

Emission Factors for Use in Reporting Public Sector Greenhouse Gas Emissions

VERSION 2.0

Prepared for:

Climate Action Secretariat
Ministry of Environment

By:

Shared Services BC

In consultation with:

Ellen F. Battle Consulting Inc.

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Ministry Approval

Approved by:

Lee Thiessen, Director Climate Change, Ministry of Environment

Date

Colleen Sparks, Director Carbon Neutral Government,
Ministry of Environment

Date

Orest Maslany, Director Corporate Sustainability,
Shared Services BC

Date

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1. Introduction

In November 2007, British Columbia enacted legislation to establish provincial goals for reducing greenhouse gas (GHG) emissions. Under the *Greenhouse Gas Reductions Targets Act*, the B.C. public sector must become carbon neutral in its operations by 2010.¹ Beginning for the 2008 calendar year, all provincial public sector organizations (PSOs) are required to report annually, in accordance with the Act and the Carbon Neutral Government Regulation, on their GHG emissions, actions taken to reduce these emissions, plans for achieving future reductions, and offset purchases.²

The purpose of this document is to detail the emission factors to be used for calculating and reporting PSO emissions.³ Emission factors express the mass of GHGs resulting from a specific kind of activity, such as the generation of heat in buildings or the consumption of fuel by motor vehicles. To illustrate, an emission factor can show how much carbon dioxide is produced by burning one litre of gasoline in your car.

The government has developed its own web-based applications to assist with GHG measurement and reporting. “SMARTTool” calculates and reports the emissions from PSO buildings, supplies (paper), and fleet vehicles and equipment. “SMARTTEC”—the SMART Travel Emissions Calculator—computes the GHGs from government business travel, which feed into SMARTTool for reporting. The emission factors documented in this report are used by both applications to calculate estimates of GHG emissions.

1.1 Principles for Specifying Emission Factors

The government has established some principles to guide the specification of GHG emission factors:

- 1) If information allows, the preference is to identify emission factors that best reflect PSO circumstances—for example, an organization’s particular source of electricity or fuel. Over time, the government will seek to develop and apply B.C.-specific emission factors in order to improve the accuracy of public sector GHG tracking.
- 2) Where B.C.-specific information is not available, standardized emission factors from national and international data sources will be used. In particular, factors will be taken from Canada’s GHG Inventory⁴ and other recognized sources (see Section 1.3).
- 3) A key objective is to facilitate emissions tracking and ensure that measurement and reporting requirements are not overly burdensome and costly for PSOs. Therefore,

¹ Bill 44 – 2007, http://www.leg.bc.ca/38th3rd/1st_read/gov44-1.htm. The legislation also requires government business travel to be carbon neutral as of October 2007. This requirement does not apply to the broader provincial public sector, as defined in Note 2.

² PSOs encompass core government entities funded through the Consolidated Revenue Fund (e.g., ministries, special offices, tribunals) and broader public sector agencies—health authorities, school districts (K-12), colleges and universities, and Crown corporations under the Government Reporting Entity. The B.C. government and each PSO must have publicly released their first carbon neutral action report by the end of June 2009.

³ See the Glossary of Terms and Acronyms for a definition of technical terms used in this report.

⁴ Environment Canada (2009), *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada 1990-2007*.

in certain cases, such as where an emissions source is too small to justify additional data gathering by an organization, the government will provide simplified methods for estimating emissions.

- 4) Overall, the most conservative emission factors will be adopted when decisions about these factors must be made. The intent of this principle is to be consistent with the international reporting conventions and protocols.

1.2 GHG Emission Factors Defined

The PSO emission factors are expressed in kilograms (kg) of GHG emissions per unit of consumption activity. Typically, the factors for a given category of activity—for example, building energy or fleet fuel consumption—are expressed in common units to enable comparison across different fuel types, travel modes, etc.

The Carbon Neutral Government Regulation lists six distinct greenhouse gases or groups of gases: carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), sulphur hexafluoride (SF₆), and perfluorocarbons (PFCs).⁵ In practice, for most PSOs, the only GHGs emitted in any significant amount are the three principal gases associated with fuel combustion for energy (CO₂, CH₄, and N₂O) and, to a lesser extent, HFCs released from refrigeration and air conditioning equipment.⁶ However, at least one PSO (the University of British Columbia) will be reporting SF₆ emissions from power lines that it operates to distribute electricity to facilities on its property.

Wherever possible, PSO emission factors are specified by individual gas. In certain instances, an aggregate factor for multiple gases is provided in kg of CO₂-equivalent (CO₂e) emissions. CO₂e is the standard unit for measuring and comparing emissions across GHGs of varying potency in the atmosphere (see Section 1.4).

1.3 Information Sources

The primary source document for PSO emission factors is Environment Canada's *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada 1990-2007*. Appendix 12 of the most recent National Inventory Report ("2009 NIR") provides standardized factors for stationary and mobile fuel combustion and other emitting activities.

For some emission factors, international documents have been used, including the Climate Registry's *General Reporting Protocol*.⁷ In other cases, B.C.-specific emission factors have been developed using data provided by energy companies and business travel providers.

⁵ B.C. Reg. 392. 2008. See http://www.bclaws.ca/Recon/document/freeside/--%20g%20--/greenhouse%20gas%20reduction%20targets%20act%20%20sbc%202007%20%20c.%2042/05_regulation/s/10_392_2008.xml.

⁶ PFCs and SF₆ are produced primarily in aluminum and magnesium smelting/processing and semi-conductor manufacturing. SF₆ is also emitted from electricity transmission equipment. For PSO reporting purposes, only the GHG emissions from power generation are included in the electricity emission factors below (see Section 2.2).

