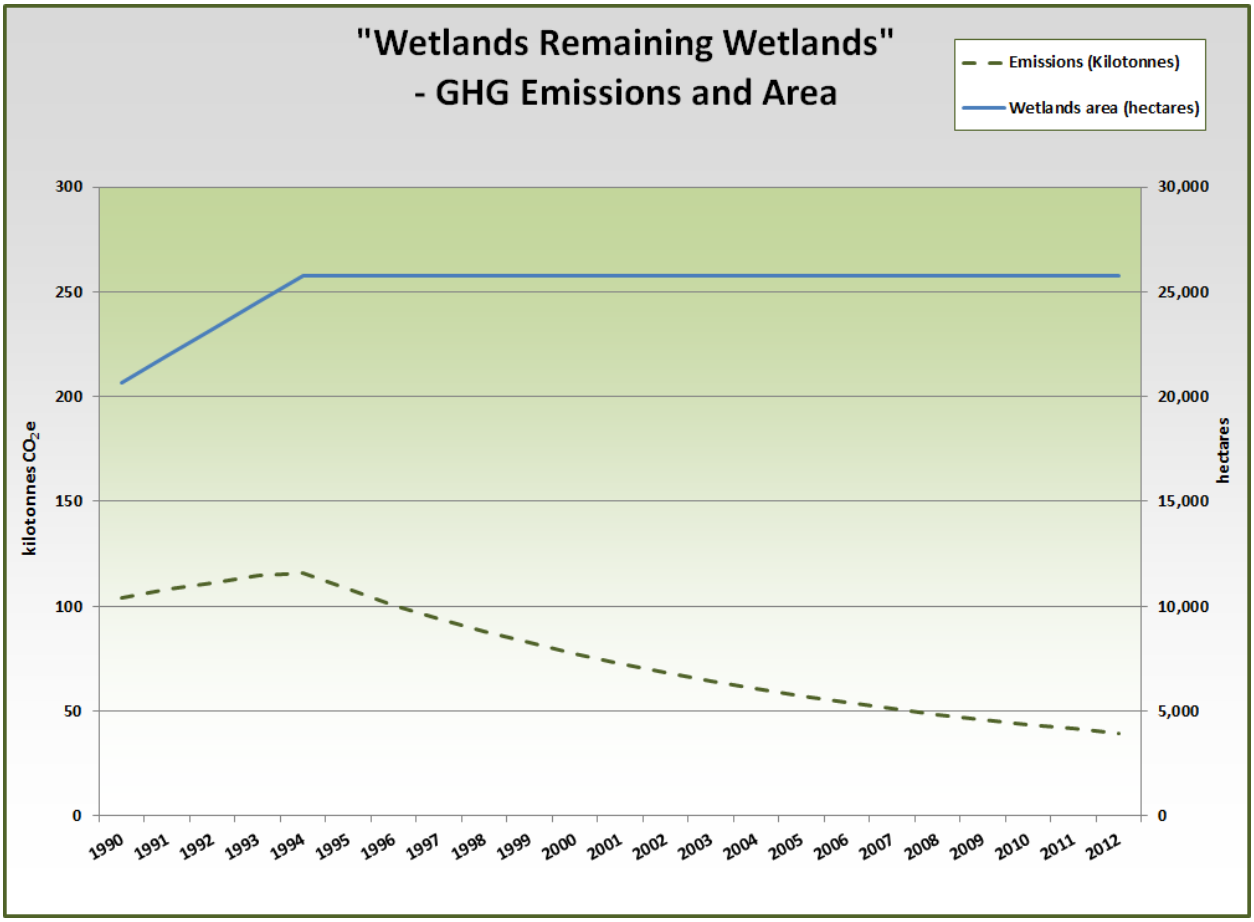


Figure 29: "Wetlands Remaining Wetlands" – Net GHG Emissions and Area

"Grassland Remaining Grassland" Category

Emissions from grasslands (i.e., the "grasslands remaining grasslands" category) were 2 kilotonnes CO_2e in 2012. Human activities on managed grassland are fire suppression, seeding new plant species and grazing practices. These emissions are being reported as a "memo item". This is a substantial relative (but not absolute) increase since 2007 in which emissions were essentially zero, and a 44% decrease from 2002. Emissions in this category correspond to biomass burning due to natural causes (e.g. wildfire) or to human activities.[44] The high variability over time series results from the episodic nature of the fire events.

[44] This category includes burning of managed grassland naturally by lightning, by accidental ignition, as a management tool for control of invasive plants and to stimulate growth of native species, or as part of military training exercises. It is a net source of CH_4, CO, and N_2O.

10. ANNEXES

10.1 Abbreviations, Acronyms and Measures

Table 18: Abbreviations, Acronyms and Measures

Abbreviation, Acronym or Measure	Definition
Al_2O_3	Alumina
B.C.	British Columbia
CAC	Criteria Air Contaminant
CANSIM	Canadian Socio-economic Information Management System (Statistics Canada)
CAPP	Canadian Association of Petroleum Producers
CBM	Carbon Budget Model
CEEI	Community Energy and Emissions Inventory
CEPA	*Canadian Environmental Protection Act*
c.f.	refer to
CFCs	Chlorofluorocarbons
CFS	Canadian Forest Service
CGA	Canadian Gas Association
CH_4	Methane
CIEEDAC	Canadian Industrial Energy End-Use Data and Analysis Centre
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent – 1 CO_2e is the GWP from the release of 1 kg of CO_2
CPPI	Canadian Petroleum Products Institute
EC	Environment Canada
e.g.	for example
g	grams
GDP	Gross domestic product
GGRTA	*Greenhouse Gas Reductions Target Act*
GHG	Greenhouse gas
GWh	gigawatt hours
GWP	Global warming potential
GJ	gigajoule
GTIS	Global Trade Information Services
ha	hectares
HFCs	Hydrofluorocarbons

