2018 B.C. METHODOLOGICAL GUIDANCE FOR QUANTIFYING GREENHOUSE GAS EMISSIONS

FOR PUBLIC SECTOR ORGANIZATIONS, LOCAL GOVERNMENTS AND COMMUNITY EMISSIONS

BRITISH COLUMBIA
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1. Introduction

This document sets out the current best practices for quantifying and reporting greenhouse gas emissions from B.C.'s provincial public sector organizations, local governments and communities. B.C.'s best practices represent a robust and continually improving catalogue of emissions factors and emissions calculation methodologies that have drawn heavily on protocols established by the World Resources Institute and the Climate Registry, and published emission factors from authoritative sources such as: Natural Resources Canada, Environment Canada, the US Environmental Protection Agency and the UK Department of Environment, Food and Rural Affairs. This document also represents the consolidation of the previously stand-alone versions of Public Sector, Local Government and Community Energy and Emissions Inventory emissions methodology guides. It can be used by anyone using these other documents, or other groups who wish to calculate their organization's corporate emissions. (Please note that the private sector entities subject to the B.C. Greenhouse Gas Inventory Report and Greenhouse Gas Emission Reporting Regulation must utilize quantification methods prescribed by the Regulation.)

Measuring greenhouse gas emissions is an important first step in improving the management of those emissions, and the activities/operations responsible for producing them. Whether or not an organization plans to become carbon neutral, measuring and managing emissions can result in cost savings, increased organizational efficiencies and better asset management.

This document provides a basis for measuring emissions that will allow any organization that is required to or wishes to voluntarily measure their greenhouse gas emissions a way to do so that is consistent with up-to-date best practices and provides comparable emissions reporting province-wide.

This document applies to BC public sector emission measurement and reporting for the 2018 reporting year.

1.1 Principles for Specifying Emission Factors

The following principles have guided the development of the greenhouse gas emissions (GHG) emission factors and estimation methods found in this document:

1) If information allows, the preference is to identify emission factors that best reflect individual 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 to improve the accuracy of 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 National GHG Inventory Report (NIR),[1] and other recognized sources (see Section 1.3).

3) A key principle is to facilitate emissions tracking and ensure that measurement and reporting requirements are not overly burdensome or costly. Therefore, in certain cases

[1] Environment Canada. (2016). *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada 1990-2014. The Canadian Government's* Submission to the United Nations Framework Convention on Climate Change.

(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) In developing simplified estimation methods, upper bound assumptions will be used in accordance with the principle of conservativeness – erring on the side of overestimating rather than underestimating emissions.

1.2 GHG Emission Factors Defined

Emission factors are expressed in kilograms (kg) or metric tonnes (t) 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 (CO_2); methane (CH_4); nitrous oxide (N_2O); hydrofluorocarbons (HFCs); sulphur hexafluoride (SF_6); and perfluorocarbons (PFCs). For most organizations, the primary GHGs emitted in significant amounts are the three principal gases associated with fuel combustion for energy (CO_2, CH_4 and N_2O) and, to a much lesser extent, HFCs released from refrigeration and air conditioning equipment.[2]

In the case of liquid fossil fuel blends with biofuel (e.g., ethanol, biodiesel), gasoline or diesel are combined with varying proportions of biofuels (e.g., E10, B5, B20), resulting in emission factors that are weighted averages of the biofuel and fossil fuel factors. However, since international protocols require the separate reporting of biogenic emissions from combustion (see Section 2.1); the CO_2 emissions from the biofuel component (Bio CO_2) must be calculated and reported separately from those of the fossil fuel component.

Wherever possible, emission factors are specified by individual gas. In certain instances, an aggregate factor for multiple gases is provided in kg or t of CO_2 equivalent (CO_2e) emissions. CO_2e is the standard unit for measuring and comparing emissions across GHGs of varying potency in the atmosphere (see Section 1.3).

1.3 Global Warming Potentials and Emissions Calculations

Greenhouse gases vary in their ability to trap heat in the atmosphere (radiative forcing) [3]. "Global warming potential" (GWP) is a measure of this ability. The GWP of a greenhouse gas 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 GWP for each GHG is expressed as the ratio of its heat trapping ability relative to that for CO_2. Updates to British Columbia's GWPs were made in line with updates by the United Nations Framework Convention on Climate Change and the Canadian Federal Government to GWPs approved by the Intergovernmental Panel on Climate Change's (IPCC's) 4th Assessment Report.

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[2] In British Columbia, PFCs and SF_6 are produced primarily in aluminum and magnesium smelting/processing and semi-conductor manufacturing. SF_6 is also used as a cover gas in electricity transmission equipment.

[3] 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).

By definition, the GWP of CO_2 equals one. Methane or CH_4 has a GWP of 25, indicating that its radiative forcing is 25 times that of CO_2. In other words, releasing one tonne of CH_4 will have the same warming impact as releasing 25 tonnes of CO_2. This impact is often expressed using the concept of carbon dioxide equivalent, or CO_2e: that is, one tonne of CH_4 can also be expressed as 25 tonnes of CO_2e. See Annex 2 for a complete list of GWPs for all gases covered by the *Climate Change Accountability Act* (CCAA) (formerly the *Greenhouse Gas Reductions Targets Act* (*GGRTA)).*

GWPs are particularly important within the context of emissions reporting since international protocols require the reporting of both individual GHGs and their carbon dioxide equivalents (CO_2e). For this reason, the calculation of GHG emissions generally involves (1) multiplying the emission factor for a GHG by an appropriate measure of consumption (activity) to produce the corresponding emissions for that GHG and then (2) multiplying those emissions by its GWP to produce the corresponding CO_2e emissions.

The primary source document for emission factors is the *British Columbia Greenhouse Gas Inventory Report 2012* (PIR).[4] Where provincial data is not available, the factors from Environment Canada's *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada 1990-2014*, released in 2016*,* have been used.[5, 6]

International documents, such as the Climate Registry's *General Reporting Protocol*,[7] have been used for some emission factors. B.C.-specific emission factors have been developed in other cases, using data provided by B.C. energy companies and business travel providers.

The emission factors reported in this document represent the B.C. government's understanding of the factors appropriate for emission sources and fuel types in 2018. As experience is gained with estimating GHG emissions, 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.

1.4 Users/Audience

1.4.1 Public Sector Organizations

In November 2007, British Columbia enacted legislation to establish provincial goals for reducing greenhouse gas (GHG) emissions. Under the *Climate Change Accountability Act (CCAA)*, the B.C. public sector must be carbon neutral in its operations for 2010 and every year thereafter.[8] Beginning

[4] British Columbia (2015). *British Columbia Greenhouse Gas Inventory Report 2012.* Annex 10.3 provides standardized factors for stationary and mobile fuel consumption and other emitting activities.
[5] Environment Canada (2016). *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada 1990-2014*.
[6] The PIR factors match most of those found in the NIR, however, for simplicity and ease of use, the PIR factors will be referenced throughout this document where the data is available in both documents.
[7] The Climate Registry (2015). *General Reporting Protocol*, Version 2.1 & 2016 Climate Registry Default Emission Factors. 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: www.theclimateregistry.org.
[8] See http://www.bclaws.ca/civix/document/id/complete/statreg/07042_01, for the *Climate Change Accountability Act*, Bill 44 – 2007 and the *Carbon Neutral Government Regulation,* B.C. Reg. 392/2008. The legislation also requires core 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 12.

for the 2008 calendar year, provincial public sector organizations (PSOs)[9] were required to report annually, in accordance with the *CCAA* and the *Carbon Neutral Government Regulation (CNGR)*.

The *CNGR* defines the activities or emission sources that are "in scope" for the purposes of PSO emission reporting and offsetting. Since it was introduced in 2008, "in scope" activities/sources have been clarified through a series of policy decisions which have been summarized in the Scope Summary Document which is available at the following **link**.

The emissions factors and emissions calculation methodologies described in this document have been integrated into SMARTTool, the online toolset currently provided by the BC government to support PSO and LG GHG measurement and reporting requirements Centralized provision of the toolset facilitates consistent reporting across all organizations, capacity to quickly implement updates and relieves them of the need to develop in-house GHG accounting expertise.

The following sections of this document apply directly to PSOs for their in-scope activities:

- Section 2: Direct/Indirect Emissions: Stationary Sources: Buildings, etc.
- Section 3: Transportation
- Section 4: Indirect Emissions: Business Travel (Provincial government only)[10]
- Section 6: Indirect Emissions: Office Paper

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

1.4.2 Local Governments

The majority of local governments in B.C. have voluntarily signed the Climate Action Charter (CAC) committing to develop strategies and take actions to achieve the following goals:

- being carbon neutral in respect of their operations by 2012;[11]
- measuring and reporting on their community's GHG emissions profile; and
- creating complete, compact, more energy efficient rural and urban communities

Under the Climate Action Charter the joint Provincial Government – Union of British Columbia Municipalities (UBCM) Green Communities Committee (GCC) was created to support local governments in planning and implementing climate change initiatives. The Carbon Neutral Working Group (the working group) was established to advise the GCC in carrying out this mandate with respect to corporate carbon neutrality. The GCC and the working group collaborated to produce the Carbon Neutral Workbook (the Workbook), which provides guidance to local governments on what is in scope to measure and offset within the boundaries of their corporate emissions. The

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[9] PSOs encompass Provincial government entities funded through the Consolidated Revenue Fund (e.g., ministries, special offices, and tribunals) and broader public sector agencies including health authorities, school districts, colleges and universities, and Crown corporations under the Government Reporting Entity.

[10] Under the Carbon Neutral public Sector commitment, only Provincial government organizations that report through the Consolidated Revenue Fund (e.g., ministries, special offices, tribunals) are required to track the emissions from business travel.

[11] Solid waste facilities regulated under *the Environmental Management Act* are not included in operations for the purposes of this Charter.

boundaries for calculating emissions are based on the energy used in the delivery of traditional local government services:[12]

- Administration and Governance;
- Drinking, Storm and Waste Water;
- Solid Waste Collection, Transportation and Diversion;
- Roads and Traffic Operations;
- Arts, Recreational and Cultural Services; and
- Fire Protection.

Local governments may choose to use SMARTTool, but the GCC also supports the use of other GHG measurement tools for the purposes of the Climate Action Charter. To ensure methodology, emission factors and outputs from other tools are consistent and comparable with SMARTTool results, a local government choosing to use another inventory and reporting tool will be required to meet the following standards:

1. Use the same corporate boundaries as defined in the Workbook;
2. Use the GHG measurement methods and emission factors in this guide, and updates as provided by the Climate Action Secretariat
3. Complete and adhere to the Business Processes Checklist
4. Report on annual total corporate emissions and offsets as calculated by a GHG inventory tool (via an Energy Consumption Summary Reporting Template**)**; and
5. Obtain Chief Administrative Officer (CAO)/ Chief Financial Officer (CFO) attestation that all of the above listed actions were taken (via the *Self Certified Business Process Checklist)*.

Access to SMARTTool can be provided to interested local governments. Contact Carbon.Neutral@gov.bc.ca for details.

All of the supporting materials for these standards are available on the Climate Action Toolkit website at: http://www.toolkit.bc.ca/resource/becoming-carbon-neutral-workbook-and-guidebook

By understanding and applying the information contained in this methodology document and completing the *Self Certified Business Process Checklist for SMARTTool/Alternative Tool* available at www.toolkit.bc.ca, local governments can be assured that their GHG emissions inventory are accurate and consistent with those being developed by local governments across British Columbia.

The following sections of this document apply directly to LGs for their in-scope activities:

- Section 2: Direct/Indirect Emissions: Stationary Sources: Building, etc.
- Section 3: Transportation
- Section 8: Sample Calculation
- Annex – Glossary of Terms, Global Warming Potentials, Building Energy Estimation Methods, etc.

[12] Within the traditional service sectors not all emissions will be captured. Any emissions related to the operation and maintenance of traditional services are included. Emissions related to new construction, business travel, employee commuting and materials are not included.

For each activity category, a brief description is given along with an explanation of data sources and emission factor calculations. Note emissions from office paper and business travel are **not** in scope for local governments.

1.4.3 Other Users (Communities/Academics/Consultants/etc.)

Other potential users of this document include the broad community of users of the Community Energy and Emissions Inventory (CEEI) reports, energy and emissions modelling and planning consultants, energy utilities, academic researchers and non-governmental organizations. It is also worth noting that the CEEI is gaining increasing exposure outside of B.C. as international audiences begin to recognize the leading-edge work that is occurring.

Typically the CEEI reports are released along with a Technical Methods and Guidance Document that details the process by which the greenhouse gas emissions estimates in the CEEI reports are produced. Using common emission factors and referring to this document in the specific guidance material for the CEEI program will ensure comparability across the different programs referenced above.

2. Direct/Indirect Emissions: Stationary Sources: Buildings, etc.

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.[13]

2.1 Direct Emissions: Stationary Fuel Combustion

Description: A variety of fossil fuels may be combusted to produce heat and power including: natural gas, propane, light fuel oil (No. 2 heating oil), heavy fuel oil (No. 5 heating oil), kerosene, marine diesel, diesel fuel, and gasoline. In addition to fossil fuels, wood fuel and wood waste may also be combusted to produce heat. For the purposes of emissions reporting in alignment with international protocols, biogenic emissions ($BioCO_2$) from biomass combustion, including wood, wood waste, ethanol, biodiesel and renewable natural gas must be reported.[14]

For biomass combustion, $BioCO_2$ emissions must be reported separately from CH_4 and N_2O emissions[15] but PSOs are only required to offset the CH_4 and N_2O emissions from biomass combustion. Any organization considering biomass should be aware that there are ongoing international discussions around the proper treatment of biomass and how to best account for the $BioCO_2$ storage and emissions of different harvested wood products (e.g. waste wood vs. virgin wood) and the associated forest management practices occurring on the land base. The impacts of future accounting changes can be minimized to the extent that biomass is diverted from waste streams and that non-waste biomass comes from sustainably managed forest lands.

In SMARTTool, stationary fuel consumption data are entered either in common units of energy usage (e.g., Gigajoules – GJ, kilowatt hours - kWh) or are converted to GJ within the application itself.