⁷ The Climate Registry (2008), *General Reporting Protocol*, Version 1.1. B.C. is a member of the Climate Registry, which is a cross-border initiative to develop common measurement, verification, and reporting requirements for GHG emissions. See <http://www.theclimateregistry.org>.

1.4 Global Warming Potential and Emissions Calculations

All greenhouse gases vary in their ability to trap heat in the atmosphere. In order to aggregate potencies across GHGs, emissions of each gas must be converted to CO₂-equivalency by multiplying through by the appropriate Global Warming Potential (GWP). The GWP of a given gas is a measure of its heat-trapping ability compared to an equivalent amount of CO₂. As shown in Appendix A, the 100-year GWPs of the gases considered here range from 21 (CH₄) to 23,900 (SF₆)—all relative to a GWP of 1 for CO₂.

For PSO measurement purposes, the conversion to CO₂e occurs after the emission factors have been applied to calculate the emissions of each gas. That is, the emission factors presented below have not been adjusted for their GWPs.

To calculate GHG emissions, the emission factors are simply multiplied by the measure of consumption activity. For example, the natural gas emission factors for CO₂, CH₄, and N₂O are multiplied by the quantity of natural gas consumed in a PSO's buildings. The resulting emissions for each GHG are then multiplied by their GWPs and the results, in kg CO₂e, are summed to give total building emissions from natural gas use.

1.5 Structure of this Report

The remainder of this report documents the PSO emission factors by activity category and provides a sample calculation of GHG emissions:

- Section 2: Buildings
- Section 3: Supplies (Paper)
- Section 4: Fleet
- Section 5: Business Travel (Provincial Government only)⁸
- Section 6: Sample Emissions Calculation

For each activity category, a brief description is given along with an explanation of data sources and emission factor calculations.

The emission factors reported below represent the B.C. government's current understanding of the factors appropriate to PSO emission sources and fuel types. As experience is gained with estimating GHG emissions in the public sector, the list of emission factors may be expanded. It is also expected that the factors themselves and other key inputs (e.g., energy conversion factors, GWPs) will be updated as GHG measurement methodologies and data sources evolve.

As a result, this document will be periodically revised to reflect changes to the emission factors and related variables.

2. Buildings

GHG emissions are produced from activities associated with the lighting, heating, and cooling of facilities and the powering of machinery and equipment within those facilities. For the B.C. public sector, three basic categories of buildings-related GHG emissions must be tracked:

⁸ Under the Carbon Neutral Public Sector commitment, only core government organizations that report through the Consolidated Revenue Fund (e.g., ministries, special offices, tribunals) are required to track the emissions from employee business travel.

- Direct emissions from consuming fossil and biomass fuels burned in furnaces, boilers, and other stationary combustion equipment;
- Indirect emissions through the consumption of purchased electricity and steam; and
- Direct fugitive emissions from air conditioning and refrigeration systems.

2.1 Direct Emissions: Stationary Fuel Combustion

Description: Several different fossil fuels may be consumed in PSO buildings: natural gas, propane, light fuel oil (No. 2 heating oil), heavy fuel oil (No. 5 heating oil), kerosene, diesel fuel, and gasoline.⁹ In addition, several organizations burn wood fuel and wood waste in some of their buildings. Under international reporting requirements, the CO₂ emissions from biomass combustion—including wood, wood waste, ethanol, and biodiesel—must be reported separately from the other direct emissions from combustion.¹⁰ However, the CH₄ and N₂O emissions from biomass combustion are to be included with these other direct combustion emissions.

In SMARTTool, building fuel consumption data are either entered in common units of energy usage, Gigajoules (GJ), or are converted to GJ within the application itself.

Data sources: The 2009 NIR provides standardized emission factors for stationary fuel combustion sources.¹¹ For natural gas, the CO₂ emission factor is taken from Table A12-1 under the entry “British Columbia – Marketable,” while the CH₄ and N₂O emission factors are from Table A12-2 under “Residential, Construction, Commercial/Institutional, Agriculture.” Propane emission factors are from Table A12-3 under the entries for “All Other Uses.” Table A12-4 provides factors for light and heavy fuel oil and kerosene (all under “Forestry, Construction, Public Administration, and Commercial/Institutional”) as well as for diesel. For gasoline burned in generators, the emission factor for off-road mobile combustion from Table A12-11 is applied. The factors for “Wood Fuel/Wood Waste” are from Table A12-25.

Energy conversion factors to convert to GJ from cubic metres of natural gas and litres of liquid fuels are from Statistics Canada’s most recent *Report on Energy Supply and Demand in Canada* (RESO).¹²

Calculations: The PSO emission factors in Table 1 have been calculated by applying the energy conversion factors shown to the 2009 NIR emission factors in Table 2. The

⁹ To date, no PSOs have reported using heavy fuel oil or kerosene in their buildings, but these fuels have been included here for completeness.

¹⁰ The CO₂ released to the atmosphere during combustion of biomass is the same quantity that had been absorbed from the atmosphere during plant growth. Because CO₂ absorption from plant growth and the emissions from combustion occur within a relatively short timeframe to one another (typically 100-200 years), there is no long-term change in atmospheric CO₂ levels. For this reason, biomass is often considered “carbon-neutral” and the Intergovernmental Panel on Climate Change (IPCC) *Guidelines for National Greenhouse Gas Inventories* specify the separate reporting of CO₂ emissions from biomass combustion. See IPCC (2006), *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, p. 5.5; and the Climate Registry (2008), *General Reporting Protocol*, pp. 33-34.

¹¹ Environment Canada (2009), *National Inventory Report 1990-2007*, Annex 12, pp. 584-601.

¹² Statistics Canada (2009), *Report on Energy Supply and Demand in Canada 2007*, p. 119.