Abbreviation, Acronym or Measure	Definition
i.e.	that is
IPCC	Intergovernmental Panel on Climate Change
kg	kilograms
km	kilometres
kt	kilotonnes (thousand tonnes)
kWh	kilowatt hours
L	litres
LULUCF	Land use, land-use change and forestry (sector of emissions)
m^3	cubic metres
MEM	(B.C.) Ministry of Energy and Mines
MGEM	Mobile Greenhouse Gas Emission Model
MGO	Marine gas oil
Mha	mega hectares (million hectares)
MPB	Mountain Pine Beetle (infested forest)
Mt	megatonnes (million tonnes)
N/A	Not applicable
NAICS	North American Industry Classification System
NFCMARS	National Forest Carbon Monitoring, Accounting and Reporting System
NF_3	Nitrogen trifluoride
NIR	National Inventory Report
N_2O	Nitrous oxide
NPP	Net primary production
NRCan	Natural Resources Canada
PFCs	Perfluorocarbons
ppm	parts per million
QA/QC	Quality assurance/quality control
RESD	Report on Energy Supply and Demand in Canada
SF_6	Sulphur hexafluoride
STP	Standard temperature and pressure
TJ	terajoule
UNFCCC	United Nations Framework Convention on Climate Change
VOC	Volatile organic compound

10.2 Global Warming Potentials for Greenhouse Gases

Table 19: Global Warming Potentials for Greenhouse Gases[45]

GHG	Formula	100-Year GWP (2nd Assessment Report – used for 1990-2012 PIR)	*100-Year GWP (4th Assessment Report – to be used for 1990-2013 PIR)*
Carbon Dioxide	CO_2	1	*1*
Methane	CH_4	21	*25*
Nitrous Oxide	N_2O	310	*298*
Sulphur Hexafluoride	SF_6	23,900	*22,800*
Nitrogen Trifluoride	NF_3	-	*17,200*
Hydrofluorocarbons (HFCs)			
- HFC-23	CHF_3	11,700	*14,800*
- HFC-32	CH_2F_2	650	*675*
- HFC-41	CH_3F	150	*92*
- HFC-43-10mee	$C_5H_2F_{10}$	1,300	*1,640*
- HFC-125	C_2HF_5	2,800	*3,500*
- HFC-134	$C_2H_2F_4$ (CHF_2CHF_2)	1,000	*1,100*
- HFC-134a	$C_2H_2F_4$ (CH_2FCF_3)	1,300	*1,430*
- HFC-143	$C_2H_3F_3$ (CHF_2CH_2F)	300	*353*
- HFC-143a	$C_2H_3F_3$ (CF_3CH_3)	3,800	*4,470*
- HFC-152a	$C_2H_4F_2$ (CH_3CHF_2)	140	*124*
- HFC-227ea	C_3HF_7	2,900	*3,220*
- HFC-236fa	$C_3H_2F_6$	6,300	*9,810*
- HFC-245ca	$C_3H_3F_5$	560	*693*
Perfluorocarbons (PFCs)			
- Perfluoromethane	CF_4	6,500	*7,390*
- Perfluoroethane	C_2F_6	9,200	*12,200*
- Perfluoropropane	C_3F_8	7,000	*8,800*
- Perfluorobutane	C_4F_{10}	7,000	*8,860*
- Perfluorocyclobutane	$c\text{-}C_4F_8$	8,700	*10,300*
- Perfluoropentane	C_5F_{12}	7,500	*9,160*
- Perfluorohexane	C_6F_{14}	7,400	*9,300*

[45] B.C. currently uses global warming potentials established in the IPCC second assessment report. See www.ipcc.ch/index.htm.

10.3 Emission Factors

The following emission factors are drawn or derived from those listed in Annex 8 of the National Inventory Report and are those most commonly used in British Columbia. Additional emission factors are provided in the NIR and/or are developed on the basis of site, time and source-specific fuel testing.

Emission Factors for Fuel Combustion[46]

Table 20: Emission Factors for Fuel Combustion

Fuel Type	CO_2	CH_4	CH_4 (CO_2e)	N_2O	N_2O (CO_2e)	Total CO_2e	Units
Natural Gas - Producer Consumption	2,151	6.4	134.4	0.06	18.6	**2,304**	g/m^3
Natural Gas – Industrial Consumption[1]	1,916	0.037	0.777	0.033	10.23	**1,927**	g/m^3
Natural Gas – Pipelines	1,916	1.9	39.9	0.05	15.5	**1,971**	g/m^3
Natural Gas – Vehicles at STP[2]	1,890	9	189	0.06	18.6	**2,098**	g/m^3
Gasoline – On Road Vehicles[3]	2,289	0.14	2.94	0.022	6.82	**2,299**	g/L
Gasoline – Off-Road	2,289	2.7	56.7	0.05	15.5	**2,361**	g/L
Gasoline – Boats	2,289	1.3	27.3	0.066	20.46	**2,337**	g/L
Diesel (Light-duty Trucks)[3]	2,663	0.068	1.43	0.22	68.2	**2,733**	g/L
Diesel (Heavy-duty Vehicles)	2,663	0.11	2.31	0.151	46.81	**2,712**	g/L
Diesel – Off road	2,663	0.15	3.15	1.1	341	**3,007**	g/L
Diesel – Refineries and other	2,663	0.133	2.793	0.4	124	**2,790**	g/L
Diesel – Train	2,663	0.15	3.15	1.1	341	**3,007**	g/L
Diesel – Ships	2,663	0.15	3.15	1.1	341	**3,007**	g/L
Light Fuel Oil – Ships	2,725	0.26	5.46	0.073	22.63	**2,753**	g/L
Light Fuel Oil – Industrial[4]	2,725	0.006	0.126	0.031	9.61	**2,735**	g/L
Light Fuel Oil – Residential	2,725	0.026	0.546	0.006	1.86	**2,727**	g/L
Light Fuel Oil – Commercial and Institutional	2,725	0.026	0.546	0.031	9.61	**2,735**	g/L
Heavy Fuel Oil – Ships	3,124	0.28	5.88	0.079	24.49	**3,154**	g/L
Heavy Fuel Oil – Industrial[4]	3,124	0.12	2.52	0.064	19.84	**3,146**	g/L
Aviation Gasoline	2,342	2.2	46.2	0.23	71.3	**2,460**	g/L
Aviation Turbo Fuel	2,534	0.029	0.609	0.071	22.01	**2,557**	g/L
Kerosene (Electric Utilities, Industrial, Producer Consumption)[4]	2,534	0.006	0.126	0.031	9.61	**2,544**	g/kg
Coal – Canadian Bituminous[4]	2,190	0.03	0.63	0.02	6.2	**2,197**	g/kg
Coal – Sub-Bituminous[4]	1,745	0.03	0.63	0.02	6.2	**1,732**	g/kg
Coal Coke	2,479	0.03	0.63	0.02	6.2	**2,487**	g/kg
Petroleum Coke – Upgrading Facilities	3,494	0.12	2.52	0.0231	7.161	**3,504**	g/L