Data sources: The standardized emission factors for stationary fuel combustion are drawn from two sources; Table 20 of the 2012 PIR,[16] and the 1990-2014 NIR as follows.[17]

- The natural gas CO_2 emission factor is taken from Table A6-1 (NIR) under the entry "British Columbia – Marketable".
- The natural gas CH_4 and N_2O emission factors are taken from Table A6-2 (NIR) under "Residential, Construction, Commercial/Institutional, Agriculture".

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[13] See http://www.bclaws.ca/Recon/document/ID/freeside/392_2008 for the *Carbon Neutral Government Regulation,* B.C. Reg. 392/2008.

[14] TheCO_2 released *to* the atmosphere during combustion of biomass is assumed to be the same quantity that had been absorbed *from* the atmosphere during plant growth. Because CO_2 absorption from plant growth and the emissions from combustion occur within a relatively short timeframe of one another (typically 100-200 years), there is no long-term change in atmospheric CO_2 levels. For this reason, biomass is often considered "carbon-neutral" and the Intergovernmental Panel on Climate Change (IPCC) *Guidelines for National Greenhouse Gas Inventories* specifies the separate reporting of CO_2 emissions from biomass combustion. See: IPCC (2006), *2006 IPCC Guidelines for National Greenhouse Gas Inventories,* p. 5.5; and the Climate Registry (2013), *General Reporting Protocol Version 2.0*, p. 36.

[15] Based on current international standards, British Columbia already reports the CH_4 and N_2O portions of biomass combustion as line items in the Provincial Inventory Report. $BioCO_2$ biomass emissions are currently reported as memo items.

[16] British Columbia (2015). *British Columbia Greenhouse Gas Inventory Report 2012*, pp. 62-63.

[17] Environment Canada (2016). *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada 1990-2014,* Annex 6

- The propane emission factors are taken from Table A6-3 (NIR) under the entries for "All Other Uses".
- The light fuel oil, heavy fuel oil, kerosene and diesel emissions factors are taken from Table A6-4 (NIR) (with light fuel oil, heavy fuel oil and kerosene falling under "Forestry, Construction, Public Administration and Commercial/Institutional" and diesel falling under "Refineries and Others")
- The gasoline and marine diesel emissions factors are taken from Table A6-12 (NIR) under the respective entries for "Off-Road Gasoline" and "Diesel Ships".
- The wood emissions factors are taken from Table A6-32 (NIR) under the entries for "Wood Fuel/Wood Waste Industrial Combustion" and "Conventional Stoves Residential Combustion".

Energy conversion factors to convert to GJ from cubic metres of natural gas and litres of liquid fuels are drawn from Statistics Canada's *Report on Energy Supply and Demand in Canada* (RESD).[18]

Calculations: In B.C., the *Renewable and Low Carbon Fuel Requirements Regulation* (*RLCFRR*)[19] sets the requirements for the amount of renewable fuel in the province's transportation and heating fuel blends. Effective January 1st, 2011, fuel suppliers were required to incorporate 5% renewable fuel content for gasoline and 4% for diesel. In SMARTTool, for any given volume of reported gasoline consumption, 95% of the fuel is deemed to be fossil fuel gasoline and the remaining 5%, ethanol. For diesel, 96% is fossil fuel diesel and 4%, biodiesel.

Additionally, FORTIS has launched a renewable natural gas product for customers in the Lower Mainland, Fraser Valley, Interior and the Kootenays. Eligible customers have the option of purchasing a portion of their natural gas usage as renewable natural gas by paying the higher commodity cost. FORTIS purchases biogas, upgrades it, injects it into its distribution network and allocates it to customers according to the amount they purchased. Please contact Carbon.Neutral@gov.bc.ca for assistance with loading RNG into SMARTTool.
Note that if an organization captures their own biogas for stationary combustion, they should calculate the percentage of pure methane in the biogas and then apply the renewable natural gas emissions factors accordingly.

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18 Statistics Canada (2015). *Report on Energy Supply and Demand in Canada 2013*, p. 123.
19 See http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/394_2008 for the *Renewable and Low Carbon Fuel Requirements Regulation,* B.C. Reg. 394/2008.

The emission factors in columns (3) to (7) of Table 1 have been calculated by applying the energy conversion factors from column (2) of Table 1 to the emission factors from Table 2.

Table 1: EMISSION FACTORS: Stationary Fuel Combustion (GJ)

(1) Fuel Type	(2) Energy Conversion Factor	Emission Factor (kg/ GJ)				
		(3) Bio CO_2	(4) CO_2	(5) CH_4	(6) N_2O	(7)[c] CO_2e
Natural Gas	0.03885 GJ/ m^3	–	49.58	0.0010	0.0009	49.87
Propane	0.02531 GJ/ L	–	59.86	0.0009	0.0043	61.15
Light Fuel Oil	0.03880 GJ/ L	2.77	68.12	0.0007	0.0008	68.37
Heavy Fuel Oil	0.04250 GJ/L	–	74.26	0.0013	0.0015	74.74
Kerosene	0.03768 GJ/ L	–	67.94	0.0007	0.0008	68.20
Diesel Fuel	0.03830 GJ/ L	2.77	67.43	0.0035	0.0104	70.62
Marine Diesel	0.03830 GJ/L	2.77	67.43	0.0065	0.0019	68.16
Gasoline	0.03500 GJ/ L	3.22	62.86	0.0771	0.0014	65.22
Wood Fuel – Industrial (50% moisture)	0.00900 GJ/ kg	93.33	–	0.0100	0.0067	2.24
Wood Fuel – Residential (0% moisture)	0.01800 GJ/ kg	82.11	–	.6833	.0067	19.07
Ethanol (E100)	0.02342 GJ/L	64.43	–	a	a	a
Biodiesel (B100)	0.03567 GJ/L	69.36	–	b	b	b
Renewable Natural Gas	0.03885 GJ/ m^3	49.58	–	0.0010	0.0009	0.29

[a] Gasoline CH4 and N2O emission factors (by mode and technology) are used for ethanol.
[b] Diesel CH4 and N2O emission factors (by mode and technology) are used for biodiesel.
[c] The CO_2e values in column (7) exclude Bio CO_2

Table 2: EMISSION FACTORS: Stationary Fuel Combustion[20] (common UOMs)

(1) Fuel Type	(2) Unit of Measure(UOM)	(3) Bio CO_2	(4) CO_2	(5) CH_4	(6) N_2O	(7) CO_2e
Natural Gas	kg/ m³	–	1.926	0.000037	0.000035	1.937
Propane	kg/ L	–	1.515	0.000024	0.000108	1.548
Light Fuel Oil	kg/ L	0.0990	2.643	0.000026	0.000031	2.653
Heavy Fuel Oil	kg/ L	–	3.156	0.000057	0.000064	3.176
Kerosene	kg/ L	–	2.560	0.000026	0.000031	2.570
Diesel Fuel	kg/ L	0.0990	2.582	0.000133	0.0004	2.705
Marine Diesel	kg/L	0.0990	2.582	0.00025	0.000073	2.610
Gasoline	kg/ L	0.0755	2.200	0.0027	0.00005	2.283
Wood Fuel – Industrial (50% moisture)	kg/ kg	0.840	–	0.00009	0.00006	0.020
Wood Fuel – Residential (0% moisture)	kg/ kg	1.478	–	0.0123	0.00012	0.343
Ethanol (E100)	kg/L	1.509	–	a	a	a
Biodiesel (B100)	kg/L	2.474	–	b	b	b
Renewable Natural Gas	kg/m³	1.926	–	0.000037	0.000035	0.011

[a] Gasoline CH4 and N2O emission factors (by mode and technology) are used for ethanol.
[b] Diesel CH4 and N2O emission factors (by mode and technology) are used for biodiesel.
[c] The CO_2e values in column (7) exclude Bio CO_2

2.2 Indirect Emissions: Purchased Electricity

Description: In a hydroelectric-based power system such as British Columbia's, the GHG emissions from electricity generation can vary significantly from year to year. This variation is influenced by both the quantity purchased by consumers and the variation in water supply conditions and reservoir levels. During years with low stream flows and/or low reservoir levels, hydro power must be supplemented through fossil-fuel (thermally) generated electricity purchased from neighbouring jurisdictions and/or through increased use of B.C. thermal generation facilities, leading to higher provincial GHG emissions. During years with higher stream flows and/or high reservoir levels, less thermal power is needed and GHG emissions are relatively lower.

Emissions also differ among B.C.'s electric utilities with each having different ratios of hydro to thermal power in their supply mixes. Depending on their building locations, consuming organizations may acquire electricity from BC Hydro, FortisBC or a municipal distributor.[21] In addition, some organizations currently have properties in other provinces (e.g. Alberta and Ontario) and countries (e.g. England, Japan and China).

[20] See Environment Canada (2016). *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada 1990-2014* and British Columbia (2014). *British Columbia Greenhouse Gas Inventory Report 2012*.
[21] There are seven municipal electric utilities, respectively serving Grand Forks, Kelowna, Nelson, New Westminster, Hemlock Valley, Penticton and Summerland.

Some organizations purchase Renewable Energy Certificates (REC's), Green Rights or Green Power from Green Power suppliers. In the case of PSOs, emissions reduced by purchasing RECs are only recognized in jurisdictions where 50% or more of the power is produced from fossil fuel generators and where it has been demonstrated there is a reasonable level of assurance that the REC's are appropriately verified.

Data sources: BC Hydro's website reports the GHG intensity of the electricity it generates along with that of B.C.'s independent power producers.[22] However, the emissions associated with electricity imports for in-province consumption have not been reflected in electricity emission factors published in the guide to date.[23] The incorporation of imports is currently under consideration.

Taken from the BC Hydro website, the emission factor reported in Table 3 below represents the sum of emissions from BC Hydro generating facilities and independent power producers, divided by the net electricity generated at those facilities.[24]

While FortisBC and the municipal distributors do not publicly report GHG emissions, their emissions can be estimated from electricity supply data. Information on the supply mix is obtained directly from utility contacts on an annual basis.

Emissions from PSO buildings located in provinces other than British Columbia must be measured and reported using emission factors for those provinces. Those emission factors are drawn from the current version of the NIR.

For PSO buildings located in other countries, emission factors are based on data from the International Energy Agency (IEA) for CO_2 emissions per kWh from electricity and heat generation.[25] The published three year rolling averages (2012-2014) for individual countries were incorporated into this report. These data can be used to estimate emission factors for fossil fuel combustion in international cities.

Calculations: In Table 3 below, the BC Hydro emission factor is based on the reported GHG Intensity for the utility's total domestic supply. The emission factor of 10.67 tonnes CO_2e per Gigawatt-hour (GWh) has been calculated as an average of BC Hydro's GHG intensities for 2013 through 2015.[26] A rolling three-year average is used to partially smooth out the annual fluctuation in the electricity emission factor due to changing water conditions and accompanying reliance levels on thermal generation.[27]

The FortisBC emission factor of 2.587 tCO_2e/GWh has been estimated using a weighted average of the GHG intensity of Fortis' own hydroelectric plants, other renewable electricity, and purchases from BC Hydro. In calculating this average, an emission factor of zero was assigned to existing

[22] See http://www.bchydro.com/about/sustainability/climate_action/greenhouse_gases.html

[23] Since 2011, BC Hydro's wholly-owned subsidiary Powerex has reported GHG emissions associated with gross imported electricity, as required under B.C.'s Reporting Regulation.

[24] See https://www.bchydro.com/about/sustainability/climate_action/greenhouse_gases.html

[25] See http://www.iea.org/

[26] The reported GHG intensities were 12, 11 and 9 tCO_2e/GWh, respectively, for 2013, 2014 and 2015.

[27] 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., 2014) may not necessarily reflect the water conditions in the current years for which emissions are being measured (e.g., 2016/17). Averaging over a three-year period will reduce the year-to-year differences.

hydro and other renewable (energy from wood waste) generation and purchases, which accounted for just over three-quarters of the utility's 2009 supply.[28] The BC Hydro emission factor was then applied to the remaining purchases in the supply mix to reach the final emission factor.

Since the cities of Grand Forks, Kelowna, Penticton, and Kelowna acquire all of their electricity from FortisBC, they are assigned the FortisBC emission factor. The City of New Westminster and town of Hemlock Valley redistribute BC Hydro electricity are therefore 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.[29] These supply shares and the Fortis emission factor have been used to estimate a weighted average emission factor of 1.164 tCO_2e/GWh.

The electricity emissions factors for Alberta, Ontario, Quebec, and Nova Scotia are the three-year (2012-2014) average values reported for "Overall Greenhouse Gas Intensity" in the 1990-2014 NIR.[30] Their large magnitude relative to the B.C. emission factors reflects the substantially higher shares of fossil-fuel 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.

The emission factors for the U.K., India, Japan, China and Hong Kong required no further calculations as their values were already calculated as CO_2e emissions per kWh from electricity and heat generation[31].

[28] Wood waste generated electricity has been assigned a zero emission factor given that the CO_2 emissions from biomass are not included in Fortis' GHG inventory under international reporting rules.
[29] See: www.nelson.ca/EN/main/services/electrical-services.html.
[30] Environment Canada (2016). *National Inventory Report 1990-2014 Part 3*, Annex 13
[31] See http://www.iea.org/.

Table 3: EMISSION FACTORS: Purchased Electricity

Public Utility	Emission Factor (tCO_2e/ GWh)	Emission Factor ($kgCO_2e$/ GJ)
BC Hydro	10.67	3.0
Kyuquot Power *(BC Hydro reseller)*	10.67	3.0
FortisBC	2.587	0.719
City of Grand Forks *(FortisBC reseller)*	2.587	0.719
City of Kelowna *(FortisBC reseller)*	2.587	0.719
Nelson Hydro	1.164	0.323
City of New Westminster *(BC Hydro reseller)*	10.67	3.0
City of Penticton *(FortisBC reseller)*	2.587	0.719
City of Summerland *(FortisBC reseller)*	2.587	0.719
Hemlock Valley *(BC Hydro reseller)*	10.67	3.0
Alberta	800	222
Ontario	67	19
United Kingdom	454	126
India	805	224
Japan	563	156
China	705	196
Hong Kong	783	217
Nova Scotia	710	197
Quebec	2.26	.633
Note: Energy Conversion Factor = 0.0036 GJ/kWh		

The following table shows eight years of past emission factors for the most common electricity suppliers. If you wish to know more about past values, please contact the Climate Action Secretariat.