Table 1: PSO Emission Factors – Fuel Combustion in Buildings

Fuel Type	Energy Conversion Factor	Emission Factor (kg/GJ)		
		CO ₂	CH ₄	N ₂ O
Natural Gas	0.03832 GJ/m ³	50.00	0.0010	0.0009
Propane	0.02531 GJ/L	59.66	0.0010	0.0043
Light Fuel Oil	0.03880 GJ/L	70.23	0.0007	0.0008
Heavy Fuel Oil	0.04250 GJ/L	73.51	0.0013	0.0015
Kerosene	0.03768 GJ/L	67.25	0.0007	0.0008
Diesel Fuel	0.03830 GJ/L	69.53	0.0035	0.0104
Gasoline	0.03500 GJ/kg	65.40	0.0771	0.0014
Wood/Wood Waste	0.01800 GJ/kg	52.78	0.0028	0.0010

Table 2: Source (2009 NIR) Emission Factors – Stationary Fuel Combustion

Fuel Type	Units	CO ₂	CH ₄	N ₂ O
Natural Gas	kg/m ³	1.916	0.000037	0.000035
Propane	kg/L	1.51	0.000024	0.000108
Light Fuel Oil	kg/L	2.725	0.000026	0.000031
Heavy Fuel Oil	kg/L	3.124	0.000057	0.000064
Kerosene	kg/L	2.534	0.000026	0.000031
Diesel Fuel	kg/L	2.663	0.000133	0.0004
Gasoline	kg/L	2.289	0.0027	0.00005
Wood/Wood Waste	kg/kg	0.95	0.00005	0.00002

original NIR emission factors were manipulated only to convert them from grams to kg per unit of fuel use.

2.2 Indirect Emissions: Purchased Electricity

Description: In a hydroelectric-based power system such as British Columbia's, the GHG emissions from electricity can vary significantly from year to year not only with the quantity purchased but also with water supply conditions and hence the amount of thermal (fossil-fired) generation required. During high water years in the hydro system, less thermal power is needed and GHG emissions are relatively low. During low water years, thermal generation and emissions are typically higher.

Emissions also differ from one electric utility to the next in relation to the shares of hydro and thermal power in the supply mix. Depending on their building locations, PSOs acquire electricity

from BC Hydro, FortisBC, or a municipal distributor.¹³ In addition, some PSOs currently have properties in other provinces (Alberta and Ontario) and cities (London, Japan, and Hong Kong).

SMARTTool captures data on electricity consumption in kilowatt-hours (kWh) and makes the conversion to GJ of energy.

Data sources: BC Hydro tracks GHG emissions in its Annual Report and as part of a Global Reporting Initiative (GRI) Index.¹⁴ This tracking includes domestic purchases of electricity from independent power producers (IPPs), which together account for the largest share of BC Hydro's reported emissions (77 percent in 2007). On the other hand, the emissions associated with electricity imports for domestic use are not included.¹⁵

The GRI Index contains an indicator called "EN8(2) Greenhouse Gas Intensities" that tracks emissions per unit of electricity generated for BC Hydro's domestic supply sources. The entry for "Total Electricity Generation" gives the sum of emissions from BC Hydro power facilities and emissions from IPP purchases, divided by the electricity generated at those sources.¹⁶

While FortisBC and the municipal distributors do not publicly report on GHG emissions, their emissions can be estimated from electricity supply data. Information on the recent (2008) supply mix was obtained directly from utility contacts.

At the provincial level, the NIR reports annually on total GHG emissions, electricity generation, and GHG intensity for public utilities as a whole. The most recent year of data available is 2007.¹⁷ This information source has been used for buildings in other provinces.

For properties in other countries, information is available from the International Energy Agency (IEA) on the national fuel mix of electricity generation.¹⁸ The latest report for 2008 is based on 2006 data. These data can be used to estimate a weighted average emission factor for fossil fuel combustion in international cities.

Calculations: In Table 3, the BC Hydro emission factor is based on the reported GHG Intensity for the utility's total domestic supply. The estimate of 26 tonnes CO₂e per Gigawatt-hour (GWh) has been calculated as an average of BC Hydro's GHG intensities for 2006 through 2008.¹⁹ A rolling three-year average will be used to partially smooth

¹³ There are six municipal electric utilities serving the cities of Grand Forks, Kelowna, Nelson, New Westminster, Penticton, and Summerland.

¹⁴ See BC Hydro (2008), *BC Hydro 2008 Annual Report*, p. 44, and http://www.bchydro.com/about/company_information/reports/gri_index.html.

¹⁵ Under the international GHG protocols, BC Hydro is not required to measure and report the emissions from purchased electricity—either domestic or imported—that is passed on to consumers. BC Hydro has chosen to voluntarily report the emissions from domestic IPP purchases, but import-related emissions are not yet included in its GHG inventory.

See Indicator EN8(2) of the GRI Index at http://www.bchydro.com/about/company_information/reports/gri_index/environmental2.html.

¹⁷ See IEA (2008), *Electricity Information 2008*.

¹⁸ See for example Environment Canada (2009), *National Inventory Report 1990-2007*, Table A9-11, p. 495.

¹⁹ The reported GHG intensities were 27, 23, and 28 tCO₂e/GWh, respectively, for 2006, 2007, and 2008.