Note – Table continues on next page

[46] Unless otherwise noted, emission factors are from Annex 8 of the National Inventory Report 1990-2012. Further detailed emission factors are available in the NIR for specific circumstances (such as older vehicles and unique fuels).

Fuel Type	CO_2	CH_4	CH_4 (CO_2e)	N_2O	N_2O (CO_2e)	Total CO_2e	Units
Petroleum coke – Refineries and Others	3,814	0.12	2.52	0.0275	8.52	**3,825**	g/L
Propane – Residential[5]	1,507	0.027	0.567	0.108	33.48	**1,541**	g/L
Propane Vehicles	1,507	0.64	13.44	0.028	8.68	**1,529**	g/L
Butane	1,730	0.024	0.504	0.108	33.48	**1,764**	g/L
Ethane	976	0.024	0.504	0.108	33.4	**1,010**	g/m^3
Coke Oven Gas	687	0.04	0.84	0.04	12.4	**700**	g/m^3
Still Gas – Upgrading Facilities	2,140	0	0	0.00002	0.0062	**2,140**	g/m^3
Still Gas – Refineries and Others	1,600	0	0	0.00002	0.0062	**1,600**	g/m^3
Wood Waste (50% moisture content)	840	0.09	1.89	0.06	18.6	**860**	g/kg
Wood Waste (15% moisture content)[6]	1,590	0.51	10.71	0.068	21.08	**1,622**	g/kg
Spent Pulping Liquor (i.e. Black Liquor)	891	0.02	0.42	0.02	6.2	**898**	g/kg
Biodiesel[3]	2,449	0.11	2.31	.151	46.81	**2,498**	g/L
Ethanol[3]	1,494	0.14	2.94	0.022	6.82	**1,504**	g/L
Tires – Cement	80.1	0.03	0.63	0.004	12.4	**93**	kg/GJ
Landfill Gas - Industrial combustion	55,040	1	21	0.1	31	**55,092**	kg/TJ
Petrochemical Feedstocks	500	0	0	0	0	**500**	g/L
Napthas	625	0	0	0	0	**625**	g/L
Lubricating Oils and Greases	1,410	0	0	0	0	**1,410**	g/L
Petroleum Used for Other Products	1,450	0	0	0	0	**1,450**	g/L

[1] Emission factors applicable to manufacturing and other industry. For emission factors for other sectors – including electric utilities, construction, commercial/institutional, residential and agriculture – refer to the National Inventory Report (NIR) 1990-2010.

[2] Density of natural gas is 0.694 kg/m^3 at STP. Estimate provided by B.C. Ministry of Energy and Mines.

[3] Emission factor varies slightly for different vehicle types and technologies – refer to the NIR for specific values.

[4] Emission factor for industrial use. Emission factors for other uses may vary slightly – refer to the NIR for these values.

[5] Emission factor varies slightly for other uses of propane – refer to NIR for these values.

[6] Sourced from U.S. Environmental Protection Agency, Inventory of Greenhouse Gas Emissions and Sinks: 1990-2008 (2009).

Emission Factors for Fugitive Emissions and Industrial Processes[47]

Table 21: Emission Factors for Fugitive Emissions and Industrial Processes

Industrial Process[1]	Activity	Emission Factors					Unit
		CO_2	CH_4	CF_4	C_2F_6	CO_2 e	
Coal Mining	Underground Coal Production	0	2.78	0	0	58.4	kg/tonne coal
	Surface Coal Production	0	0.65	0	0	13.7	kg/tonne coal
Limestone Use	Glass production, non-ferrous metal production, pulp and paper mills, other chemical uses	418	0	0	0	418	kg/tonne feed
Dolomite Use	Glass production, magnesium production, smelting of iron and steel	468	0	0	0	468	kg/tonne product
Soda Ash Use	Glass manufacturing	415	0	0	0	415	kg/tonne feed
Cement Production	Limestone calcination	507	0	0	0	507	kg/tonne product
Lime Production	Limestone calcination (high calcium lime)	751	0	0	0	751	kg/tonne product
	Limestone calcination (dolomitic lime)	889	0	0	0	889	kg/tonne product
Primary Aluminium[2]	Electrolysis - Side-worked pre-baked	1,600	0	1.6	0.4	15,680	kg/tonne product
	Electrolysis - Centre-worked pre-baked	1,600	0	0.4	0.04	4,568	kg/tonne product
	Electrolysis - Horizontal stud Søderberg	1,700	0	0.4	0.03	4,576	kg/tonne product
	Electrolysis - Vertical Stud Søderberg	1,700	0	0.8	0.04	7,268	kg/tonne product

[1] Refer to the NIR for emission factors pertaining to "other and undifferentiated production"

[2] Emission factors are average factors and are not used for developing emission estimates for recent years

[47] Data from National Inventory Report 1990-2012

Emission Factors for Electricity[48]