Table 4: Historical Emission Factors for Purchased Electricity

Electricity Provider[32]	Reporting Year(s)	Emission Factor (tCO2e/GWh)	Emission Factor (kgCO2e/GJ)
BC Hydro	2016, 2017	10.67	2.964
	2014, 2015	10.0	2.8
	2013	14.0	4.0
	2010, 2011, 2012	25.0	6.9
Fortis BC	2016, 2017	2.587	0.719
	2014, 2015	2.425	0.674
	2013	3.0	1.0
	2010, 2011, 2012	6.0	1.7

2.3 Indirect Emissions: District Energy Systems, Purchased Steam, Hot Water, Etc. for Stationary Sources

Description: A number of organizations use energy such as steam to heat buildings. Some (e.g., UBC, Vancouver Coastal Health Authority) produce heat, use a portion for their own consumption and sell the surplus. Others purchase heating and/or cooling from a commercial district energy supplier, such as Vancouver's Central Heat Distribution Ltd. These providers meet the definition of a District Energy System: *a community scale network of pipes that with the aid of steam, hot or chilled water carry thermal (i.e. heating and/or cooling) energy services to a collection of buildings in a defined geographic area.* This thermal energy can be created using a variety of input feedstock fuels including biomass (forest, agricultural, municipal solid waste), biogas, renewable energy forms (e.g. geo-exchange), natural gas, and cool water. As such, it provides the opportunity to utilize locally available fuels to generate hot and cool space conditioning at a community scale and, importantly, the opportunity to centrally substitute feedstock fuels over time. This is an important way for communities to create sustainable, resilient energy delivery systems and manage the risk of dependence on any one fuel or technology."[33]

When an organization produces heating or cooling for its own consumption, the resulting GHG emissions are determined by applying the appropriate emission factors of the fuels consumed by the system (refer to section 2.1). Where an organization purchases heating or cooling from another entity, estimating emissions requires information on the fuels consumed as well as and the generation, distribution and system efficiencies.

[32] Release years correspond to the date published in the title of the document. An archive of old methodology documents can be found here: http://www2.gov.bc.ca/assets/gov/environment/climate-change/z-empty-folders-to-delete/carbon-neutral-government/measure-page/2018_bc_best_practices_methodology_for_quantifying_ghg_emissions.pdf

[33] See the International District Energy Associations (2015) definition at: http://www.districtenergy.org/what-is-district-energy

Data sources: The average efficiency of district energy systems can vary significantly depending on characteristics such as the age of the plant, distribution losses and operation and maintenance practices. A District Energy emissions calculator based on the General Reporting Protocol[34] has been developed for organizations to help them determine which of the tiers in Table 5 below they should use for emissions measurement and reporting purposes. The calculator can be found here in the links on the right hand side of the web page.

- STEP 1: Use the calculator to determine the district energy system's emissions intensity.
- STEP 2: Compare the calculated emissions intensity with the thresholds set out in Table 5.
- STEP 3: Select the tier where the calculated value falls by referencing the upper and lower thresholds.

Organizations that load their purchased steam in pounds or kg into SMARTTool for conversion into GJ of energy will be able to continue doing so. Note the previous tiered steam emission factors for steam (Natural Gas at 65%, 75%, and 85%) from previous iterations of the BC Best Practices Guide have been carried over into the new tiers in Table 5. The RESD provides an average conversion factor for translating kg of steam into GJ of energy[35].

Organizations should document all of the variables they input into the calculator as a record for reference by other/future staff, for annual Self Certification purposes, and for possible third party verification. This documentation should be updated on an annual basis as system efficiencies will vary based on local climate, exposure, occupancy patterns, heating controls, insulation, and other factors. Documentation should also be sent to Carbon.Neutral@gov.bc.ca. Use the same email address for any questions about the foregoing. Please note that a new framework on the recognition of renewable and low carbon energy supplies in District Energy systems is under development.

Note: Where a PSO produces heating/cooling energy and sells a portion to another PSO, the producing PSO must either load that quantity of energy sold as a negative value in SMARTTool, or separately identify the emissions from the sales using the District Energy calculator. These emissions are then deducted from the producer's GHG inventory to avoid double counting when aggregating emissions across the B.C. public sector. However, if an organization produces heating/cooling energy and sells a portion to another organization that is not a PSO, they must report in full the emissions resulting from the production and distribution of that energy.

[34] The Climate Registry (2015). *General Reporting Protocol*, Version 2.0
[35] Statistics Canada (2015). *Report on Energy Supply and Demand in Canada 2013. p. 123*

Table 5: EMISSION FACTORS: District Energy Emission Tiers/Thresholds

Example Fuel Type(s) and System	Tier	tCO_2e/GWh Lower – Upper Thresholds	tCO_2e/GJ Lower – Upper Thresholds
Biomass at 65% system efficiency	1	50.45 - 84.39	0.0140 - 0.0233
25% Natural Gas / 75% Renewable at 75% system efficiency	2	84.40 – 118.29	0.0234 - 0.0328
50% Natural Gas / 50% Renewable at 85% system efficiency	3	118.30 - 152.19	0.0329 - 0.0422
50% Biomass / 50% Natural Gas at 65% system efficiency	4	152.20 - 186.09	0.0423 - 0.0516
75% Natural Gas / 25% Renewable at 75% system efficiency	5	186.10 – 220.09	0.0517 - 0.0610
Natural Gas at 85% system efficiency	6	220.00 - 253.89	0.0611 - 0.0704
Natural Gas at 75% system efficiency	7	253.90 - 287.79	0.0705 - 0.0798
Natural Gas at 65% system efficiency	8	287.80 - 321.69	0.0799 - 0.0893
Gasoline at 75% system efficiency	9	321.70 - 355.59	0.0894 - 0.0987
Gasoline at 70% system efficiency	10	355.60 and higher	0.0988 and higher

2.4 Direct Fugitive Emissions: Stationary Air Conditioning and Refrigeration

Description: Fugitive emissions from stationary cooling equipment are attributed to the leakage and loss of HFC and PFC based coolants from air conditioning and commercial type refrigeration systems. Coolant loss can occur during the manufacturing, operation, and disposal of such equipment.

Data sources: The Climate Registry offers three methods for reporting and/or estimating emissions from stationary air conditioning and refrigeration. The "Mass Balance" and "Simplified Mass Balance" methods can be used to measure and report coolant loss when information on system charges, top-ups, coolant disposal and coolant recycling is available. The Climate Registry also provides a "Screening Method" to estimate fugitive emission releases from HFC and PFC coolants when detailed information is not available.[36]

Calculations: Emissions from stationary air conditioning and refrigeration for the BC Government were calculated using both the "Simplified Mass Balance" and "Screening Method" using HVAC incident report log and equipment inventory information.

[36] The Climate Registry (2015). *General Reporting Protocol Version 2.0*, pp. 123-133.

Table 6: GHG Emissions from Stationary Air Conditioning and Refrigeration across the B.C. Government (Consolidated Revenue Fund) Portfolio

Year	Calculation Method	Calculated tCO2e	Total 2008 CRF GHG tCO2e	HFC Composition
2007	Simplified Mass Balance	2.56	104,753	0.0024%
2008	Simplified Mass Balance	7.71	104,753	0.0074%
2007/8	Screening Method	3.57	104,753	0.0034%

Use of either method produced emissions estimates significantly less than 1% for PSOs. This is attributable in part to the prevalence of R-22, an HCFC based coolant that is not in scope for reporting under the CNGR, and in widespread use amongst PSO's.

Based on these estimates, it is expected that the fugitive emissions from stationary cooling are significantly less than 1% (approximately 0.01%) of each PSOs/local governments' total GHG footprint. If these fugitive emissions are onerous to measure and collect, PSOs/local governments should examine the "how to treat small emissions" decision tree in the Annex 3.

Organizations who wish to voluntarily report on HFC and PFC emissions from stationary cooling may use the "Mass Balance" or "Simplified Mass Balance" methods as described in Chapter 16 of Climate Registry's General Reporting Protocol[37] to calculate and report emissions from these sources. Depending on the method chosen, organizations may require detailed information on refrigeration system purchases, servicing, and retirement.

[37] The Climate Registry (2015). *General Reporting Protocol Version 2.0*, pp. 123-133.

3. Direct Emissions: Mobile Sources - Transportation

Transportation is another source of GHG emissions. Three categories of emissions are discussed in detail below:

- Direct emissions from fossil fuels combustion in vehicles and equipment.
- Direct fugitive emissions from mobile air conditioning systems.
- Indirect emissions from fossil fuels combustion in various modes of travel.

3.1 Direct Emissions: Mobile Fuel Combustion

Description: Emission factors are specified for seven transport modes:

- Light-duty vehicles (excluding trucks, SUVs, and minivans)
- Light-duty trucks[38] (including SUVs and minivans)
- Heavy-duty
- Motorcycles
- Off-road vehicles and equipment (e.g., snowmobiles, ATVs, lawnmowers and trimmers, tractors, construction equipment)
- Marine
- Aviation

Ten fuel types have different emission factors associated with them:

- Gasoline
- Diesel
- Propane
- Natural gas
- Biodiesel
- Ethanol
- Marine Gasoline
- Marine Diesel
- Aviation Gasoline
- Aviation Turbo Fuel

SMARTTool accepts fuel consumption data in litres by mode of transport and fuel type. This information is required because the emission factors for CH_4 and N_2O vary by vehicle type and transport mode.

Hybrid electric vehicles are not considered 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 is reflected in their lower overall fuel consumption, and therefore lower GHG emissions. Hydrogen powered transit busses and electric vehicles produce zero emissions at the tail-

[38] 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 duty as those vehicles with a GVWR greater than 3,900 kg.

pipe and are therefore not included in emissions reporting for mobile sources. However, the electricity consumed by an electric vehicle may very well be tracked as part of a building's plug load.

Data sources: Table A6-12 of the 1990-2014 NIR[39] and Table 20 of the 2012 PIR[40] provide emission factors for mobile fuel combustion sources. The factors for gasoline and diesel cars and trucks vary with emission control technology which correlates with vehicle age.

For the purposes of estimating an organization's emissions, the assumed emission factors are "Tier 1" for gasoline-fueled light-duty cars and trucks, "Three-Way Catalyst" for gasoline heavy-duty trucks and "Advance Control" for all diesel-fueled on-road vehicles.[41] The technologies corresponding with these emission factors were introduced in the mid-1990s. We assume that most fleet vehicles are newer than the mid-1990s, and therefore that they are fitted with *at least* this level of emission controls.

Table A6-12 in the NIR 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 the actual emission factor is a weighted average of the biofuel and fossil fuel factors[42].

Calculations: In B.C., the *RLCFRR* sets the requirements for the amount of renewable fuel in the province's transportation and heating fuel blends.[43] Effective January 1st, 2011, fuel suppliers were required to incorporate 5% renewable fuel content for gasoline and 4% for diesel. In SMARTTool, for any given volume of reported gasoline consumption, 95% of the fuel is deemed to be fossil fuel gasoline and the remaining 5%, ethanol. For Diesel, 96% is fossil fuel diesel and 4%, biodiesel. Where applicable, the emission factors listed in Table 7 below has been adjusted to account for the renewable fuel content under the *RLCFRR*. Please note that the regulation does not affect the CH_4 or N_20 factors, as the methodology uses the emission factors for gasoline and diesel to calculate the CH_4 and N_20 content in biofuels.

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. Table 9 outlines how this conversion is done.

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[39] Environment Canada (2016). *National Inventory Report 1990-2014,* Part 2, p. 198.

[40] British Columbia (2015). *British Columbia Greenhouse Gas Inventory Report 2012*, p. 62-63.

[41] 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 duty as those vehicles with a GVWR greater than 3,900 kg. *Ibid.,* p. 37.

[42] International protocols require the separate reporting of biogenic emissions from fossil fuel-based emissions (see Section 2.1), the CO2 emissions from the biofuel component must be calculated and reported separately from those of the fossil fuel component.

[43] Aviation fuels have no similar regulation.

Table 7: EMISSION FACTORS: Fleet Fuels - Standard Mixes

(1) Transport Mode	(2) Fuel Type	(3) Units	**Emission Factor** (kg/ L or kg/kg as noted in Column 3)				
			(4) Bio CO_2	(5) CO_2	(6) CH_4	(7) N_2O	(8) CO_2e
Light-duty Vehicle[a]	Gasoline (E5)	kg/ L	0.0755	2.200	0.00023	0.00047	2.346
	Diesel (B4)	kg/ L	0.0990	2.582	0.000051	0.00022	2.649
	Propane	kg/ L	–	1.515	0.00064	0.000028	1.539
	Natural Gas[b]	kg/ kg	–	2.738	0.013	0.000086	3.089
Light-duty Truck (includes SUV and Minivan)[a]	Gasoline (E5)	kg/ L	0.0755	2.200	0.00024	0.00058	2.379
	Diesel (B4)	kg/ L	0.0990	2.582	0.000068	0.00022	2.650
	Propane	kg/ L	–	1.515	0.00064	0.000028	1.539
	Natural Gas[b]	kg/ kg	–	2.738	0.013	0.000086	3.089
Heavy-duty[a]	Gasoline (E5)	kg/ L	0.0755	2.200	0.000068	0.00020	2.262
	Diesel (B4)	kg/ L	0.0990	2.582	0.00011	0.000151	2.630
	Natural Gas[b]	kg/ kg	–	2.738	0.013	0.000086	3.089
Motorcycle	Gasoline (E5)	kg/ L	0.0755	2.200	0.00077	0.000041	2.232
Off-Road (Vehicle/ Equipment)	Gasoline (E5)	kg/ L	0.0755	2.200	0.0027	0.00005	2.283
	Diesel (B4)	kg/ L	0.0990	2.582	0.00015	0.001	2.884
	Natural Gas[b]	kg/ kg	–	2.738	0.013	0.000086	3.089
Marine	Gasoline (E5)	kg/ L	0.0755	2.200	0.00023	0.000067	2.226
	Diesel (B4)	kg/ L	0.0990	2.582	0.00025	0.000073	2.610
Aviation	Gasoline	kg/ L	–	2.365	0.0022	0.00023	2.489
	Turbo Fuel	kg/ L	–	2.560	0.000029	0.000071	2.582
Various	Biodiesel[c] (B100)	Kg/ L	2.474	–	e	e	Varies
	Ethanol[d] (E100)	kg/ L	1.509	–	f	f	Varies

Note: emission factors for fleet fuel consumption are based on Tier 1 or Advance Control emission control technologies.