Table 3: PSO Emission Factors – Purchased Electricity

Public Utility	Emission Factor (tCO ₂ e/GWh)	Energy Conversion Factor (GJ/kWh)	Emission Factor (kg/GJ)
BC Hydro	26	.0036	7.2
FortisBC	6	.0036	1.7
City of Grand Forks	6	.0036	1.7
City of Kelowna	6	.0036	1.7
Nelson Hydro	3	.0036	0.8
City of New Westminster	26	.0036	7.2
City of Penticton	6	.0036	1.7
City of Summerland	6	.0036	1.7
Alberta	840	.0036	233.3
Ontario	200	.0036	55.6
United Kingdom	542	.0036	150.6
Japan	468	.0036	130.0
China	761	.0036	211.4

out the annual fluctuation in the electricity emission factor due to changing water conditions.²⁰

The FortisBC emission factor of 6 tCO₂e/GWh has been estimated using a weighted average of the GHG intensity of Fortis' own hydroelectric plants, purchased hydro and other renewable electricity, and purchases from BC Hydro. In calculating this average, a zero emission factor was assigned to existing hydro and other renewable (energy from wood waste) generation and purchases, which accounted for just over three-quarters of the utility's 2008 supply.²¹ The BC Hydro emission factor was then applied to the remaining purchases in the supply mix.

Since the cities of Grand Forks, Kelowna, Penticton, and Kelowna acquire all of their electricity from Fortis, they are assigned the same emission factor. Likewise, the City of New Westminster is served by BC Hydro and so is given its emission factor. The City of Nelson's municipal utility, Nelson Hydro, generates about 55 percent of its annual electricity requirements from a local hydro plant and purchases the rest from Fortis.²² These supply shares and the Fortis emission factor have been used to estimate a weighted average emission factor of 3 tCO₂e/GWh for 2008.

²⁰ Since there is a lag in collecting and reporting GHG emissions data, the emission factor estimated for the most recent calendar year of data available (e.g., 2008) may not necessarily reflect the water conditions in the current year for which emissions are being measured (e.g., 2009). Averaging over a three-year period will reduce the year-to-year differences.

²¹ Wood waste generated electricity has been assigned a zero emission factor given that the CO₂ emissions from biomass are not included in Fortis' GHG inventory under international reporting rules.

²² See <http://www.city.nelson.bc.ca/html/hydro.html>.

The electricity emission factors for Alberta and Ontario are the three-year (2005-2007) average values reported for “Overall Greenhouse Gas Intensity” in the 2009 NIR.²³ Their large magnitude relative to the B.C. emission factors reflects the substantially higher shares of fossil-fired generation in the supply mix, particularly in Alberta’s case. Going forward, if additional emission factors are needed for facilities in other provinces, they will be calculated in the same manner as those for Alberta and Ontario.

The emission factors for the U.K., Japan, and Hong Kong have been calculated by applying the NIR emission factors and RESD energy conversion factors to the fossil fuel components (hard coal, coal gases, oil, and natural gas) of the electricity generation mix.²⁴ This is an approximation, since data are not readily available on the specific emission factors for each country. The final emission factors in Table 3 represent a weighed average of the fossil fuel factors in proportion to their generation shares.

Again, it should be noted that the emission factors shown exclude electricity imports, which have grown significantly in B.C. in recent years. The general issue of accounting for GHG emissions from electricity trade has been under review by the partners to the Western Climate Initiative.²⁵ The B.C. government will make a decision on whether to include imports and exports in the electricity emission factor going forward.

2.3 Indirect Emissions: Purchased Steam

Description: A number of PSOs also use steam to heat buildings. Some (e.g., UBC, Vancouver Coastal Health Authority) produce steam, use a portion for their own consumption, and sell the surplus. Others purchase steam from a commercial district heating supplier, such as Vancouver’s Central Heat Distribution Ltd., or another PSO.

Where a PSO produces steam for its own consumption, the resulting GHG emissions are estimated by applying the appropriate combustion emission factors to the quantity of fossil fuel burned in the steam boiler. Where a PSO purchases steam from another entity, estimating emissions requires information on both the fuel source and the boiler efficiency.

SMARTTool captures data on purchased steam in pounds or kg and converts to GJ internally.

Data sources: The RESD provides an average conversion factor for translating kg of steam into GJ of energy.²⁶ The combustion emission factors for natural gas, light and heavy fuel oil, diesel, and wood waste are provided in Table 1 on page 5.

Boiler efficiencies can vary significantly depending on characteristics such as the age of the steam plant and operation and maintenance practices. Existing steam boilers typically show average efficiencies of 65 to 75 percent, but newer high-efficiency models can achieve 80 per cent or higher. In the calculations below, a conservative boiler efficiency of 65 percent is

²³ Environment Canada (2008), *National Inventory Report 1990-2007*, Tables A9-7 and A9-10, pp. 505 and 508.

²⁴ For the purposes of the estimation, “hard coal” is assumed to be foreign bituminous, “coal gases” to be coke oven gas, and “oil” to be diesel when applying the NIR emission factors to the IEA generation data.

²⁵ The Western Climate Initiative (WCI) is a collaborative initiative of seven U.S. states and three Canadian provinces to develop regional strategies for addressing climate change, including a cap-and-trade GHG emissions trading program to begin in 2012. B.C., Alberta, and Quebec are the Canadian partners. See <http://www.westernclimateinitiative.org>.

²⁶ Statistics Canada (2009), p. 119.

assumed. However, PSOs are free to specify a higher boiler efficiency if they can provide verifiable, documented evidence in support of this efficiency from their steam supplier.

Calculations: The default emission factors in Table 4 are based on a natural gas-fired, oil-fired, or wood waste-fired boiler operating at 65 percent efficiency. They have been calculated by dividing the appropriate combustion emission factors in Table 1 by 0.65. If a PSO can successfully demonstrate a higher boiler efficiency for its steam purchases, then the emission factors will be scaled accordingly.