Table 22: Emission Factors for Electricity

Year	1990	2000	2005	2007	2008	2009	2010	2011	2012
Category	**Electricity Generation (GWh)**								
Combustion	1,390	3,930	3,820	3,160	3,390	3,020	3,050	1,860	1,540
Natural Gas	1,310	3,350	3,140	2,160	2,370	2,030	1,850	1,150	1,032
Other Fuels[1] (Biomass, Refined Petroleum Products, Other)	79.4	585	689	1,000	1,020	993	1,210	700	513
Steam from Waste Heat				733	768	648	651	38.8	27.6
Hydro	46,400	50,800	50,300	54,700	48,600	46,300	45,000	51,700	56,100
Other Renewables[2]							123	187	158
Other Generation[3]						1,920	2,980	2,510	2,720
Total	**47,800**	**54,700**	**54,100**	**58,600**	**52,800**	**51,900**	**51,800**	**56,300**	**60,500**
Greenhouse Gas Intensity (g GHG per kWh electricity produced)									
CO_2 Intensity ($g\ CO_2/kWh$)	17.0	35.0	24.0	19.0	27.0	25.0	23.0	13.0	8.1
CH_4 Intensity ($g\ CH_4/kWh$)	0.004	0.009	0.006	0.005	0.007	0.006	0.006	0.003	0.002
N_2O Intensity ($g\ N_2O/kWh$)	0.0006	0.001	0.0006	0.0005	0.0008	0.0008	0.0007	0.0004	0.0002
Overall Generation Intensity ($g\ CO_2e/kWh$)	**17**	**35**	**24**	**19**	**28**	**25**	**23**	**14**	**8.2**
Unallocated Energy[4] (GWh)	2,200	2,300	2,100	-5,140	740	2,200	1,900	810	2,500
SF_6 Emissions ($kt\ CO_2e/kWh$)	43	43	36	36	44	41	42	20	34
Consumption Intensity ($g\ CO_2e/kWh$)	**19**	**37**	**26**	**18**	**29**	**27**	**25**	**14**	**9.1**

[1] Other Fuels- Includes GHG emissions from the combustion of refined petroleum products (light fuel oil, heavy fuel oil, and diesel), petroleum coke, still gas and other fuels not easily categorized

[2] Other Renewables - includes electricity generation by wind, tidal and solar

[3] Other Generation - NAICS category 221119, Other Electric Power Generation

[4] The "unallocated energy" negative value for 2007 is a residual figure (i.e., statistical difference) from Statistics Canada data.

[48] Data from the National Inventory Report 1990-2012

10.4 Inventory Data Sources

Collecting Inventory Data

Inventory data can be derived using "bottom up" methods (i.e., site-specific quantification of emissions) or by "top down" approaches (that utilize aggregated statistical data to estimate emissions). Canada's inventory is prepared using predominately top down approaches, providing estimates at a sectoral and provincial/territorial level of segregation, without attribution to individual emitters. A bottom-up approach is used for a limited number of emission sources.

Non-point (or "area") sources of emissions are spatially diffuse and/or very numerous (e.g., burning of fossil fuels for transportation). These are typically calculated using technology-specific or average emission factor calculations, or "mass balance" equations (the difference between the amounts of a component – such as carbon – contained in feed materials or fuels and the amounts contained in the products, wastes or non-emitted residuals). Environment Canada has, for example, 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 (IPCC and UNFCCC) standards and practices.

Emissions from individual emitters may be measured or estimated from individual plant data, or from facility throughput and emission factors.

Energy Sector Data Sources

The principal data source for estimating stationary combustion and transport emissions is the *Report on Energy Supply and Demand in Canada* (RESD), prepared annually by Statistics Canada (2012 Preliminary Report #57-003-X). The report is a compilation of 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, road transportation).

Emissions in the transport sub-sector are allocated using Canada's Mobile Greenhouse Gas Emission Model (MGEM), which disaggregates reported fuel consumption from the RESD into 23 vehicle categories based on model year, fuel, and vehicle type.

Fugitive emissions are more difficult to estimate than combustion emissions. Numerous reports from government organizations and industry groups are used in the development of emission quantification for fugitive emissions. Data sources specific to fugitive emissions are listed in Table 23 Energy Sector Fugitive Emission Categories.

Table 23: Energy Sector Fugitive Emission Categories, Associated Activities and Data Sources

Emission Category	Associated Activities	Data Sources
Conventional Crude Oil Extraction and Processing	Releases from wells, flow lines and batteries	Report on Energy Supply and Demand in Canada (RESD). Statistics Canada (#57-003)
		1990–2012 GHG emissions associated with net exports – from Smyth (2010)
	Venting of casing and solution gas	A National Inventory of Greenhouse Gas (GHG), Criteria Air Contaminant (CAC) and Hydrogen Sulphide (H_2S) Emissions by the Upstream Oil and Gas Industry. CAPP Study 2005
	Evaporative losses from storage facilities	Supply and Disposition of Crude Oil and Equivalent, CANSIM Table 126-0001. Statistics Canada (2014)
		Industry Facts and Information by Region and Province, CAPP
		Drilling and Production Statistics, British Columbia Ministry of Energy and Mines (MEM)
Natural Gas Extraction and Processing	Releases from wells, gathering systems, field facilities and gas batteries	RESD, Statistics Canada
		A National Inventory of Greenhouse Gas (GHG), Criteria Air Contaminant (CAC) and Hydrogen Sulphide (H_2S) Emissions by the Upstream Oil and Gas Industry. CAPP Study 2005
	Seal leaks	Supply and Disposition of Natural Gas, Monthly, CANSIM Table 131-0001. Statistics Canada
	Line cleaning operations	Drilling and Production Statistics. MEM
Petroleum Refining	Process venting, equipment leaks, wastewater treatment, cooling towers, storage tanks and loading operations	Economic and Environmental Impacts of Removing Sulphur from Canadian Gasoline and Distillate Production. Canadian Petroleum Products Institute (CPPI) 2004
		RESD. (Statistics Canada #57-003XIB)
	Flaring of excess gas	
Coal Mining	Releases from exposed coal surfaces, coal rubble and venting within coal deposit	Management of Methane Emissions from Coal Mines: Environmental, Engineering, Economic and Institutional Implications of Options. King 1994
	Post-mining activities including preparation, non-vehicular transportation, storage and final processing	Coal and Coke Statistics, Catalogue No. 45-002. Statistics Canada
Natural Gas Transmission	Equipment leaks, compressor start-up, process venting, purging of lines during maintenance	CH_4 and VOC Emissions from the Canadian Upstream Oil and Gas Industry. CAPP 1999
		Ancillary tables provided to Environment Canada by Brian Ross from Clearstone Engineering Ltd. (describing CO_2 emissions)
		Natural Gas Transportation and Distribution, Catalogue No. 57-205. Statistics Canada
Natural Gas Distribution	Equipment leaks, compressor start-up venting, purging of lines during maintenance	1995 Air Inventory of the Canadian Natural Gas Industry. Canadian Gas Association (CGA) 1997
	Station vents	Vented Emissions from Maintenance at Natural Gas Distribution Stations in Canada. GRI 2000
		Natural Gas Transportation and Distribution, Catalogue No. 57-205. Statistics Canada
Oil Transmission in Pipelines	Loading and unloading of tankers, storage losses, equipment leaks, process venting	A National Inventory of Greenhouse Gas (GHG), Criteria Air Contaminant (CAC) and Hydrogen Sulphide (H_2S) Emissions by the Upstream Oil and Gas Industry. CAPP 2005