[a] Based on Tier 1 or Advance Control emission control technologies.
[b] Adapted from Table 20 of the 2012 PIR factors and converted to kg of compressed natural gas.
[c] Diesel CH_4 and N_2O emission factors (by transport mode) used for biodiesel.
[d] Gasoline CH_4 and N_2O emission factors (by transport mode) used for ethanol.
[e] Diesel CH_4 and N_2O emission factors (by mode and technology) are used for biodiesel.
[f] Gasoline CH_4 and N_2O emission factors (by mode and technology) are used for ethanol.

In order to determine the emission factor of a custom blend, the emission factors of the renewable and the fossil fuel must be weighted by their proportion in the mix. The following example calculation shows how a user should calculate the emission factor associated with an 80/20 blend of gasoline and ethanol in a light-duty vehicle.

To calculate the correct factor for your unique fuel mix, simply substitute in the relevant weighting of your component fuels.

Pure gasoline, light vehicle (kg/l):

$BioCO_2$	CO_2	CH_4	N_2O	CO_2e
0	2.316	0.00023	0.00047	**2.462**

Pure ethanol (E100), light vehicle (kg/l):

$BioCO_2$	CO_2	CH_4	N_2O	CO_2e
1.509	**0**	0.00023	0.00047	**0.1458**

Mix, 80%-20% gasoline-ethanol (kg/l):

$BioCO_2$:	20% × 1.509 = 0.3018		
CO_2:	80% × 2.316 = 1.8528		
CH4:	80% × 0.00023 +	20% × 0.00023 =	0.00023
N2O:	80% × 0.00047 +	20% × 0.00047 =	0.00047
CO_2e:	80% × 2.462 +	20% × 0.1458 =	1.999

Therefore, for an 80-20 blend of gasoline and ethanol (E20), the following emission factors apply:

$BioCO_2$	CO_2	CH_4	N_2O	CO_2e
0.3018	1.8528	0.00023	0.00047	**1.999**

The following table provides the emission factors of common unmixed fuel products in different vehicle classes, allowing the calculation of factors for unique blends. Weight each factor here according to its share in the mixed fuel, as per the example above.

Table 8: EMISSION FACTORS: Fleet Fuels - Unmixed

(1) Transport Mode	(2) Fuel Type	(3) Units	Emission Factor (kg/ L or kg/kg as noted in Column 3) (4) Bio CO2	(5) CO2	(6) CH4	7) N2O	(8) CO2e
Light-Duty Vehicle	Gasoline	kg/L	-	2.316	0.00023	0.00047	2.462
	Diesel	kg/L	-	2.690	0.000051	0.00022	2.757
	Propane	kg/L	-	1.515	0.00064	0.000028	1.539
	Natural Gas	kg/kg	-	2.738	0.013	0.000086	3.089
Light-Duty Truck	Gasoline	kg/L	-	2.316	0.00024	0.00058	2.495
	Diesel	kg/L	-	2.690	0.000068	0.00022	2.757
	Propane	kg/L	-	1.515	0.00064	0.000028	1.539
	Natural Gas	kg/kg	-	2.738	0.013	0.000086	3.089
Heavy Duty	Gasoline	kg/L	-	2.316	0.000068	0.0002	2.377
	Diesel	kg/L	-	2.690	0.00011	0.000151	2.738
Motorcycle	Gasoline	kg/L	-	2.316	0.00077	0.000041	2.347
Off-Road (Vehicle/Equipment)	Gasoline	kg/L	-	2.32	0.0027	0.00005	2.398
	Diesel	kg/L	-	2.69	0.00015	0.001	2.992
Marine	Gasoline	kg/L	-	2.32	0.00023	0.000067	2.342
	Diesel	kg/L	-	2.69	0.00025	0.000073	2.718
Various	100% Biodiesel	kg/L	2.474	-	a	a	Varies by mode
	100% Ethanol	kg/L	1.509	-	b	b	Varies by mode

a) Diesel CH_4 and N_2O emission factors (by mode and technology) are used for biodiesel.
[b]) Gasoline CH_4 and N_2O emission factors (by mode and technology) are used for ethanol.

3.2 Natural Gas Vehicle Emission Factors

Light-duty natural gas vehicles are fueled with compressed natural gas (CNG), which is measured in kilograms. Volumes are not typically used for measurement of natural gas as compression varies with temperature and pressure. By using mass for measurement, these differences are removed. Federal regulations require that natural gas be dispensed on a cents per kilogram basis.

The NIR and PIR provide emission factors for the mobile combustion of natural gas in grams per litre (g/ L).[44, 45] As a result, these factors do not align with the common unit for compressed natural gas measurement at the pump.

[44] Environment Canada (2016). *National Inventory Report 1990-2014 Part 2*. These emission factors relate to natural gas in its gaseous state as it flows through a pipeline, prior to compression.
[45] British Columbia (2015). *British Columbia Greenhouse Gas Inventory Report 2012*, p. 62.

SMARTTool has been configured with emission factors in kg of emissions per unit of consumption – also kg in the case of compressed natural gas. Table 9 shows the calculations that have been performed to convert the 1990-2014 NIR/2012 PIR 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).[46]

Table 9: Compressed Natural Gas Vehicle Emission Factor Calculations

Step	Units	CO_2	CH_4	N_2O	CO_{2e}
1. Obtain natural gas emission factors from the NIR (at STP)	g/ L	1.89	0.009	0.00006	2.133
2. Convert to g/ m^3 by multiplying by 1,000 (L/ m^3)	g/ m^3	1,890	9	0.06	2132.880
3. Convert to g/ kg by dividing by 0.694 (density of natural gas at STP in kg/ m^3)	g/ kg	2,723.3	13.0	0.086	3073.928
4. Convert to kg/ kg by dividing by 1 000 (g/ kg)	kg/ kg	2.723	0.013	0.000086	3.074

3.3 Direct Fugitive Emissions: Mobile Air Conditioning

Description: Atmospheric releases of motor vehicle coolants such as hydrofluorocarbons (HFCs) occur throughout the lifecycle of motor vehicle air conditioning (MVAC) units. Unlike a building's heating, ventilation, and air conditioning (HVAC) systems, 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.

Data sources: 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.[47] This method has been used to calculate a default emission factor, in kg of HFCs per vehicle. In order to apply the default factor, organizations must provide the number of vehicles in its fleet with MVAC.

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.[48] The most common refrigerant used in MVAC is HFC-134A, with a global warming potential of 1,430.

Calculations: Multiplying the 1.5 kg capacity charge by the 20 percent operating emission factor and converting to CO_2e emissions yields a default emission factor of 429 kg CO_2e per vehicle per year. Using this emission factor in conjunction with fleet inventory information, the total estimate for emissions from mobile cooling was less than 1% of the BC Government's (Consolidated Revenue Fund) total GHG inventory for 2008.

[46] The natural gas density of 0.694 kg/m^3 at STP is based on the *British Columbia Greenhouse Gas Inventory Report 2012*, p. 63

[47] The Climate Registry (2015). *General Reporting Protocol Version 2.0*, pp. 128-133.

[48] The Climate Registry (2015). 2015 Climate Registry Default Emission Factors – Released April 9, 2015, Table 16.2, p. 70.

Table 10: Per Vehicle Estimate of HFCs from Mobile Air Conditioning

Greenhouse Gas (kg)	Emissions per Vehicle per Year (kg CO_2e)
Hydrofluorocarbons	429

[a] default emission factor for HFCs from mobile air conditioning are emissions which consist of HFC-134a.

Organizations typically have two options for calculating and reporting mobile cooling emissions. Organizations with information on the MVAC servicing for their fleets (e.g., for transit fleets) may use these data to report their HFC emissions directly using the Climate Registry's "Simplified Mass Balance Approach."[49] This method requires information on the quantities of each refrigerant used and recovered from MVAC equipment reported directly. Organizations without access to detailed mobile refrigerant information may estimate and report their annual refrigerant use at 429 kg CO_2e per each vehicle with air conditioning. This value provides a conservative estimate of emissions resulting from HFC-134a use.

[49] The Climate Registry (2054). *General Reporting Protocol Version 2.0*, pp. 123-133.

4. Indirect Emissions - Business Travel

Description: In accordance with the CCAA, the Provincial government (e.g., ministries, special offices, tribunals) is required to quantify, reduce, offset and report the business travel emissions of its public officials. The GHG Protocol provides three methods for quantifying business travel emissions listed below in order of preference. The Protocol recommends selection of a method based on availability of data:

1. **Fuel-based method:** involves determining the amount of fuel(s) consumed in the course of business travel and applying the appropriate emission factor for the fuel(s)
2. **Distance-based method:** involves determining the distance and travel mode(s) and applying the emission factor appropriate for the mode(s)
3. **Spend-based method:** involves determining the expenditures and travel mode(s) and applying the emission factors appropriate for the mode(s)

Between 2008 and 2016[50], the Provincial government used an on-line data collection tool called SMARTTEC to collect business travel data from approximately 9,000 employees. SMARTTEC used the distance-based method described above: for each business trip, employees used SMARTTEC to record the details of their trip including travel mode(s), fuel type(s), and travel distance(s), enabling the calculation of related emissions. In addition to their SMARTTEC entries, employees were required to enter some of the same information along with details about their out-of-pocket expenses into an on-line system known as iExpenses to obtain reimbursement of those expenses.

4.1 Using iExpenses Data

Data Sources: In 2016, based on an analysis of:

- the data already collected by iExpenses system;
- the configurability of the current version of iExpenses; and
- other travel expenditure data within the government accounting system,

the decision was made to retire SMARTTEC and shift from its distance-based approach to a hybrid of the distance- and spend-based methods in order to reduce data collection burden on employees. Transition to the hybrid approach involved modest reconfiguration of the iExpenses system, and was facilitated by the rich historical distance-based dataset collected over previous years by SMARTTEC. Reconfiguration of iExpenses made it capable of tracking travel details that include: travel mode(s), some fuel type(s), and some travel distance(s) in addition to related expenditures.

Calculations: Where travel distances are collected by iExpenses, business travel emissions can still be quantified using the distance-method. Otherwise, travel emissions must be calculated with the spend-method. The table below illustrates when each method is used with iExpenses data.

[50] April 1, 2008 and April 22, 2016

Table 11: iExpenses Data and Estimation Methods

Employee's Travel Mode	iExpenses "Expense Type" Selection	iExpenses "Travel Mode" Selection	iExpenses Data Collected / Available	GHG Estimation Method
Air Travel, common routes	Air You Paid	Helicopter, Airplane, Float Plane	$, km/route	**Distance-Based**
Air Travel, Other routes	Air You Paid	Helicopter, Airplane, Float Plane	$	**Spend-Based**
Rental vehicle	Car Rental	Car, other, Truck/SUV	fuel, $, km	**Distance-Based**
Personal vehicle	Mileage	Car, other, Truck/SUV	fuel, $, km	**Distance-Based**
Ferries	Ferry	N/A	$, km/route	**Distance-Based**
Rail, inter-city bus, other public transport	Public Transport	Other	$	**Spend-Based**
Taxis	Public Transport	Taxi	$	**Spend-Based**
City Bus, Light Rail, Seabus,	Public Transport	Transit	$	**Spend-Based**
Accommodation	Accommodation	Hotel, Private, Other	# of Nights	**Spend-Based**

More details about the methodology including emission factors are provided in Annex 5 on both the distance- and spend-based methods.

4.2 Using Other Accounting System Data

Data Sources: While approximately 60% of Provincial government's expenditures on business travel are tracked through its iExpenses system, the remaining 40%, largely expenditures on air travel and public transport, are not.[51] These expenditures, like those from iExpenses, are tracked within the Provincial government's financial accounting system. The system tracks them in a series of accounts and subaccounts as follows:

- Accounts representing expenditures for:
  - ministry directly-paid "air travel" - 33% of total
  - employee travel vouchers[52] for travel on "other modes" – 7% of total

  each of which is further broken down into the following sub-accounts:

    - between Victoria/Vancouver;
    - in-province travel;
    - out-of-province travel; and

[51] Provincial Government Core Policy Manual, section C.1.1 "*All expenses associated with travel must be paid by the employee travelling except for airline tickets and some taxi billings*."

[52] Travel vouchers are used by employees who cannot use iExpenses to seek reimbursement. Instead, they use travel vouchers which provide a paper-forms approach for employees to obtain reimbursement for their travel expenses. Employees generally submit completed forms to their finance staff for entry into the government's accounting system.

- out-of-country travel.

Calculations: In this case, information about most frequent travel mode was only available for ministry directly-paid air travel, not employee travel vouchers, specifically:

- for ministry directly-paid air travel, historical SMARTTEC information about travel modes and approximate distance enabled the development of emission factors by subaccount; and
- for travel expenditures associated with travel vouchers, a single emission factor was developed for all subaccounts given the lack of information about most frequent travel mode.

	Subaccount	Travel Mode Possibilities	Most Frequent Travel Mode
Directly Paid Air Travel	Victoria to Vancouver	Float plane, helicopter, short-haul air	Float Plane
	In-Province	Short haul flights; medium haul air	Short Haul
	Out-of-Province	Medium and long haul flights	Long Haul
	Out-of-Canada	Long haul flights	Long Haul
Travel Voucher On Other Modes	Victoria to Vancouver	All ground transport modes and accommodations	N/A
	In-Province	All ground transport modes and accommodations	N/A
	Out-of-Province	All ground transport modes and accommodations	N/A
	Out-of-Canada	All ground transport modes and accommodations	N/A

More details about the methodology including emission factors are provided in Annex 5 on both the distance- and spend-based methods.

4.3 Accommodation

Description: In addition to transportation-related GHGs from business travel, indirect emissions result from employee stays in hotels, bed and breakfasts and private accommodation.

Data sources: In March of 2011, InterVISTAS Consulting Inc. published a GHG report on the accommodation emissions for Coast Hotels and Resorts in 2009[53]. The report followed the accounting and reporting guidelines of *The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard, Revised Edition* published by World Resources Institute and the World Business Council for Sustainable Development.