Table 4: PSO Default Emission Factors – Purchased Steam^a

Steam Production Fuel Source	Energy Conversion Factor (GJ/kg)	Emission Factor (kg/GJ)		
		CO ₂	CH ₄	N ₂ O
Natural Gas	.00275	76.92	0.0015	0.0014
Light Fuel Oil	.00275	108.05	0.0010	0.0012
Heavy Fuel Oil	.00275	113.09	0.0021	0.0023
Diesel Fuel	.00275	106.97	0.0053	0.0161
Wood Waste	.00275	81.20	0.0043	0.0017

^a Based on an assumed 65 percent steam boiler efficiency.

Some steam plants may be dual-fuelled. Typically, this involves boilers that run predominantly on natural gas, with minor amounts of fuel oil or diesel during peak periods. In such cases, the natural gas-fired steam emission factors may be applied to all energy consumption.

Note: Where a PSO produces steam and sells a portion to another PSO, the producer must identify separately the emissions from the steam sales using the methodology above. These emissions will be deducted from the producer's GHG inventory to avoid double counting when aggregating emissions across the B.C. public sector.

2.4 Direct Fugitive Emissions: Stationary Air Conditioning and Refrigeration

[This section is being updated.]

3. Supplies (Paper)

Another source of indirect emissions is the purchase of non-fuel goods and services used by PSOs. At the present time, the only supply item for which GHG emissions are measured is office paper. The intention is to expand the coverage of emissions tracking to include other public sector procurement.

Description: Emission factors for office paper are differentiated on the basis of the percentage of post-consumer recycled (PCR) content in the paper. In practice, the PCR content can range between 10 and 100 percent.²⁷

Three different sizes of office paper are currently specified—8.5" x 11", 8.5" x 14", and 11" x 17". In each case, data on the quantity of 500-sheet packages are entered into SMARTTool.

Data sources: Ideally, it would be best to specify emission factors that accurately reflected the manufacturing process for PSO paper purchases. In the absence of B.C.-specific information, proxy emission factors have been derived from the U.S. Environmental Defense Fund (EDF) Paper Calculator.²⁸ This tool assesses the lifecycle impacts of paper production and disposal and is updated regularly with peer-reviewed data.

The Paper Calculator inputs the paper grade (e.g., copy paper), quantity by weight, and PCR content and estimates the associated GHG emissions in pounds of CO₂e.

Table 5: PSO Emission Factors – Office Paper^a

PCR Content (%)	Emission Factor (kg CO ₂ e/pkg)		
	8.5" x 11"	8.5" x 14"	11" x 17"
0	6.452	8.212	12.905
10	6.213	7.908	12.427
20	5.974	7.603	11.949
30	5.735	7.299	11.471
40	5.257	6.995	10.993
50	5.018	6.691	10.514
60	4.779	6.386	10.036
70	4.660	6.082	9.558
80	4.540	5.778	9.08
90	4.301	5.474	8.602
100	4.062	5.169	8.124

^a Based on a 500-sheet package of 20-pound bond paper weighing 2.27, 2.89, and 4.55 kg, respectively, for the three paper sizes.

Calculations: To generate the emission factors in Table 5, the weight of a 500-sheet package was first determined for each paper size. This weight and the PCR content were then entered into the Paper Calculator and the resulting estimate of GHG emissions was converted from lbs to kg CO₂e.

²⁷ See the Ecopaper Database at <http://www.canopyplanet.org/EPD/index.php> for a listing of papers available in the Canadian marketplace and their PCR contents.

²⁸ See <http://www.papercalculator.org>.

Emission factors for other PCR contents (e.g., 85 percent) can be interpolated by averaging between the values shown.

It should be noted that, unlike the other PSO emission factors documented here, the entries in Table 5 are lifecycle emission factors.²⁹

4. Fleet

The PSO fleet of vehicles and heavy equipment is a further source of GHG emissions. Two categories of fleet-related emissions are tracked:

- Direct emissions from burning fossil fuels in vehicles and equipment; and
- Fugitive emissions from mobile air conditioning systems.

4.1 Direct Emissions: Mobile Fuel Combustion

Description: Emission factors are specified for seven transport modes: light-duty vehicles, light-duty trucks (including SUVs and minivans), heavy-duty vehicles, motorcycles, off-road vehicles and equipment (e.g., snowmobiles, ATVs, lawnmowers and trimmers, tractors, construction equipment), marine, and aviation. Six fuel types have different emission factors associated with them: gasoline, diesel, propane, natural gas, biodiesel, and ethanol.

SMARTTool captures data on fuel consumption in litres by mode of transport and fuel type. Alternatively, it accepts mileage data in kilometres travelled and applies average fuel efficiencies to estimate fuel consumption by mode and fuel. This information is required because the emission factors for CH₄ and N₂O are differentiated by type of vehicle or other transport mode.

Hybrid electric vehicles are not identified separately since their fuel consumption is captured under gasoline cars and trucks. The higher fuel economy of these vehicles relative to conventional gasoline cars and trucks will be reflected in lower overall fuel consumption, and therefore lower GHG emissions, than if the hybrids had not been purchased.

Data sources: Table A12-11 of the 2009 NIR provides emission factors for mobile fuel combustion sources.³⁰ The factors for gasoline and diesel cars and trucks are differentiated by the level of emission control technology, which relates to vehicle age.

For the purposes of estimating PSO emissions, the default emission factors will be “Tier 1” for gasoline-fuelled light cars and trucks, “Three-Way Catalyst” for gasoline heavy trucks, and “Advance Control” for all diesel-fuelled on-road vehicles.³¹ The majority of PSO fleets will be vehicles dating from the mid-1990s, when the introduction of these technologies began in the U.S. For vehicles meeting the EPA’s Tier 2 standards

²⁹ Lifecycle emissions account for all emissions relating to the production, use, and disposal of a product, including the extraction of raw materials, product manufacturing, and intermediate transport steps.

³⁰ Environment Canada (2009), *National Inventory Report 1990-2007*, pp. 592-593.