Industrial Processes Sector Data Sources

In general, industrial process emissions are calculated by multiplying activity data (e.g., quantity of the product produced) by an appropriate emission factor. However, there are more complex categories such as aluminum production which necessitate use of more elaborate formulae. Additional details on such methodologies can be found in Annex 3.2 of the NIR. Table 24 summarizes the data sources used to compile activity data and emission factors for each emission category.

Table 24: Industrial Processes Sector Categories, Associated Activities and Data Sources

Emission Category	Associated Activities	Data Sources
Cement Production	Quantity of clinker produced	Clinker production 1990-1996: A Review of Energy Consumption and Related Data: Canadian Cement Manufacturing Industry, 1990-2008. Canadian Industrial Energy End-Use Data and Analysis Centre (CIEEDAC) 2010 Clinker production 1997-2004: Catalogue #44-001. Statistics Canada Clinker production 2005-2012: CANSIM Table 303-0060 and 303-0061. Statistics Canada Clinker capacity: 1990-2006: Canadian Minerals Yearbook. Natural Resources Canada (NRCan) Cement section of the Canadian Minerals Yearbook provided the 2008–2012 data, Panagapko D. 2008–2012 Emission factor: Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. IPCC
Lime Production	Quantity of lime produced	Lime production: Canadian Minerals Yearbook. NRCan 1990-2006 and Lime section of the *Canadian Minerals Yearbook.* Panagapko D 2007–2012 Emission factor: Canadian Lime Institute
Limestone and Dolomite Use	Quantity of limestone or dolomite consumed	Limestone and dolomite consumption: Canadian Minerals Yearbook. NRCan 1990-2006 Emission factor: Identifying and Updating Industrial Process Activity Data in the Minerals Sector for the Canadian Greenhouse Gas Inventory. AMEC Earth & Environmental 2006
Soda Ash Use	Quantity of soda ash consumed	Soda Ash consumption: Global Trade Information Services (GTIS) 1995-2009 Statistics Canada's Canadian International Merchandise Trade Database (Statistics Canada) 2010–2012. Non-Metallic Mineral Products Industries: Statistics Canada #44-250 Emission factor: mass balance stoichiometry
Aluminium Production	Quantity of aluminium produced	Aluminium production: Aluminium Association of Canada Emission factors. Aluminium Association of Canada
Consumption of Halocarbons and SF_6	Quantity of halocarbons and SF_6 consumed	HFC Consumption and SF_6 Use Data: Environment Canada voluntary survey for HFC importers and distributors, and magnesium casters, total Canadian/ B.C. SF_6 use; 2011 and 2012 data were estimated Emission factors: Good Practice Guidance. IPCC
Other and Undifferentiated Production	Quantity of fuel used for non-energy purposes	Fuel consumed: RESD #57-003 Emission factors: Canada's Greenhouse Gas Emissions: Estimates for 1990, prepared for Environment Canada, Jaques, AP; 1998 Fossil Fuel and Derivative Factors, McCann, TJ; A Review of Energy Consumption in Canadian Oil Refineries. CIEEDAC 2006

Solvents and Other Product Use Sector Data Sources

The data on domestic sales of Canadian N_2O production provided by Nitrous Oxide Canada and N_2O import data purchased from Statistics Canada's merchandise trade database are used to estimate the total national sales. It is assumed that all of N_2O sold for anaesthetic is emitted into the atmosphere and none is metabolized (by patients receiving the anaesthetic). Emissions are apportioned to B.C. based on a national emission per capita factor multiplied by the population of B.C.

Agricultural Sector Data Sources

Agriculture sector emissions are calculated by multiplying activity data (e.g., number of livestock) by an appropriate emission factor. Table 25 summarizes the data sources used to compile activity data and emission factors for each agriculture sector emission category.