A total of five properties were evaluated (two in Vancouver, one in Edmonton, one in Victoria and one in Prince George). The properties in Western Canada provide a spatial sampling of locations in different climates to represent different energy consumption patterns. The properties varied in size

[53] InterVISTAS Consulting Inc. (2011), *Coast Hotels & Resorts: Greenhouse Gas Report Fiscal Year 2009*

from 132 rooms in Victoria to 299 in Edmonton. The intensity-based indicators for those five hotels were then extrapolated to 22 hotels in BC and 7 in Alberta.

Calculations: iExpenses tracks accommodations in the same manner as SMARTTEC has historically; in terms of the number of nights stayed in a hotel/motel, bed and breakfast or private accommodations.

In Table 12 below, the emission factor for a night's stay has been calculated by dividing the total GHG emissions for the sample hotels by the number of potential room nights assuming full occupancy:

Emission Factor (kg/ CO_2e/ night) = 51,310 tonnes CO_2e*1000/ (7,238 rooms * 365 nights)

From this method, both a domestic BC emissions value (11.90 kg CO_{2e} / night) and a national/international emissions value (20.78 CO_2e / night) were derived. The national/international value is a conservative estimate as it incorporates data from electricity generation in Alberta, which results in significantly greater emissions per kilowatt hour than in the rest of Canada due to coal being the primary energy source. Based on 2014 accommodation data from SMARTTEC, 93.84% of Provincial government accommodation stays were within BC and 6.16% were national or international. Based on these figures a weighted average can be calculated to derive a single accommodation factor of 12.45 kg CO_{2e} / night.

This emission factor for hotels has been assigned to the other categories of private accommodation and bed and breakfasts in the absence of available information for those categories.

Table 12: EMISSION FACTORS: Accommodation

Accommodation Type	Emission Factor [a] (kg CO_2e/ night)
Hotel Room, Private, Bed and Breakfast	12.45

[a] Hotel room emission factor is applied to all accommodation types.

5. Indirect Emissions: Office Paper

Description: Emission factors for office paper are differentiated by size and the percentage of post-consumer recycled (PCR) content. In practice, the PCR content can range between 0 and 100 percent.[54]

Three different sizes of office paper (any colour) are in scope – 8.5" x 11", 8.5" x 14" and 11" x 17". In each case, data on the number of 500-sheet (20lb) packages are entered into SMARTTool.

Some organizations may have begun to use alternative paper types such as wheat, eucalyptus, sugarcane, bamboo, etc. While these papers likely have emission factors that differ from conventional paper, limited literature is currently available on their carbon intensity. As a best approximation, the emission factors in Table 14 for 100% PCR of the corresponding paper size should be applied to these alternative papers.

Data sources: Ideally, it would be best to specify emission factors that accurately reflect the extraction, transportation, manufacturing and disposal processes for specific paper purchases. In the absence of paper-specific information, proxy emission factors have been derived from the Environmental Paper Network (EPN) Paper Calculator.[55] 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 CO_2e.

Table 13: EMISSION FACTORS: Office Paper

PCR Content (%)	Emission Factor (kg CO_2e/ pkg) 8.5" x 11"	8.5" x 14"	11" x 17"
0	6.358	8.094	12.743
10	6.123	7.795	12.272
20	5.888	7.496	11.802
30	5.653	7.197	11.331
40	5.418	6.898	10.860
50	5.184	6.599	10.390
60	4.949	6.300	9.919
70	4.714	6.001	9.449
80	4.479	5.703	8.978
90	4.244	5.404	8.508
100	4.010	5.105	8.037

Note: emission factors for office paper are 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.

[54] See the Ecopaper Database at http://c.environmentalpaper.org/home for a listing of papers available in the Canadian marketplace and their PCR contents.

[55] http://c.environmentalpaper.org/home

Calculations: To generate the emission factors in Table 14, the weight of a 500-sheet package was first determined for each paper size. This weight (in metric tons) and the PCR content were then entered into the Paper Calculator and the resulting estimate of GHG emissions was converted from lbs to kg CO_2e. 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 emission factors within this document, the entries in Table 14 are lifecycle emission factors.[56]

6. Community Energy and Emissions Inventory (CEEI) Emission Factors – Agricultural Emission Factors

Only the 2007 & 2012 CEEI reports include enteric fermentation (due to a lack of data it was not included in the 2010 reports)[57]. Manure management is excluded because the emissions values used by the NIR do not reflect regional and local variations in the storage and use of manure, and agricultural soils are excluded because we have insufficient information about them at a local level. The CEEI Working Group is currently exploring the possibility of including manure management and agricultural soils emissions in the 2014 CEEI reports, scheduled to be released in late 2016.

Furthermore, the categories in the NIR do not include all GHG emissions resulting from agricultural operations. For example, emissions from use of diesel in trucks to deliver hay are included in "transportation". Emissions from water heaters and space heaters are included in "buildings". Emissions from diesel used in tractors would be an "off-road" emission. None of these are included in the "Agriculture" sector of CEEI.

Emission factors for cattle were derived at the provincial level using IPCC Tier 2 equations for different subcategories of cattle based on stages of production See page 78 of the 2016 NIR for details on the calculations. CEEI calculates emissions based on the number of cattle, hogs and other animals in each regional district. For each regional district, the number of animals is multiplied by the estimated methane emissions from each animal (from the NIR) to give total methane (CH_4) emissions. These are multiplied by the GWP factor of 25 converting methane (CH_4) emissions to carbon dioxide equivalents (CO_2e).

Table 15 below presents data from the 2016 NIR table A3-33 which shows "CH_4 Emission Factors for Enteric Fermentation for Cattle from 1990 to 2014". It contains factors for eight different types of cattle, and the factors for each vary from year to year. The original 2007 CEEI Reports used 2007 factors (2007 NIR) from this table, whereas the new 2007 and 2012 CEEI Reports use the 2012 factors (2014 NIR). This table contains the most recent factors in the final row as well as older factors for the purpose of comparison.

[56] 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.

[57] Enteric fermentation is a digestive process by which carbohydrates are broken down by microorganisms into simple molecules for absorption into the bloodstream of an animal.

Table 14: EMISSION FACTORS: CH_4 - Enteric Fermentation for Cattle[58,59]

	EF(EF)T – kg CH_4/head/year							
Year	**Dairy Cows**	**Dairy Heifers**	**Bulls**	**Beef Cows**	**Beef Heifers**	**Heifers for Slaughter**	**Steers**	**Calves**
2007 (2007 NIR)	116.5	74.6	87.8	84.7	71.4	68.0	59.6	43.3
2007 (2014 NIR)	125.0	72.3	87.6	88.1	72.5	61.1	54.4	39.5
2012 (2014 NIR)	128.1	72.4	88.1	86.7	71.2	61.2	55.7	39.6
2014 (2016 NIR)[60]	155.1	78.4	121	116.3	88	53.1	47.9	43.7

Table 16 below presents methane emissions from animals other than cattle taken from the 2016 NIR Table A8-41: CH_4 Emission Factors for Enteric Fermentation for Non-cattle Animals.

Table 15: Non-cattle Animal Category – Enteric Fermentation Emission Factor

Non-cattle Animal Category – Enteric Fermentation Emission Factor (kg CH_4/head/year)	
Boars, Sows, Pigs	1.5
OTHER LIVESTOCK	
Sheep, Lambs	8
Goats	5
Horses	18
Buffalo, Bison[61]	55
POULTRY[62]	Not Available

[58] Environment Canada (2016). National Inventory Report: Greenhouse Gas Sources and Sinks in Canada 1990-2014, Table A3-18

[59] See IPPC website for related publications, for example: www.ipcc-nggip.iges.or.jp/public/gp/bgp/4_2_CH4_and_N2O_Livestock_Manure.pdf

[60] Environment Canada (2016). National Inventory Report: Greenhouse Gas Sources and Sinks in Canada 1990-2014, Table A3-18

[61] This emission factor is for water buffalo. There are no recognized studies of enteric emissions from bison, so the IPCC Tier 1 water buffalo figure is used here, as it is in the NIR

[62] Poultry does not generate significant methane by enteric fermentation, so poultry was not counted in CEEI

7. Sample Calculation

Table 17 provides a sample application of an emission factor to calculate GHG emissions, based on 100 litres of propane consumption in buildings.

Table 16: Sample Emissions Calculation

Step	Formula	Calculation		
1. Convert the actual consumption to a common unit of measurement.	Actual Consumption (L) x Energy Conversion Factor (GJ/ L) = Converted Fuel Consumption (GJ)	100 L X 0.02531 GJ/ L = **2.531 GJ**		
2. Calculate the emissions of each GHG using the appropriate emission factor	Converted Fuel Consumption (GJ) x Emission Factor by GHG (kg/ GJ) = Emissions by GHG	**CO_2** 2.531 GJ x 59.86 kg **CO_2** / GJ = 151.5 kg **CO_2**	**CH_4** 2.531 GJ x .0009 kg **CH_4** / GJ = 0.0023 kg **CH_4**	**N_2O** 2.531 GJ x 0.0043 kg **N_2O** / GJ = 0.0109 kg **N_2O**
3. Convert the emissions of each greenhouse gas to CO2 equivalency (CO_2e) using the appropriate Global Warming Potential	Emissions by GHG x GWP = Emissions (kg CO_2e)	**CO_2** 151.5 kg **CO_2** x 1 = 151.5 kg **CO_2e**	**CH_4** 0.0023 kg **CH_4** x 25 = 0.0570 kg **CO_2e**	**N_2O** 0.0109 kg **N_2O** x 298 = 3.243 kg **CO_2e**
4. Sum across the gases to calculate total CO2e emissions	**CO_2** + **CH_4** + **N_2O** (all in kg **CO_2e**) = Total **CO_2e**	151.5 kg **CO_2e** + 0.0570 kg **CO_2e** + 3.243 kg **CO_2e** = 154.8kg **CO_2e**		
5. Convert total emissions from kg to tonnes for reporting purposes.	Emissions in kg CO_2e / 1 000 kg / t = Emissions in tonnes CO_2e	154.8 kg **CO_2e** / 1 000 kg / t = 0.155 t **CO_2e**		

Annex 1: Glossary of Terms and Acronyms

Note: Definitions derived from:

- IPCC Fifth Assessment Report, Glossary of Terms (available at: https://www.ipcc.ch/site/assets/uploads/2018/02/AR5_SYR_FINAL_Annexes.pdf).
- Market Advisory Committee to the California Air Resources Board (2007), "Recommendations for Designing a Greenhouse Gas Cap-and-Trade System for California."
- The Climate Registry (2014), *General Reporting Protocol Version 2.0*, pp. 160-166.

Table 17: Terms and Acronyms

Abbreviation, Acronym or Measure	Definition
Carbon dioxide (CO_2)	A naturally occurring gas (0.03% of atmosphere) that is also a by-product of the combustion of fossil fuels and biomass, land-use changes, and other industrial processes. It is the principal anthropogenic greenhouse gas. It is the reference gas against which other greenhouse gases are measured and therefore has a Global Warming Potential of 1. (IPCC)
Carbon-equivalent (CO_2e)	"The universal unit of measurement to indicate the global warming potential (GWP) of each of the six greenhouse gases, expressed in terms of the GWP of one unit of carbon dioxide." (GHG Protocol) Expressing all GHGs in terms of tonnes of CO_2e allows the different gases to be aggregated.
Community Energy and Emissions Inventory	The Community Energy and Emissions Inventory (CEEI) represents energy consumption and greenhouse gas emissions from community activities in on-road transportation, buildings and solid waste. Estimates of land-use change from deforestation activities and enteric fermentation from livestock under the Agricultural sector are also available.
Biofuel	A fuel produced from dry organic matter or combustible oils produced by plants. Examples of biofuel include alcohol (from fermented sugar), black liquor from the paper manufacturing process, wood and soybean oil.
Direct emissions	Emissions from sources that are owned or leased by a PSO or sources used by local governments to deliver traditional local government services
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. tonnes of fuel consumed, tonnes of product produced) and absolute GHG emissions" (GHG Protocol)
Emissions	"The release of substances (e.g., greenhouse gases) into the atmosphere. Emissions occur both through natural processes and as a result of human activities." (CARB)
Enteric fermentation	Enteric fermentation is a digestive process by which carbohydrates are broken down by microorganisms into simple molecules for absorption into the bloodstream of an animal.
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	(U.S.) Environmental Protection Agency
Fugitive emissions	The unintended or incidental release 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 SF_6 from electric power distribution equipment.