³¹ The NIR defines light-duty cars and trucks as those with a Gross Vehicle Weight Rating (GVWR) of 3,900 kg or less and heavy trucks as those with a GVWR greater than 3,900 kg. *Ibid.*, p. 281.

Table 6: PSO Emission Factors – Fleet Fuel Consumption^a

Transport Mode	Fuel Type	Units	Emission Factor		
			CO ₂	CH ₄	N ₂ O
Light-duty Vehicle ^a	Gasoline	kg/L	2.289	0.00012	0.00016
	Diesel	kg/L	2.663	0.000051	0.00022
	Propane	kg/L	1.51	0.00064	0.000028
	Natural Gas ^b	kg/kg	2.725	0.013	0.000086
Light-duty Truck (includes SUV and Minivan) ^a	Gasoline	kg/L	2.289	0.00013	0.00025
	Diesel	kg/L	2.663	0.000068	0.00022
	Propane	kg/L	1.51	0.00064	0.000028
	Natural Gas ^b	kg/kg	2.725	0.013	0.000086
Heavy-duty Vehicle ^a	Gasoline	kg/L	2.289	0.000068	0.00020
	Diesel	kg/L	2.663	0.00012	0.000082
Motorcycle	Gasoline	kg/L	2.289	0.0014	0.000045
Off-Road (Vehicle/Equipment)	Gasoline	kg/L	2.289	0.0027	0.00005
	Diesel	kg/L	2.663	0.00015	0.0011
Marine	Gasoline	kg/L	2.289	0.0013	0.000066
	Diesel	kg/L	2.663	0.00015	0.0011
Aviation	Gasoline	kg/L	2.342	0.0022	0.00023
	Turbo Fuel	kg/L	2.534	0.00008	0.00023
Various	Biodiesel ^c	Kg/L	2.449	**	**
	Ethanol ^d	kg/L	1.494	*	*

^a Based on Tier 1 or Advance Control emission control technologies.

^b Adapted from 2009 NIR emission factors converted to kg of compressed natural gas.

^c Gasoline CH₄ and N₂O emission factors (by transport mode) used for biodiesel.

^d Gasoline CH₄ and N₂O emission factors (by transport mode) used for ethanol.

(phased in between 2004 and 2007), the 2009 NIR states that the Tier 1 emission factors should be applied.³² PSOs that are able to identify older vehicles in their fleet can refer to the appropriate emission factors (“Tier 0,” “Non-Catalytic Controlled,” “Moderate Control, respectively) in Table A12-11 of the NIR.

Table A12-11 also contains emission factors for propane and natural gas vehicles, motorcycles (“Non-Catalytic Controlled”), off-road vehicles, gasoline boats, diesel ships, aviation gasoline and turbo fuel, and renewable or biofuels (biodiesel and ethanol). In practice, biofuels are blended with fossil fuels, specifically gasoline or diesel, in varying proportions (e.g., E10, B5, B20), so that

³² *Ibid.*, p. 593.

the actual emission factor is a weighted average of the biofuel and fossil fuel factors. However, since international rules require the separate reporting of biogenic emissions from combustion (see Section 2.1), the CO₂ emissions from the biofuel component must be calculated separately from those of the fossil fuel component. These biofuel CO₂ emissions are then not included in the total direct emissions from mobile combustion.

Calculations: With the exception of natural gas, the only change that has been made to the original NIR emission factors in Table 6 is a conversion from grams to kilograms of fuel consumption. The natural gas emission factor has been converted from kg/L to kg/kg of compressed natural gas—the form in which the fuel is dispensed at the pump. Appendix B outlines how this conversion is done.

4.2 Direct Fugitive Emissions: Mobile Air Conditioning

Description: HFCs are emitted when motor vehicle air conditioning (MVAC) is used. Unlike building HVAC, however, MVAC servicing is not part of the regular service schedule. Moreover, fuel consumption, which is measurable, does not provide insight into MVAC use. Given differences in climate, usage on the coast is likely to be very different from that in the interior.

The Climate Registry offers a “Screening Method” for estimating emissions based on an upper bound capacity charge for MVAC equipment multiplied by an operating emission factor.³³ This method has been used to calculate a default emission factor, in kg of HFCs per vehicle, for use in SMARTTool. In order to apply the default factor, a PSO must provide the number of vehicles in its fleet with MVAC.

Data sources: The Climate Registry recommends an upper bound capacity charge of 1.5 kg and an operating emission factor of 20 percent of capacity per year for mobile air conditioning.³⁴ The most common refrigerant used in MVAC is HFC-134A, with a global warming potential of 1,300.

Calculations: Multiplying the 1.5 kg capacity charge by the 20 percent operating emission factor and converting to CO₂e emissions yields a default emission factor of 390 kg per vehicle. So, for a sample fleet of 1,000 light-duty vehicles, the total HFC-134A emissions would be estimated at 390 tCO₂e annually.

Table 7: PSO Default Emission Factor – HFCs from Mobile Air Conditioning^a

Greenhouse Gas (kg)	Emissions per Vehicle (kg)
Hydrofluorocarbons	390

^a Emissions consist of HFC-134a.

Note: PSOs with information on the MVAC servicing for their fleets (e.g., for transit fleets) may use these data to estimate their HFC emissions directly using the Climate Registry’s “Tier B Method,” or “Simplified Mass Balance Approach.” This method requires information on the quantities of each refrigerant used and recovered from MVAC equipment.

³³ The Climate Registry (2008), *General Reporting Protocol*, pp. 128-132.

³⁴ *Ibid.*, Table 16.3, p. 130.

5. Business Travel

[This section is being updated.]