Table 25: Agriculture Sector Categories, Associated Activities and Data Sources

Emission Category	Activity	Data Sources
a: Enteric Fermentation	Domestic animal populations	Animal populations: Various Statistics Canada publications and CANSIM tables. Refer to Table 6-3 in the National Inventory Report (NIR) for specific references Emission Factors: Improving Estimates of Methane Emissions Associated with Enteric Fermentation of Cattle in Canada by Adopting an IPCC Tier-2 Methodology. Department of Animal Science, University of Manitoba, Boadi DA, Ominski KH, Fulawka DL, Wittenberg KM, 2004
b: Manure Management	Domestic animal populations	Animal populations: Various Statistics Canada publications and CANSIM tables – refer to Table 6-3 in the NIR for specific references CH_4 Emission Factors: Improving Estimates of Methane Emissions Associated with Animal Waste Management Systems in Canada by Adopting an IPCC Tier 2 Methodology. Department of Land Resource Science, University of Guelph, Marinier et al. 2004 N_2O Emission Factors: 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Intergovernmental Panel on Climate Change (IPCC)
c: Agriculture Soils		
Direct Emissions: - Fertilizer application	Fertilizer sales	IPCC Tier 2 method. Statistics Canada
- Crop residues	Amount of nitrogen in crop residue	Crop Production: Field Crop Reporting Series, 1990–2008 (Annual). Catalogue No. 22-002, Statistics Canada. The fate of nitrogen in agroecosystems: an illustration using Canadian estimates, Nutrient Cycling in Agroecosystems. 67: 85–102, Janzen et al. 2003
- Cultivated histosols	Area of cultivated histosols	Area of cultivated histosols: G. Padbury and G. Patterson, personal communication with Environment Canada Emission Factor: 2006 IPCC Guidelines for National Greenhouse Gas Inventories. IPCC
- Changes in tillage	Area estimates of non-tillage and reduced tillage	Area estimates of non-tillage and reduced tillage: Census of Agriculture Emission reduction estimates: Estimation of N_2O emissions from agricultural soils in Canada. I. Development of a country-specific methodology. Canadian Journal of Soil Science 88: 641–654, Rochette P, Worth DE, Lemke RL, McConkey BG, Pennock DJ, Wagner-Riddle C, Desjardins RL. 2008

Emission Category	Activity	Data Sources
- Irrigation	Area of irrigated cropland	Area of irrigated cropland: Census of Agriculture. Statistics Canada Emission Factor: Rochette et al. 2008
- Summer fallow	Area of summer fallow	Area of summer fallow: Census of Agriculture. Statistics Canada Emission Factor: Rochette et al. 2008
Pasture, Range and Paddock	Domestic animal populations	Animal populations: Various Statistics Canada publications and CANSIM tables – refer to Table 6-3 in the NIR for specific references Emission Factors: IPCC 2006 Guidelines for National Greenhouse Gas Inventories. IPCC
Indirect Sources	Fertilizer sales Domestic animal populations	Fertilizer sales and nitrogen content data: Canadian Fertilizer Institute Animal populations: Various Statistics Canada publications and CANSIM tables – refer to Table 6-3 in the NIR for specific references Emission Factors: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. IPCC

Waste Sector Data Sources

Emissions from wastewater treatment and waste incineration are estimated by multiplying an appropriate emission factor by relevant activity data (i.e., demographic 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. 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 CH_4 emissions. Table 26 summarizes the data sources used to compile activity data and derive emission factors for each emission category. The line item revision for the 2012 PIR was calculated based on a bottom-up approach using the sum of known additional 2012 gas capture amounts published in landfill annual reports, and via direct contact with facilities.

Table 26: Waste Sector Categories, Associated Activities and Data Sources

Emission Category	Activity	Data Sources
Solid Waste Disposal on Land	Quantity of waste sent to landfills Historical composition of waste sent to landfills Quantity of CH_4 captured and flared	Waste Management Industry Survey. Statistics Canada National Wood Residue Database. Natural Resources Canada (NRCan) Recommendations for Improving the Canadian Methane Generation Model for Landfills. Natural Resources Institute, University of Manitoba Calculation Tools for Estimating Greenhouse Gas Emissions from Wood Products Manufacturing Facilities. National Council for Air and Stream Improvement, Inc. 2003 An Analysis of Resource Recovery Opportunities in Canada and the Projection of Greenhouse Gas Emission Implications. NRCan 2006 An Inventory of Landfill Gas Recovery and Utilization in Canada 2013. Greenhouse Gas Division of Environment Canada National Waste Composition (1967). Table 1.1-9: Summary of International Refuse Composition, of the Handbook of Environmental Control. Volume II: Solid Waste. CRC Press 1973 Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. Intergovernmental Panel on Climate Change (IPCC) Inventory of Landfill Gas Recovery and Utilization in Canada. National Office of Pollution Prevention, Environment Canada 2003
Wastewater Handling	Quantity of CH_4 emitted per capita Quantity of N_20 emitted per capita protein consumption Population of B.C. Protein consumption per capita in Canada	Demographic Statistics (Annual). Catalogue No. 91-213-XIB. Statistics Canada 2006 Annual Demographic Estimates: Canada, Provinces and Territories, Catalogue no. 91-215-X. Demography Division, Statistics Canada 2013 Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. IPCC Food Statistics: 2010, Catalogue No. 21-020-XIE. Statistics Canada
Waste Incineration	Quantity of waste incinerated Amount of carbon per unit mass of waste	Municipal Solid Waste Incineration in Canada: An Update on Operations 1999–2001. Environment Canada 2003 Integrated Solid Waste Management. GH Tchobanoglous, Theisen H, Vigil S, 1993 Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. IPCC

Land Use, Land-use Change and Forestry Sector Data Sources and Tables

Estimation of GHG emissions in the land use, land-use change and forestry sector requires extensive modeling of variables and parameters developed from a wide range of data sources. This section provides an overview of modeling and data sources – a more detailed description of modeling procedures and data sources can be found in the NIR (section A3.4).

Afforestation, Deforestation and "Forest Land Remaining Forest Land" Category

Version 3 of the Carbon Budget Model (CBM) of the Canadian Forest Service (CFS)[49] was used to estimate GHG emissions and removals related to B.C.'s managed forests. This is a comprehensive modeling system that accounts for various data pertaining to managed forests, including:

- Forest inventory information including forest age, area and species composition
- Ecosystem processes including growth, litter fall, natural tree mortality and decomposition
- Natural disturbances (e.g., wildfires)
- Management activities including commercial thinning, clear-cutting, partial-cutting, salvage-cutting and controlled burning of harvest residues
- Carbon transfers between the atmosphere and forest sinks including dead organic matter, woody debris, standing volume and soil carbon
- Removals of merchantable biomass (i.e., logging)
- Conversion of forests for other land use (i.e., deforestation)
- Conversion of other land types into forested land (i.e., afforestation)

Activity data used in the National Forest Carbon Monitoring, Accounting and Reporting System (NFCMARS) are compiled by the CFS 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 Ministries of Forests, Lands and Natural Resource Operations, Environment and Agriculture. Recent updates to the activity data include a significant expansion of the CFS deforestation sample network in B.C. to the municipal areas, and refinement of deforestation satellite image mapping which included use of new high resolution data sources and expert validation. Some updates were made to the data set for 2000 to 2008, and a more extensive update in the 2008-2012 time period. This work has utilized existing national reporting methodologies, and will be incorporated into the National Inventory Report.