Abbreviation, Acronym or Measure	Definition
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)	"Greenhouse gases differ in their effect on the Earth's radiation balance depending on their concentration, residence time in the atmosphere, and physical properties with respect to absorbing and emitting radiant energy. By convention, the effect of carbon dioxide is assigned a value of one (1) (i.e., the GWP of carbon dioxide =1) and the GWPs of other gases are expressed relative to carbon dioxide. For example, in the U.S. national inventory, the GWP of nitrous oxide is 298 and that of methane 25, indicating that a tonne of nitrous oxide has 298 times the effect on warming as a ton of carbon dioxide. Slightly different GWP values for greenhouse gases have been estimated in other reports. Some industrially produced gases such as sulfur hexafluoride (SF_6), perfluorocarbons (PFCs), and hydrofluorocarbons (HFCs) have extremely high GWPs. Emissions of these gases have a much greater effect on global warming than an equal emission (by mass) of the naturally occurring gases. Most of these gases have GWPs of 1,300 - 23,900 times that of CO_2. The US and other Parties to the UNFCCC report national greenhouse gas inventories using GWPs from the IPCC's Second Assessment Report (SAR). SAR GWPs are also used for the Kyoto Protocol and the EU ETS. GWPs indicated in this document also refer to the IPCC's Second Assessment Report." (CARB)
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: www.globalreporting.org).
Greenhouse gases (GHGs)	"Greenhouse gases include a wide variety of gases that trap heat near the Earth's surface, slowing its escape into space. Greenhouse gases include carbon dioxide, methane, nitrous oxide and water vapor and other gases. While greenhouse gases occur naturally in the atmosphere, human activities also result in additional greenhouse gas emissions. Humans have also manufactured some gaseous compounds not found in nature that also slow the release of radiant energy into space." (CARB)
HVAC	Heating, Ventilating and Air Conditioning
Hydrofluorocarbons (HFCs)	"One of the six primary GHGs. Synthetic industrial gases, primarily used in refrigeration and other applications as commercial substitutes for chlorofluorocarbons (CFCs). There are no natural sources of HFCs. The atmospheric lifetime of HFCs is decades to centuries, and they have "global warming potentials" thousands of times that of CO_2, depending on the gas. HFCs are among the six greenhouse gases to be curbed under the Kyoto Protocol." (CARB)
Indirect emissions	Emissions that are a consequence of the operations of the reporting organization (i.e., PSO, local government, community), but occur at sources owned or controlled by another organization.
Intergovernmental Panel on Climate Change (IPCC)	"Recognizing the problem of potential global climate change, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) established the Intergovernmental Panel on Climate Change (IPCC) in 1988. It is open to all members of the UN and WMO. The role of the IPCC is to assess on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation. The IPCC does not carry out research nor does it monitor climate related data or other relevant parameters. It bases its assessment mainly on peer reviewed and published scientific/technical literature." (CARB)

Abbreviation, Acronym or Measure	Definition
Inventory	"A greenhouse gas inventory is an accounting of the amount of greenhouse gases emitted to or removed from the atmosphere over a specific period of time (e.g., one year). A greenhouse gas inventory also provides information on the activities that cause emissions and removals, as well as background on the methods used to make the calculations. Policy makers use greenhouse gas inventories to track emission trends, develop strategies and policies and assess progress. Scientists use greenhouse gas inventories as inputs to atmospheric and economic models" (CARB)
IPP	Independent Power Producer
kg	Kilogram
kilotonne	1,000 tonnes
km	Kilometre
kWh	kilowatt-hour
L	Litre
lb	pound (weight)
m^3	cubic metre
Methane (CH_4)	"One of the six greenhouse gases to be curbed under the Kyoto Protocol. Atmospheric CH_4 is produced in nature, but human related sources such as landfills, livestock feedlots, natural gas and petroleum systems, coal mines, rice fields, and wastewater treatment plants also generate substantial CH_4 emissions. CH_4 has a relatively short atmospheric lifetime of approximately 10 years, but its 100-year GWP is currently estimated to be approximately 25 times that of CO_2." (CARB)
MVAC	Motor Vehicle Air Conditioning
NIR	National Inventory Report (Environment Canada)
Nitrous oxide (N_2O)	"One of the six greenhouse gases to be curbed under the Kyoto Protocol. N2O is produced by natural processes, but substantial emissions are also produced by such human activities as farming and fossil fuel combustion. The atmospheric lifetime of N2O is approximately 100 years, and its 100-year GWP is currently estimated to be 298 times that of CO_2." (CARB)
Office Paper	Multipurpose copy paper for use in laser printers, fax machines and photocopiers or multifunction devices.
Perfluorocarbons (PFCs)	"PFCs are among the six greenhouse gases to be curbed under the Kyoto Protocol. PFCs are synthetic industrial gases generated as a by-product of aluminum smelting and uranium enrichment. They also are used in the manufacture of semiconductors. There are no natural sources of PFCs. PFCs have atmospheric lifetimes of thousands to tens of thousands of years and 100-year GWPs thousands of times that of CO_2, depending on the specific PFC." (CARB)
pkg	Package
PIR	British Columbia's Provincial Greenhouse Gas Inventory Report (Ministry of Environment and Climate Change Strategy)
PSO	A B.C. public sector organization subject to the government's carbon neutral commitment under the *Climate Change Accountability Act* (formerly the *Greenhouse Gas Reduction Targets Act)*.
RESD	Report on Energy Supply and Demand (Statistics Canada).
STP	Standard Temperature and Pressure

Abbreviation, Acronym or Measure	Definition
Sulphur Hexafluoride (SF_6)	One of the six greenhouse gases to be curbed under the Kyoto Protocol. SF_6 is a synthetic industrial gas largely used in heavy industry to insulate high-voltage equipment and to assist in the manufacturing of cable-cooling systems. There are no natural sources of SF_6. SF_6 has an atmospheric lifetime of 3,200 years. Its 100-year GWP is currently estimated to be 22,800 times that of CO_2." (CARB)
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.
U.S.	United States (of America)

ANNEX 2: Global Warming Potentials

Table 19 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 2007 values from the IPCC's *Fourth Assessment Report*; as such, they represent the standard emission factors to be used at this time in greenhouse gas emissions calculations in British Columbia.[63, 64]

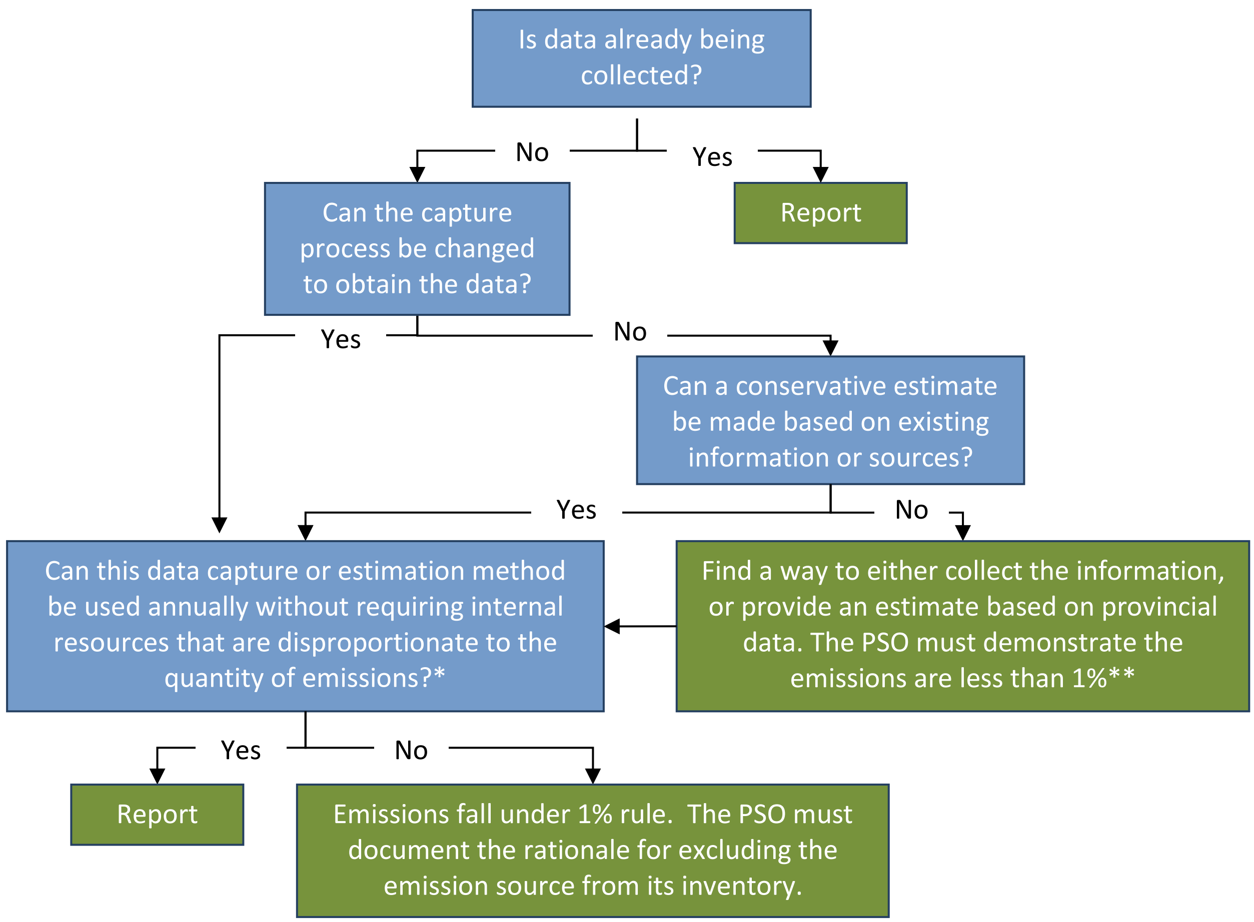
Table 18: Global Warming Potentials

Greenhouse Gas	Chemical Formula	100-Year GWP
Carbon dioxide	CO_2	1
Methane	CH_4	25
Nitrous oxide	N_2O	298
HFC-23	CHF_3	14,800
HFC-32	CH_2F_2	675
HFC-41	CH_3F	92
HFC-43-10mee	$C_5H_2F_{10}$	1,640
HFC-125	C_2HF_5	3,500
HFC-134	$C_2H_2F_4$ (CHF_2CHF_2)	1,100
HFC-134a	$C_2H_2F_4$ (CH_2FCF_3)	1,430
HFC-143	$C_2H_3F_3$ (CHF_2CH_2F)	353
HFC-143a	$C_2H_3F_3$ (CF_3CH_3)	4,470
HFC-152a	$C_2H_4F_2$ (CH_3CHF_2)	124
HFC-227ea	C_3HF_7	3,220
HFC-236fa	C_3H_2F6	9,810
HFC-245ca	$C_3H_3F_5$	693
Perflouro-methane (*)	CF_4	7,390
Perflouro-ethane (*)	C_2F_6	12,200
Perflouro-propane (*)	C_3F_8	8,830
Perflouro-butane (*)	C_4F_{10}	8,860
Perflouro-cyclobutane (*)	c-C_4F_8	10,300
Perflouro-pentane (*)	C_5F_{12}	9,160
Perflouro-hexane (*)	C_6F_{14}	9,300
Sulphur hexafluoride	SF_6	22,800

[63] British Columbia (2015). *British Columbia Greenhouse Gas Inventory Report 2012*, p. 61
[64] Greenhouse Gases marked with an asterisk (*) were added from the *Carbon Neutral Government Regulation*.

ANNEX 3: How to Treat Small Emissions Sources

For many organizations, dealing with small emissions sources can be challenging. For Public Sector Organizations, if an emissions source is onerous to collect *and* is expected to comprise less than 1% of the organization's total emissions inventory, it is considered out of scope. The decision tree below was developed to help PSOs and LGs determine whether or not a certain source of emissions falls under this rule. Other methods to address small emission sources are outlined in the General Reporting Protocol. If, an emissions source is considered out-of-scope after using this decision tree, the source of the emission and the rationale for its exemption should be included as a part of a PSO's self-certification documentation and Carbon Neutral Action Report.



ANNEX 4: Estimating a Building's Energy Use

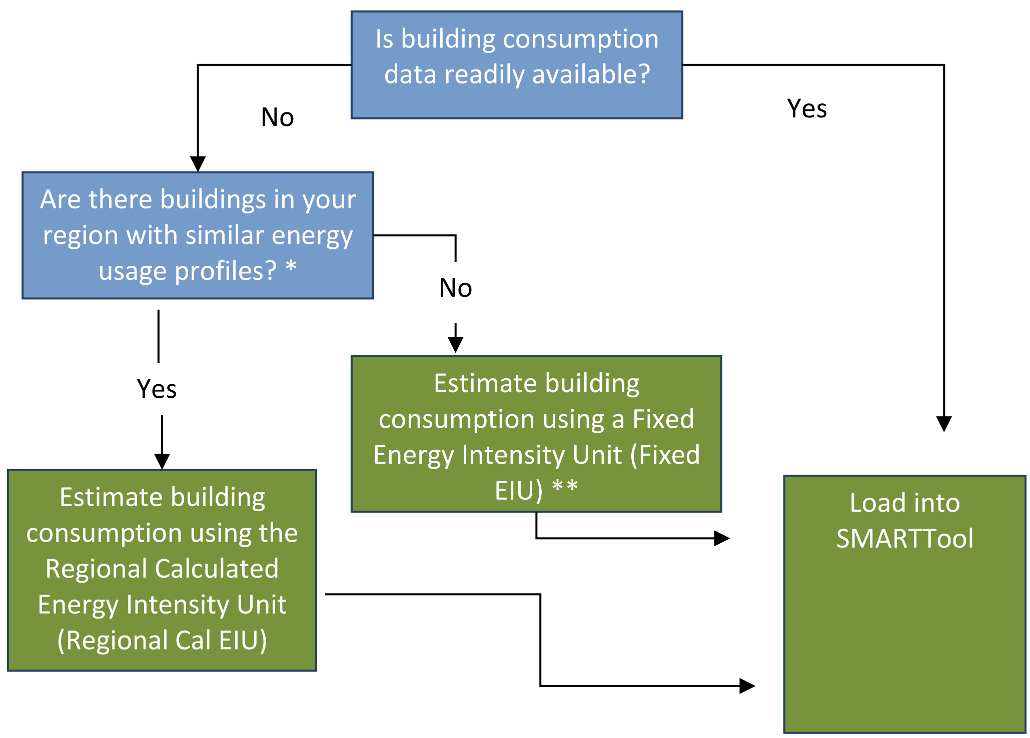
1. Introduction

The following information is intended to provide a summary of the two estimation methods which are currently configured in SMARTTool. These methods estimate energy consumption when such data is not readily available.

These methods rely on a building's Gross Floor Area; the total area, as measured between the principal exterior surfaces of the enclosing fixed walls of the building(s). This includes *all areas* inside the building(s) such as: occupied tenant areas, common areas, stair wells, meeting areas, break rooms, restrooms, elevator shafts, mechanical equipment areas, and storage rooms.[65]

2. Estimation Method Details

Regional Calculated Energy Intensity Unit (Regional Calc EIU)



[65] Energy Star Portfolio Manager (2015). *Glossary 2014*, https://portfoliomanager.energystar.gov/pm/glossary

For this approach to be reasonably accurate, energy data should be available for a sufficient proportion of a PSO's buildings portfolio within the same climatic region. As guidance, it is suggested that energy data should be available for at least 51% of a PSO's buildings in particular classification (e.g., educational facilities) and within the same climatic region. In addition, having at least 2 years of historical data is recommended to smooth out year-over-year variability.

This method allows an organization to estimate its energy use for a given building from data available for similar buildings in their portfolio within the same climatic region. For this approach to be reasonably accurate there must be sufficient known energy per region per building type within the organization.

Using available energy data from a PSO's buildings within a specific climatic region and classification, this approach involves calculating the energy use per square meter (i.e., energy intensity) and applying of that energy intensity to the floor area of the similar buildings requiring estimates. Once consumption is estimated in this way, one applies the appropriate emission factors and GWP to estimate related greenhouse gas emissions.