6. Sample Calculation

Table 9 provides a sample application of an emission factor to calculate GHG emissions, based on 100 litres of propane consumption in buildings.³⁵

Table 8: Sample Emissions Calculation

Step	Formula	Calculation	Result	
1. Convert the quantity of consumption activity to a common unit of measurement	Fuel consumption (GJ) = fuel consumption (L) * energy conversion factor (GJ/L)	100 L x 0.02531 GJ/L	2.5 GJ	
2. Calculate the emissions of each GHG using the appropriate emission factor	GHG emissions (kg) = fuel consumption (GJ) * emission factor (kg/GJ)	CO ₂	2.5 GJ x 59.66 kg/GJ	149.2 kg
		CH ₄	2.5 GJ x 0.0009 kg/GJ	0.0022 kg
		N ₂ O	2.5 GJ x 0.0043 kg/GJ	0.0108 kg
3. Convert the emissions of each greenhouse gas to CO ₂ equivalency using the appropriate Global Warming Potential	GHG emissions (kg CO ₂ e) = GHG emissions (kg) * GWP	CO ₂	149.2 kg * 1	149.2 kg CO ₂ e
		CH ₄	0.0022 kg * 21	0.0462 kg CO ₂ e
		N ₂ O	0.0108 kg * 310	3.348 kg CO ₂ e
4. Sum across the gases to calculate total CO ₂ e emissions	Total GHG emissions (kg CO ₂ e) = CO ₂ + CH ₄ + N ₂ O (all in kg CO ₂ e)	149.2 kg + 0.0462 kg + 3.348 kg	152.6 kg CO ₂ e	
5. Convert total emissions from kg to tonnes for reporting purposes	Total GHG emissions (tCO ₂ e) = total emissions (kg)/1,000 (kg/t)	152.6 kg/1,000 kg/t	0.153 tCO ₂ e	

³⁵ Other examples of emission calculations are provided on the SMARTTool website at <https://www.whereregideaswork.gov.bc.ca>.

Appendix A: Global Warming Potentials

The following table presents the 100-year Global Warming Potentials for the GHGs being tracked by the B.C. public sector. These GWPs are listed in the Carbon Neutral Government Regulation and are the 1995 values from the IPCC's *Second Assessment Report*, as endorsed by Environment Canada.³⁶

Table A1: Global Warming Potentials

Greenhouse Gas	Chemical Formula	100-Year GWP
Carbon dioxide	CO ₂	1
Methane	CH ₄	21
Nitrous oxide	N ₂ O	310
HFC-23	CHF ₃	11 700
HFC-32	CH ₂ F ₂	650
HFC-41	CH ₃ F	150
HFC-43-10mee	C ₅ H ₂ F ₁₀	1 300
HFC-125	C ₂ HF ₅	2 800
HFC-134	C ₂ H ₂ F ₄ (CHF ₂ CHF ₂)	1 000
HFC-134a	C ₂ H ₂ F ₄ (CH ₂ FCF ₃)	1 300
HFC-152a	C ₂ H ₄ F ₂ (CH ₃ CHF ₂)	140
HFC-143	C ₂ H ₃ F ₃ (CHF ₂ CH ₂ F)	300
HFC-143a	C ₂ H ₃ F ₃ (CF ₃ CH ₃)	3 800
HFC-227ea	C ₃ HF ₇	2 900
HFC-236fa	C ₃ H ₂ F ₆	6 300
HFC-245ca	C ₃ H ₃ F ₅	560
Sulphur hexafluoride	SF ₆	23 900

³⁶ Environment Canada (2009), *National Inventory Report 1990-2007*, pp. 22-23.

Appendix B: Natural Gas Vehicle Emission Factors

Light-duty natural gas vehicles are fuelled with compressed natural gas (CNG), which is measured in kilograms. Canada's *National Inventory Report* provides emission factors for the mobile combustion of natural gas in grams per litre (g/L).³⁷ As a result, these factors do not align with the common unit for CNG measurement at the pump.

SMARTTool specifies emission factors in kg of emissions per unit of consumption—also kg in the case of CNG. Table B1 shows the calculations that have been performed to convert the 2009 NIR emission factors to the format used by SMARTTool. In particular, this involves adjusting for the density of natural gas in its gaseous state at standard temperature and pressure (STP).³⁸

Table B1: Natural Gas Vehicle Emission Factor Calculations

Step	Units	CO ₂	CH ₄	N ₂ O
1. Obtain natural gas emission factors from the 2009 NIR	g/L	1.89	0.009	0.00006
2. Convert to g/m ³ by multiplying by 1,000 (L/m ³)	g/m ³	1,890	9	0.06
3. Convert to g/kg by dividing by 0.6937 (density of natural gas at STP in kg/m ³)	g/kg	2,724.5	13.0	0.086
4. Convert to kg/kg by dividing by 1,000 (g/kg)	kg/kg	2.725	0.013	0.000086

³⁷ Environment Canada (2009), *National Inventory Report 1990-2007*, p. 592. These emission factors relate to natural gas in its gaseous state as it flows through a pipeline, prior to compression.

³⁸ The natural gas density of 0.6937 kg/m³ at STP is based on 2006 information from Terasen Gas on the chemical composition of natural gas flowing through B.C. pipelines.

Glossary of Terms and Acronyms³⁹

ARES: Accommodation and Real Estate Division (Ministry of Labour and Citizens' Services)

Carbon dioxide (CO₂): The most common greenhouse gas released by human activities. It is produced from decaying materials, respiration of plant and animal life, and combustion of organic materials and fossil fuels.

Carbon-equivalent (CO₂e): The universal unit of measurement to indicate the global warming potential of each greenhouse gas, expressed in terms of the GWP of one unit of CO₂. It is used to evaluate emissions of different greenhouse gases on a common basis.