A description of activity data and data sources for the various emission sources/sinks in this category are given in Table 27.

[49] See: http://carbon.cfs.nrcan.gc.ca/index_e.html.

Table 27: Activity Data and Data Sources for Afforestion and Deforestation and Forest Land Categories

Emission Category	Activity	Data Sources
Afforestation	Area of afforestation	Canadian Forest Service National Afforestation Inventory, Interim Report for 2005-2011 years
Deforestation	Area of deforestation	Canadian Forest Service Deforestation Event GIS Database – sample based satellite and aerial photograph interpretation combined with records data
Forest Land	Area of forest Growth rates Area of wildfire Area of mountain pine beetle impact Quantity of wood harvested	Ministry of Forests, Lands and Natural Resources Operations
Afforestation, Deforestation, Forest Land	Quantity of CO_2 removals due to tree growth Quantity of CO_2e emitted due to decomposition, fire and harvest Quantity of CO_2 removals due to crop growth	Canadian Forest Service Carbon Budget Model (CBM-CFS3) Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories Inventory Methods Manual for Estimating Canadian Emissions of Greenhouse Gases. Environment Canada CBM-CFS3: A model of carbon-dynamics in forestry and land-use change implementing IPCC standards. Ecological Modelling 220(4): 480-504. Kurz, W. A., C. C. Dymond, White, T. M., Stinson, G., Shaw, C. H., Rampley, G. J., Smyth, C., Simpson, B. N., Neilson, E. T., Trofymow, J. A., Metsaranta, J., Apps, M. J. 2009 Developing Canada's National Forest Carbon Monitoring, Accounting and Reporting System to meet the reporting requirements of the Kyoto Protocol. Mitigation and Adaptation Strategies for Global Change 11(1): 33-43. Kurz, W. A. and M. J. Apps. 2006 Good Practice Guidance for Land Use, Land-Use Change and Forestry. IPCC National Greenhouse Gas Inventories Programme. Published by the Institute for Global Environmental Strategies (IGES) for the IPCC. : 4.91-4.124. IPCC. 2004 Coordinating the Interaction of National Greenhouse Gas Accounting Systems for Forestry and Agriculture, Victoria, B.C. Canada, Canadian Forest Service, Natural Resources Canada and Agriculture and Agri-Foods Canada. Kurz, W. A. and B. McConkey. 2003 National Carbon and Greenhouse-Gas Emission Accounting and Verification System for Agriculture (NCGAVS). OECD Expert Meeting on Soil Organic Carbon Indicators for Agricultural Land, Ottawa, Canada. McConkey, B. G., C. M. Monreal, et al. 2002

Table 28: Area of Afforestation and Deforestation - by Industrial Sector

Year	1990	1998	2000	2005	2007	2008	2009	2010	2011	2012
Industrial Sector	**Area Affected (hectares)**									
Afforestation Total[1]	**Inc**	**Inc**	**Inc**	**854**	**429**	**1,004**	**Inc**	**Inc**	**Inc**	**Inc**
Deforestation Total	**10,601**	**7,172**	**7,192**	**7,008**	**7,005**	**7,005**	**6,980**	**6,969**	**6,946**	**6,946**
Sectors contributing to deforestation										
Agriculture	5,074	2,569	2,331	1,855	1,855	1,855	1,855	1,855	1,855	1,855
Forestry	1,311	936	958	1,003	1,003	1,003	1,003	1,003	1,003	1,003
Oil & Gas, Mining and Hydro Infrastructure	1,913	1,799	2,066	2,318	2,315	2,315	2,290	2,279	2,256	2,256
Oil and Gas	474	948	1,394	1,699	1,700	1,700	1,700	1,700	1,700	1,700
Mining	571	841	665	619	590	590	590	579	556	556
Hydro Infrastructure	868	10	7	0	25	25	0	0	0	0
Settlement and Transportation	2,303	1,868	1,837	1,832	1,832	1,832	1,832	1,832	1,832	1,832
Industry	150	116	129	156	156	156	156	156	156	156
Municipal	1,606	1,357	1,363	1,373	1,373	1,373	1,373	1,373	1,373	1,373
Recreation	226	199	168	106	106	106	106	106	106	106
Transportation	321	196	177	197	197	197	197	197	197	197

Data from Ministry of Environment, Ministry of Forests Land and Natural Resource Operations and the Canadian Forest Service, Natural Resources Canada

[1] Negative sign signifies area added to forest lands (i.e., "removed" from affected area of forest)

[1] Inc: Incomplete data. Also, estimates for 2005, 2007 and 2008 likely represent only a portion of the total afforestation area. Efforts are underway to collect a more complete dataset.