Table 19: Regional Energy Intensity Unit Estimation Calculation

Step	Formula for each energy type
1. For similar buildings (i.e., office/region1) with data, determine their combined annual consumption for each energy type and divide by their combined floor area	Annual energy type use / Total square meters of related floor area* = Annual Regional Energy Intensity Factor (GJ/year/m^2)
2. Estimate the quantity of each energy type used in the Building to be Estimated (BTBE)	Floor area of the BTBE* x Annual Regional Energy Intensity Factor (GJ/year/m^2) = Annual Energy type Use in BTBE (GJ)
3. Apply the emission factor by energy type to yield total emissions by energy type	Emission Factor (kg/GJ) x Consumption (GJ) = Emissions by GHG (kg)
4. Apply the global warming potentials to yield total emissions	Emissions by GHG (kg) x GWP = Emissions (kg CO_2e)
6. Sum across the gases to calculate total CO2e emissions	**CO_2** + **CH_4** + **N_2O** (all in kg **CO_2e**) = Total **CO_2e**
7. Convert total emissions from kg to tonnes for reporting purposes.	Emissions in kg CO_2e / 1 000 kg / t = Emissions in tonnes CO_2e

*If the floor area of a building has changed within the reporting period, multiply each area by the number of days during the year for which it was effective. Sum the results and divide that sum by the total number of days in the year in order to get a prorated area to use for that year.

Fixed Energy Intensity Unit (Fixed EIU)

This estimation method applies energy intensity factors published by Natural Resources Canada (NRC) through the Office of Energy Efficiency (OEE) Comprehensive Energy Use Database[66]. This database includes statistics on energy use by province, building use, type and energy type.

Calculation:

Table 20: Fixed Energy Intensity Unit Estimation Calculation

Step	Formula for each Energy type
1. For each energy type, determine the annual consumption amount.	EIU (GJ/month/m^2) x square meters of floor area [a] x 12 months = annual consumption amount (GJ)
2. Apply the emission factor by energy type to yield total emissions by energy type	Emission Factor (kg/GJ) x Consumption (GJ) = Emissions by GHG (kg)
3. Apply the global warming potentials to yield total emissions	Emissions by GHG (kg) x GWP = Emissions (kg CO_2e)
4. Sum across the gases to calculate total CO2e emissions	**CO_2** + **CH_4** + **N_2O** (all in kg **CO_2e**) = Total **CO_2e**
5. Convert total emissions from kg to tonnes for reporting purposes.	Emissions in kg CO_2e / 1 000 kg / t = Emissions in tonnes CO_2e

a. If the area of a building has changed within a monthly reporting period, multiply each area by the number of days during the month for which it was effective. Sum the results and divide that sum by the total number of days in the month in order to get a prorated area to use for that month.

The fixed EIUs in Table 22 below represent British Columbia EIUs from the (2012) NRCAN Comprehensive Energy Use Database. Note SMARTTool has also been configured with fixed EIUs

[66] Natural Resources Canada (NRC) through the Office of Energy Efficiency (OEE) Comprehensive Energy Use Database (2012)

for public sector organizations that have investment properties in Alberta, Quebec, Ontario, Nova Scotia, and oversees as well.

Table 21: Fixed Energy Intensity Units (EIU) Factors (GJ / Month / m2) for British Columbia

Building Classification	District Energy	Heating	Heating, Cooling, Lights & Plugs	Lights & Plugs
Arts, Entertainment and Recreation	0.0484	0.0484	0.0845	0.0361
Banking and Financial	0.0367	0.0367	0.0651	0.0284
Education	0.0397	0.0397	0.0692	0.0295
Food Services	0.0701	0.0701	0.1167	0.0466
Health Care and Social Assistance	0.0644	0.0644	0.1104	0.0460
Information and Cultural	0.0327	0.0327	0.0572	0.0245
Lodging	0.0273	0.0273	0.0482	0.0209
Office	0.0367	0.0367	0.0651	0.0284
Other Services	0.0418	0.0418	0.0729	0.0311
Public Services	0.0418	0.0418	0.0729	0.0311
Retail Trade	0.0404	0.0404	0.0703	0.0299
Transportation	0.0391	0.0391	0.0611	0.0220
Warehousing	0.0345	0.0345	0.0600	0.0255

Hybrid Energy Estimations

In some instances, energy data may be available for one energy type in a building; but not for another. It is appropriate then to estimate the unknown energy type using one of the methods above.

Similarly, the regional calculation may be used to estimate one energy type within a building if, while other energy types in the same building may use the Fixed EIU.

ANNEX 5: Business Travel Methodology

Beginning with the 2016 reporting year, the business travel emissions of Provincial government have been quantified using data collected through a combination of:

- iExpenses (the system used to reimburse employees for out-of-pocket travel expenses); and
- the government's accounting system which also tracks:
  - ministry directly-paid expenditures on airfare;
  - employee travel vouchers for travel on other modes.

Annex 5 includes:

- Description of the approaches based on iExpenses data and other expenditure data
- Details of the calculations underlying distance-based emission factors
- Details of the calculations underlying spend-based emission factors

1. iExpenses: Distance and Spend-Based Methods

Employees using iExpenses enter mandatory information about their business trips, including the type of expense they incurred (see column 2 in the Table 23 below), the travel mode (column 3) and fuel used along with other details (column 4).

Total kilometers travelled are determined/captured by the system where employees travel by:

- air or ferry on common routes;
- between common origin/destination combinations; and
- rental/personal vehicle,

The distance data in combination with mode and fuel type then enables the application of the distance-based method to quantify related emissions.

However, not all iExpenses entries include the data points necessary for the distance-based method. Employees who travel by air or ferry on rarely-used routes or between small cities are unable to select the specific locations from which they depart and arrive. In these situations, they select "Other" or "Other BC" and GHGs must be calculated using a spend-based method.

Column 6 of Table 23 below indicates which section of Annex 5 provides more detail on the related estimation methods in Colum 5.

Table 22: iExpenses Business Travel Selections

(1) Employee's Travel Mode	(2) iExpenses "Expense Type" Selection	(3) iExpenses "Travel Mode" Selection	(4) Key iExpenses Dropdown Selection	(5) GHG Estimation Method	(6) Annex 5 Section w/ Detailed Description
Air Travel, common routes	Air You Paid	Helicopter, Airplane, Float Plane	Route	Distance-Based	3.3.1
Air Travel, Other routes	Air You Paid	Helicopter, Airplane, Float Plane	"Other" or "Other BC" as Route option	Spend-Based	4.1
All rental vehicles	Car Rental	Car, other, Truck/SUV	Fuel type, vehicle type	Distance-Based	3.1
Ferries	Ferry	N/A	Route	Distance-Based	3.2
Ferries	Ferry	N/A	"Other"	Spend/Route-Based	3.2
Personal vehicle	Mileage	Car, other, Truck/SUV	Fuel type, vehicle	Distance-Based	3.1
Rail, inter-city bus, other public transport	Public Transport	Other	N/A	Spend-Based	4.2.3
Taxis	Public Transport	Taxi	N/A	Spend-Based	4.2.3
City Bus, Skytrain, Seabus,	Public Transport	Transit	N/A	Spend-Based	4.2.3
Accommodation	Accommodation	Hotel, Private, Other	N/A	No Change	See Page 30

2. Other Accounting System Data: Spend-Based Method

In addition to iExpense tracking of employee out-of-pocket travel expenses are those travel expenditures tracked within the government accounting system representing:

- ministry directly-paid expenditures on airfare;
- employee (paper-based) travel vouchers for travel on other modes.

Column 5 of Table 24 below indicates which section of Annex 5 provides more detail on the related travel mode in Column 4.

Table 23: iExpenses Business Travel Selections

(1)	(2) Subaccount	(3) Travel Mode Possibilities	(4) Most Frequent Travel Mode	(5) Annex 5 Section with Detailed Description
Directly Paid Air Travel	Victoria to Vancouver	Float plane, helicopter, short-haul air	Float Plane	4.1
	In-Province	Short haul flights; medium haul air	Short Haul	
	Out-of-Province	Medium and long haul flights	Long Haul	
	Out-of-Canada	Long haul flights	Long Haul	
Travel Voucher On Other Modes	Victoria to Vancouver	All ground transport modes and accommodations	N/A	4.2.4
	In-Province			
	Out-of-Province			
	Out-of-Canada			

3. Distance-Based Emission Factors

3.1 Car, Truck, or SUV

Description: This section covers travel by taxis, rental cars and business use of personal vehicles. It provides distance-based emission factors based on average fuel efficiencies for common combinations of vehicle and fuel type. Vehicle types are: (1) cars (including hybrid electric vehicles); and (2) pickup trucks/SUVs. Fuel types are: (1) gasoline; (2) diesel; (3) propane; and (4) natural gas. Fuel efficiencies have been expressed in liters per 100 kilometers driven and emission factors, in kilograms per 100 kilometers.

Data sources: For road travel, both the US Environmental Protection Agency (EPA) and NRCan publish "city" and "highway" fuel economy ratings by vehicle manufacturer and model.[67]
It is expected that most government travel falls between the conditions modeled for city and highway driving, tending closer to city estimates.[68] In 2008, the EPA established new best practices for measuring fuel economy that indicated lower fuel efficiency – or increased L/100 km – than previous measurements.[69] Accordingly, fuel economy ratings that predate 2008 are adjusted upwards.

The Insurance Corporation of British Columbia (ICBC) maintains non-public records of the composition of the provincial vehicle fleet. These data were used to develop weighted-average fuel efficiencies for hybrid, natural gas and propane vehicles in Table 25. For gasoline and diesel vehicles, data was obtained from Natural Resources Canada[70]. Distances for road travel can be derived from the Government of B.C.'s Traveller Information System.[71]

An average fuel efficiency factor of 0.2 kWh/km has been supplied for electric vehicles.[72] It should be noted that when charging an electric vehicle at a building owned by your organization, the emissions for charging the vehicle will likely already be attributed to that building.

Calculations: In the case of road travel, an uplift factor of 7.8 percent was applied to the 2007 NRCan fuel economy ratings for city driving to better reflect real-world fuel efficiencies. NRCan city ratings were then applied to 2007 ICBC data on the provincial vehicle stock by model, year, fuel type and other characteristics to derive average fuel efficiency estimates for each vehicle/fuel type listed in Table 25.

To calculate GHG emissions, the quantity of fuel consumption was first estimated by multiplying the average fuel efficiency for the particular vehicle/fuel type by the kilometers driven. Then, the appropriate emission factor was applied to this fuel consumption estimate.

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[67] US EPA (2015). *Model Year 2015 Fuel Economy Guide*, and NRCan (2014), *Fuel Consumption Guide 2015*.
[68] The NRCan city ratings have been used here for a number of reasons. For example, most highway driving in the province's metropolitan areas is characterized by considerable congestion, leading to higher fuel consumption. In the Interior, fuel efficiencies are likely to be higher than the theoretical (best practices) NRCan ratings, given weather and terrain. As a result, the city ratings can be assumed to capture some of the actual highway driving efficiencies in B.C. and lead to a more conservative estimate of the GHG emissions from business road travel.
[69] See: www.epa.gov/fueleconomy/.
[70] See: http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/menus/trends/comprehensive/trends_tran_bct.cfm
[71] See: http://drivebc.ca/directions.html
[72] See: http://www.world-nuclear.org/information-library/non-power-nuclear-applications/transport/electricity-and-cars.aspx

Table 24: EMISSION FACTORS (Distance Based): Car/Truck/SUV Travel

(1) Travel Mode	(2) Vehicle/Fuel Type	(3) Average Fuel Efficiency [a]	(4) Emission Factor (kg/L)[b]	(5)	(6)	(7)	(8)	(9) CO_2e kg / km = (8) / (3)
			Bio CO_2	CO_2	CH_4	N_2O	CO_2e	
Car (includes Taxi)	Gasoline	9.2 L/100 km [f]	0.0755	2.200	0.00023	0.00047	2.346	0.22
	Diesel	7.2 L/100 km [f]	0.0990	2.582	0.000051	0.00022	2.649	0.19
Car (includes Taxi)	Hybrid	7 L/100 km	0.0755	2.200	0.00023	0.00047	2.346	0.16
	Natural Gas[c]	5.4 kg/100 km [d]	–	2.738	0.013	0.000086	3.089	0.17
	Propane	8.2 L/100 km	–	1.515	0.00064	0.000028	1.539	0.13
Light Truck (includes SUV and Minivan)	Gasoline	12.3 L/100 km [f]	0.0755	2.200	0.00024	0.00058	2.379	0.29
	Diesel	10.8 L/100 km [f]	0.0990	2.582	0.000068	0.00022	2.650	0.29
	Hybrid	10 L/100 km	0.0755	2.200	0.00024	0.00058	2.379	0.24
	Natural Gas[c]	8.3 kg/100 km [d]	–	2.738	0.013	0.000086	3.089	0.26
	Propane	12.6 L/100 km	–	1.515	0.00064	0.000028	1.539	0.19
Electric Vehicle	Electricity	20 kWh/100 km	–	0.010[e]	–	–	0.010[e]	0.00

a. From Natural Resources Canada, ICBC, and BC Ferries sources (see Data Sources, below.)

b. From Environment Canada 1990-2014 NIR.

c. Emission factors adapted from NIR figures, converted to kg of natural gas, the common units for vehicle natural gas.

d. kg/ 100km figure for Natural Gas calculated based on 1.516 L/ kg gasoline equivalency.

e. kgCO2 per kWh

f. From Natural Resources Canada's Comprehensive Energy Use Database

3.2 Ferry

Description: This section estimates the emission factor for ferry travel based on average ferry fuel efficiency. In the context of ferry travel, fuel efficiencies have been expressed in horsepower-litres per kilometer travelled and related emission factors, in kilograms per passenger per 100 kilometers.

Data Sources: Neither BC Ferries nor Environment and Climate Change Canada currently publish comprehensive data on GHG emissions from ferry travel. However, public data on fuel consumption, route length and passenger capacity have been previously available from various BC Ferries sources and have been used in estimating average emissions per passenger per 100 kilometers below.[73]

Calculation: Table 26 below illustrates the calculation of average ferry fuel efficiency using 2005/06 data on diesel consumption for five ferry routes.