CNG: Compressed Natural Gas

Direct emissions: Emissions from sources that are owned or controlled by the reporting organization (i.e., PSO).

EDF: Environmental Defense Fund, a US-based environmental organization

Emission factor: A factor allowing GHG emissions to be estimated from a unit of available activity data (e.g. litres of fuel consumed, tonnes of product produced) and absolute GHG emissions.

Emissions: The release of greenhouse gases into the atmosphere.

Energy conversion factor: A factor used to convert a quantity of energy from its original physical unit into a common unit of measurement (e.g., GJ).

EPA: US Environmental Protection Agency

Fugitive emissions: The unintended or incidental emissions of greenhouse gases from the transmission, processing, storage, use, or transportation of fossil fuels, GHGs, other substances, including but not limited to HFC emissions from refrigeration leaks and SF₆ from electric power distribution equipment.

Gigajoule (GJ): One billion joules, where a joule is a common unit of energy for comparing across fuel types and electricity.

Gigawatt-hour (GWh): One million kilowatt-hours, enough electricity to power 100 homes for a year.

Global Warming Potential (GWP): A factor describing the radiative forcing impact (ability to trap heat in the atmosphere) of one unit of a given greenhouse gas relative to one unit of CO₂.

Global Reporting Initiative (GRI): An international initiative that has developed a sustainability reporting framework for organizations to measure and report on their economic, environmental, and social performance (see <http://www.globalreporting.org>).

Greenhouse gases (GHGs): A wide variety of gases that trap heat near the Earth's surface, preventing its escape into space. For public sector reporting purposes, the relevant gases are

³⁹ Definitions derived from: World Business Council for Sustainable Development and World Resources Institute (2004), *The Greenhouse Gas Protocol*, pp. 96-102; and The Climate Registry (2008), *General Reporting Protocol*, pp. 153-158.

carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), sulphur hexafluoride (SF₆), perfluorocarbons (PFCs), and hydrofluorocarbons (HFCs).

HVAC: Heating, Ventilating, and Air Conditioning

Hydrofluorocarbons (HFCs): A group of synthetic chemicals with various commercial uses (e.g., refrigerants) composed of one or two carbon atoms and varying numbers of hydrogen and fluorine atoms. Most HFCs are highly potent GHGs with GWPs in the thousands.

ICBC: Insurance Corporation of British Columbia

Indirect emissions: Emissions that are a consequence of the operations of the reporting organization (i.e., PSO), but occur at sources owned or controlled by another organization.

Intergovernmental Panel on Climate Change (IPCC): A body of scientists established by the World Meteorological Organization and the United Nations Environment Programme to provide objective scientific advice for informing policy decisions on climate change (see www.ipcc.org).

Inventory: A comprehensive, quantified list of an organization's GHG emissions and sources.

IPP: Independent Power Producer

kg: kilogram

kilotonne: 1,000 tonnes

kWh: kilowatt-hour

L: Litre

m³: cubic metres

Methane (CH₄): A GHG produced from the anaerobic decomposition (i.e., without oxygen) of organic matter, or as a by-product of incomplete combustion of a fossil fuel. Primary sources include fossil fuel extraction and combustion, wetlands, rice paddies, animal digestive processes, and decaying garbage.

MVAC: Motor Vehicle Air Conditioning

NIR: National Inventory Report (Environment Canada)

Nitrous oxide (N₂O): A GHG produced naturally from soil and oceans. Human activities contributing to N₂O emissions include soil cultivation, the use of nitrogen fertilizers, and the burning of organic material and fossil fuels.

Perfluorocarbons (PFCs): Synthetic industrial gases generated as a by-product of aluminum smelting and uranium enrichment. PFCs are also used as substitutes for ozone-depleting chlorofluorocarbons (CFCs) in the manufacture of semiconductors.

PSO: A B.C. public sector organization subject to the government's carbon neutral commitment under the *Greenhouse Gas Reduction Targets Act*.

RES.D. Report on Energy Supply and Demand (Statistics Canada)

STP: Standard Temperature and Pressure

Sulphur Hexafluoride (SF₆): A synthetic industrial gas used mainly as an insulating and protective gas in electrical transmission equipment and as a dielectric in electronics.

t: metric tonne, a standard measurement for the mass of GHG emissions, equivalent to 1,000 kg, 1,204.6 pounds, or 1.1 short tons.

WSI: Workplace Solutions Inc.

Selected References

- BC Hydro. 2007. *BC Hydro's Annual Report 2007: Reporting on our Triple Bottom Line Performance*. Available at: <http://www.bchydro.com/info/reports/reports853.html>.
- Climate Action Secretariat. 2008. *Draft Framework for Greenhouse Gas Measurement and Reporting*. Prepared by the Climate Neutral Working Group.
- Climate Registry, The. 2008. *General Reporting Protocol*. Version 1.1. Available at: <http://www.theclimateregistry.org/resources/protocols>.
- Environment Canada. 2009. *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada 1990-2007*. Submission to the United Nations Framework Convention on Climate Change.
- Intergovernmental Panel on Climate Change. 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Volume 5. Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T., and Tanabe K. (eds). Available at: <http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html>.
- International Energy Agency. 2008. *Electricity Information 2008*.
- Statistics Canada. 2009. *Report on Energy Supply and Demand in Canada 2007*. Catalogue No. 57-003-X. Available at: <http://www.statcan.ca/bsolc/english/bsolc?catno=57-003-X&CHROPG=1>.
- US Environmental Protection Agency. 2009. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007*. Available at: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.
- World Business Council for Sustainable Development and World Resources Institute. 2004. *The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard*. Revised edition. Available at: <http://www.ghgprotocol.org/templates/GHG5/layout.asp?MenuID=849>.