Table 29: Approximate Forestry Emissions - by Terrestrial Ecozone

Year	1990	2000	2005	2007	2008	2009	2010	2011	2012
	Approximate Forestry Emissions (kt CO_2e)								
Terrestrial Ecozone									
Pacific Maritime (net emissions)	**36,878**	**23,700**	**23,320**	**16,393**	**10,141**	**6,241**	**9,662**	**9,223**	**9,761**
NPP and Decay of Dead Organic Matter (net)	9,928	-1,146	-5,275	-7,799	-9,572	-11,116	-11,662	-12,453	-13,303
Harvest	23,335	24,198	27,746	23,613	19,154	14,755	19,227	21,366	22,020
Wildfire	2,326	25	405	151	148	2,213	1,705	0	741
Slashburn	1,288	622	444	427	412	390	392	310	302
All Other[1] Ecozones (net emissions)	**-58,298**	**-52,461**	**624**	**22,026**	**12,132**	**42,976**	**76,213**	**17,556**	**29,282**
NPP and Decay of Dead Organic Matter (net)	-116,296	-108,118	-66,365	-38,754	-38,420	-37,047	-33,370	-34,623	-35,880
Harvest	44,019	47,347	51,480	45,215	37,255	29,045	37,536	41,742	41,087
Wildfire	9,292	1,131	6,920	7,475	5,967	43,382	64,573	2,818	16,337
Slashburn	4,687	7,179	8,588	8,090	7,329	7,595	7,475	7,619	7,739
PROVINCIAL TOTAL (net emissions)	**-21,420**	**-28,762**	**23,943**	**38,418**	**22,273**	**49,217**	**85,875**	**26,779**	**39,043**
NPP and Decay of Dead Organic Matter (net)	-106,367	-109,264	-71,640	-46,553	-47,992	-48,163	-45,031	-47,076	-49,183
Harvest	67,354	71,545	79,226	68,829	56,408	43,800	56,762	63,107	63,107
Wildfire	11,619	1,156	7,326	7,626	6,115	45,596	66,278	2,818	17,078
Slashburn	5,975	7,801	9,032	8,517	7,741	7,985	7,866	7,930	8,041

Data from Ministry of Environment, Ministry of Forests Land and Natural Resource Operations and the Canadian Forest Service, Natural Resources Canada

Note: a negative value indicates removals of carbon dioxide equivalent (a sink, or sequestration), a positive value indicates a release (or source)

[1] Montane Cordillera, Boreal Cordillera, Boreal Plains and Taiga Plains

Table 30: Area of Forest Land Affected – by Category of Activity[50] [51]

Activity Category	Forest Fire	30% Com-mercial thinning	Clearcut harvesting	MPB Low	MPB Moderate	MPB Severe	MPB Very Severe	Total MPB
Year	Area Affected (hectares)							
1990	69,373	11,043	119,725	24,675	6,230	7,168		38,073
1991	24,513	14,816	132,374	16,026	9,698	21,437		47,161
1992	24,061	25,073	145,459	16,436	6,345	20,933		43,714
1993	4,237	26,964	151,801	10,253	14,948	19,636		44,837
1994	22,702	22,163	154,931	4,573	11,678	15,422		31,674
1995	47,662	25,943	157,796	10,708	7,880	9,827		28,416
1996	18,032	30,387	154,472	30,198	7,117	6,414		43,729
1997	2,059	10,792	157,412	26,845	13,531	9,958		50,334
1998	68,382	9,347	152,242	38,225	22,797	19,300		80,322
1999	11,438	7,497	181,974	69,293	44,904	15,055		129,251
2000	4,811	11,476	187,323	77,463	92,544	26,258	555	196,820
2001	9,985	8,637	175,142	358,988	241,202	55,867		656,057
2002	4,220	9,719	192,664	885,538	500,227	136,709		1,522,474
2003	248,538	7,314	164,254	2,571,383	751,801	179,945	91,364	3,594,494
2004	183,632	7,052	223,738	2,298,785	1,851,991	429,584	149,511	4,729,871
2005	38,100	4,593	229,135	2,301,958	2,140,518	507,477	374,690	5,324,643
2006	132,758	3,776	215,614	3,222,219	3,038,347	904,482	441,030	7,606,077
2007	32,782	2,432	208,626	2,439,836	2,926,106	843,319	487,471	6,696,732
2008	31,183	1,033	173,654	3,234,895	1,287,540	322,489	77,178	4,922,102
2009	236,816	319	137,318	2,562,386	1,014,599	221,187	72,776	3,870,948
2010	325,621	652	180,048	1,446,057	1,354,122	364,981	13,895	3,179,054
2011	12,487	874	202,444	1,871,725	973,435	63,828	1,692	2,910,680
2012	93,685	874	205,047	812,309	630,840	119,869	839	1,563,857

[50] For comparative purposes, and as part of the provincial inventory compilation in collaboration with the Canadian Forest Service, the total area of forest in B.C. was estimated by the Ministry of Forests and Range in 2008 to be 66,821,657 ha.

[51] Data from Ministry of Forests, Lands and Natural Resource Operations and the Canadian Forest Service, Natural Resources Canada.

"Cropland Remaining Cropland" Category

A description of activity data and data sources for the various emission sources/sinks in this category are given in Table 31.

Table 31: Activity Data and Data Sources for Cropland Remaining Cropland

Emission Category	Activity	Data Sources
CO_2 emissions and removals in mineral soils	Relative proportion of annual and perennial crops Tillage practices Area of summer fallow	Census of Agriculture
CO_2 emissions and removals from cultivation of organic soils	Area of cultivated soils	Land area: Soil and crop specialists reporting to Environment Canada Emission factor: IPCC 2006 Guidelines for National Greenhouse Gas Inventories
CO_2 emissions and removals in woody biomass	Area of vineyards, fruit orchards and Christmas tree plantations	Census of Agriculture

"Wetlands Remaining Wetlands" Category

A description of activity data and data sources for the various emission sources/sinks in this category are given in Table 32.

Table 32: Activity Data and Data Sources for Wetlands Remaining Wetlands

Emission Category	Activity	Data Sources
CO_2 emissions from reservoir surface	Decomposition of soil organic carbon from flooded land	Canadian Reservoir Database. Duchemin 2002
CO_2 emissions from cleared biomass	Decomposition of organic matter cleared prior to flooding and placed outside the reservoir and/or burning of cleared biomass	Canadian Forest Service Carbon Budget Model (CBM-CFS3)

"Grassland Remaining Grassland" Category

Table 33: Activity Data and Data Sources for Grassland Remaining Grassland

Emission Category	Activity	Data Sources
Grassland remaining grassland	Land cover	Land Cover (Circa 2000): http://www.geobase.ca/geobase/en/data/landcover/csc2000v/description.html;jsessionid=035AD079A457BC69D3022E02DDCACBE0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