[73] British Columbia Ferry Services Inc. (2006). *Fuel Consumption Reduction Plan*, p. 8; BC Ferries (2015). *Routes and Schedules Regional Index*; and BC Ferries (2015). *Variety…The Spice of Our Fleet.*

Table 25: Average Fuel Efficiency Calculation for Ferries

(1) Route	(2) Vessel Class	(3) HP	(5) Distance (km)	(6) Fuel Consumption (L)	(7) L/ km = (6) / (5)	(8) Fuel Efficiency HP/ L/ km = (3) / (7)
Vancouver – Victoria	Spirit Class	21,394	44.4	4200	95	226.17
Vancouver – Victoria	V Class	8,941	44.4	2400	54	165.41
West Van – Bowen Island		7,305	5.6	135	24	303.02
Alliford Bay – Skidegate		730	6.5	66	10	71.89
Vancouver – Salt Spring		6,000	40.7	1515	37	161.19
					Average HP/ L / km =	185.55

The average fuel efficiency of 185.55 HP/L/km was then applied to each of BC Ferries' 22 routes based on route-distance and horsepower to estimate total annual diesel fuel consumption by route. Then for each route, total estimated diesel consumption was divided by the route distance and the estimated passenger load (assuming 80 percent of each ferry's total passenger capacity) to produce a per passenger fuel efficiency factor. These route-based fuel efficiencies per passenger were then averaged over the 22 routes to yield an overall average fuel efficiency of 5.1 L/passenger-100 km. To determine the related ferry emissions factor, the emission factor for marine diesel per liter was divided by the average fuel efficiency per passenger as shown in Table 27 below.

Table 26: EMISSION FACTORS (Distance Based): Ferry Travel

(1) Travel Mode	(2) Vehicle/Fuel Type	(3) Average Fuel Efficiency[a]	(4)	(5)	(6)	(7)	(8)	(9) CO₂e
			Emission Factor (kg/L)[b]					
			Bio CO_2	CO_2	CH_4	N_2O	CO_2e	kg/psg-100km = (8) / (3)
Ferry	**Diesel**	5.1 L/psg-100 km	0.0990	2.582	0.00015	0.0011	2.914	**0.5765**

a From Natural Resources Canada, ICBC, and BC Ferries sources (see Data Sources, below.)
b From Environment Canada 1990-2013 NIR.

Greenhouse gas emissions by ferry route was then estimated using this emission factor and the distance travelled where the latter was based on route length as travelled by the ship, as opposed to the straight line distance between starting and destination points.

If a ferry route is entered as "other," the emission factor for Victoria/Vancouver is used, as travel between the mainland and Vancouver Island makes up over 90% of trips. It is likely that many of these "other" trips are shorter than the mainland-Island route, perhaps between Gulf Islands or from Vancouver Island to the Gulf Islands, meaning this assumption is conservative.

3.3 Air and Public Transport

Description: This section provides the emission factors for air travel and other forms of public transport in BC including bus, skytrain, sea bus, and rail. Emission factors are based on data from third party sources (i.e. NRCan, Translink) and expressed in emissions per passenger kilometer.

Data sources: NRCan publishes information on total Canadian GHG emissions and passenger-km for a number of transportation modes, including urban transit (city buses) and inter-city buses.[74] The 2012 year was the most recent year for which data was available at the time of the creation of the emission factors.

3.3.1 Air Transport

While NRCan also publishes aggregate data on GHG emissions and passenger-km for air travel, no breakdown is provided for haul distance. In contrast, the UK Department of Environment, Food and Rural Affairs (DEFRA) have estimated emission factors for three categories of flights:

(1) domestic;
(2) short haul international; and
(3) long haul international.[75]

Airplane: For the B.C. government's purposes, the forgoing DEFRA categories have been applied as follows:

(1) the domestic emission factor has been applied to short haul flights;
(2) the short haul international emission factor has been applied to medium haul flights; and
(3) the long haul international emission factor has been applied to long haul flights.[76]

The DEFRA air travel emission factors have been adjusted to include an eight percent uplift factor. This adjustment is based on the recommendation of the Intergovernmental Panel on Climate Change (IPCC) to account for discrepancies between geographical distance and actual flight distance.[77] These discrepancies can result from conditions such as non-linear routing that is not the shortest direct distance, delays or circling and routings of take-off and landing. BC's distance-based method uses the shortest geographical distance between the starting point and the destination. The eight percent uplift factor is used to adjust for the difference between this shortest distance calculation and the actual travel path of the aircraft.

Helicopter & Floatplane: The emission factor for helicopter and floatplane travel was calculated based on 2007 fuel consumption data provided by carriers operating flights between Vancouver harbour and Victoria harbour (Helijet and Harbour Air). Also incorporated in the emission factor is the average passenger load reported by Canadian airlines for 2007 and an estimated flight distance that accounts for the non-direct route between Vancouver and Victoria harbours.

3.3.2 Public Transport

Taxi: The distance-based emission factor for taxi has been conservatively assumed to be that for a gasoline fueled car.

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[74] NRCan (2015). Comprehensive Energy Use Database, 1990-2012
[75] DEFRA (2015). 2015 Greenhouse Gas Conversion Factor Repository.
[76] The DEFRA categories are applied on the basis of distance rather than destination because conditions of European air travel vary substantially from those in B.C. (e.g., a typical Canadian domestic flight is likely to be much longer than a typical UK domestic flight).
[77] IPCC (1999). *Aviation and the Global Atmosphere*, Section 8.2.2.3. http://www.ipcc.ch/ipccreports/sres/aviation/index.php?idp=118

Urban and Inter-city Buses: The emission factors for urban and inter-city buses have been calculated by dividing total GHG emissions for 2012 (NRCan data) by the total passenger-kilometres.

Skytrain & Sea Bus: For reporting years earlier than 2013, the emissions factors for Skytrain[78] and Sea Bus[79, 80] travel were based on publicly available information. Since 2013, related emissions factors have been calculated in the same way based on data directly obtained from TransLink.

Rail: The emission factor for rail has been calculated by dividing the Natural Resources Canada data on total passenger rail emissions in BC by the corresponding passenger-kilometres[81].

Table 27: EMISSION FACTORS (Distance-Based): Air and Public Transport

	Travel Mode	Emission Factor ($kg\ CO_2e$/psg-km)
Air Transport[82]	Float Plane	**0.2130**
	Helicopter	**0.4470**
	Airplane - Short Haul (0 km-463 km)	**0.1576**
	Airplane - Medium Haul (463 km-1,108 km)	**0.0897**
	Airplane - Long Haul (>1,108 km)	**0.1048**
Public Transport	Taxi (from Table 25)	**0.22**
	City Bus[83]	**0.1014**
	Other (Inter-city Bus) [84]	**0.05243**
	Skytrain [85]	**0.002334**
	Sea Bus [86]	**0.1547**
	Rail [87]	**0.1215**

78 TransLink Sustainability Report (2010). Psg-km data: Appendix 2.7, p.88; Emission data: Appendix 2.8, p.89
79 TransLink Sustainability Report (2010). p.88; Emission data: Appendix 2.8, p.89
80 TransLink Annual Report (2008). Psg-km data: p. 2
81 NRCan (2015). Comprehensive Energy Use Database, 1990-2012
82 DEFRA (2015). 2015 Greenhouse Gas Conversion Factor Repository.
83 NRCan (2015). Comprehensive Energy Use Database, 1990-2012
84 Ibid.
85 TransLink Sustainability Report (2010). Psg-km data: Appendix 2.7, p.88; Emission data: Appendix 2.8, p.89
86 TransLink Sustainability Report (2010). p.88; Emission data: Appendix 2.8, p.89
87 NRCan (2015). Comprehensive Energy Use Database, 1990-2012

4. Spend-Based Emission Factors

This section describes how emission factors have been determined for various travel modes when related expenditure data but little or no distance data is available. This approach generally involves the following algorithm for each travel mode when determining the associated emissions per dollar of expenditure.

Equation 1:

$$\frac{\text{Travel Mode's } \textbf{Distance-Based} \text{ Emission Factor (kg CO2e / km)}}{\text{Travel Mode's Cost per kilometer (\$ / km)}} = \text{Travel Mode's } \textbf{Spend-Based} \text{ Emission Factor (kg CO2e/ \$)}$$

Table 29 below provides the spend-based emission factors for various air transport modes using Equation 1:

Table 28: EMISSION FACTORS (Spend Based): Air Transport

(1) Air Transport Mode	(2) Distance-Based Emission Factor (kg CO2e/psg-km) (from Table 27)	(3) Average [a] Cost $ / km	(4) = (2) ÷ (3) **Spend-Based Emission Factor (kg CO2e/ $)**	(5) For these iExpenses destinations	(6) For these Directly-Paid Ministry Expend. Accounts
Float Plane	0.2130	1.52	**0.1400**	"Other" or "Other BC"	n/a
Helicopter	0.4470	2.25	**0.1990**	"Other" or "Other BC"	Victoria-Vancouver
Airplane - Short Haul	0.1576	0.93	**0.1700**	n/a	In Province
Airplane - Medium Haul	0.0897	0.75	**0.1190**	n/a	In Canada
Airplane - Long Haul	0.1048	0.81	**0.1290**	n/a	Outside Canada
Airplane – Weighted average of Short/Med/Long Haul	0.1480 [b]	0.87 [b]	**0.1700** [b]	"Other" or "Other BC" [b]	n/a

a. The average cost per kilometer has been calculated based on travel expenditures captured by iExpenses for each air transport mode and related distance as reported by SMARTTEC between 2011 and 2015.
b. In the absence of distance data, it is not possible to distinguish between short-, medium- and long haul airplane travel. In this case, a weighted average of the distance-based emission factors for those air travel categories has been used. The weighting is based on total distance reported by SMARTTEC for each category during the period between 2011 & 2015.

Air Transport - iExpenses

Within the context of air travel tracked through iExpenses, the spend-based emission factors noted in column (5) of Table 29 were applied to the business travel of employees who selected:

- float plane, helicopter, airplane as travel modes; and
- "Other" or "Other BC" as their destinations.

Air Transport – Ministry Directly-Paid Expenditures

In the context of ministry directly-paid expenditures on travel, expenditures are tracked within sub-accounts representing air travel:

- between Victoria/Vancouver;
- in-province travel;
- out-of-province travel; and
- out-of-country travel.

The air transport options for these subaccounts are presented in Table 30. The emission factor selected for each subaccount was based on historical SMARTTEC data which identifies the modes most frequently taken for each subaccount (i.e., trip category).

Table 29: EMISSION FACTORS (Spend Based): Ministry Directly-Paid Air Transport

(1) **Directly Paid Subaccount**[88]	(2) **Air Transport Options**	(3) **Common Air Transport Modes**	(4) **Emission Factor** kg CO_2e / $
Victoria to Vancouver	Float Plane, Helicopter, Short-Haul	Helicopter, float plane	**0.199**
In-Province	Short Haul; Medium Haul	Short Haul	**0.170**
Out-of-Province	Medium and long haul flights	Long Haul, Medium Haul	**0.119**
Out-of-Canada	Long haul flights	Long Haul	**0.129**

[88] The account numbers for these subaccounts are as follows: 5711 for Victoria to Vancouver; 5712 for In Province, 5713 for Out of Province and 5714 for Out-of-Canada

4.1 Public Transport

Table 31 below provides the spend-based emission factors for various modes of public transport. For the most part, these emission factors were determined using either Equation 1above and Equation 2 below:

Equation 2: Travel Mode's **Average Emissions per Trip** (kg CO_2e / trip) ÷ Travel Mode's **Cost per Trip** ($ / trip) = Travel Mode's **Spend-Based** Emission Factor (kg CO_2e/ $)

Table 30: EMISSION FACTORS (Spend-Based): Public Transport

(1) Public Transport Mode	(2) Distance-Based Emission Factor kg CO2e/psg-km (from Table 25)	(3) Emission per Trip kgCO2e/trip	(4) Average * Cost $ / km orr $ / trip	(5) = (2) or (3) ÷ (4) Spend-Based Emission Factor kg CO2e/ $	(6) For these iExpenses destinations	(7) For these Travel Voucher Accounts	(8) Estimation Equation #
Taxi	0.22	-	2.30/km	**0.0956**	ALL		1
Transit							
City Bus	-	1.2900	2.50/trip	0.5200			2
Skytrain	-	0.1050	4.00/trip	0.0260			2
Seabus	-	0.5020	2.75/km	0.1830			2
Transit Weighted Ave				**0.1280**	ALL		
Other							
Rail	0.1215	-	0.31/km	0.3919			1
Intercity Bus	-	-	-	0.5200			2
Other Weighted Ave				**0.5156**	ALL		
Travel Voucher Modes				0.2900		ALL	

The following sections provide an elaboration of the calculations involved in Table 31 above.

4.1.1 Taxi

The spend-based emission factor for Taxi was calculated using Equation 1 which requires:

- Average taxi cost per kilometer; and
- Taxi emissions per kilometer

<u>Average Taxi Cost Per Kilometer</u>
All taxis in British Columbia charge rates regulated by the Passenger Transportation Board, an independent tribunal of the Ministry of Transportation and Infrastructure[89]. Rates across British Columbia vary only slightly. The rates used for the purposes of quantifying business travel emissions are the provincial average as stated by the Board:

[89] http://www.ptboard.bc.ca/taxi-rates.htm

- **Flag Fee:** \$3.32: The flag fee is the automatic minimum fee a passenger pays for a taxi. When you order a taxi, the meter will already be at \$3.32 when you step inside[90].
- **Per Kilometer Fee:** \$2.03: Passengers are charged this fee for every kilometer they travel in a taxi, as long as the taxi is not in traffic and forced to drive slowly. If it is, the following fee may apply.
- **Wait Time:** \$40.79 per hour: This fee is charged if the taxi has to wait or slow.

According to two major taxi companies in Victoria and Vancouver, the average trip cost and length was:

- Victoria: \$21; 9.0 km; and
- Vancouver: \$15; 6.5 km,

yielding an average cost of \$2.30/km.

Average Taxi Emissions Per Kilometer
Based on the conservative assumption that taxis are generally standard gasoline-fuelled cars, the distance based emission factor is 0.22kg of CO_2e per km travelled. (Refer to Table 25 and Table 28).

Spend-Based Taxi Emission Factor
Using Equation 1 and the information above, the spend-based emission factor for taxi travel is calculated as follows

Travel Mode's **Distance-Based** Emission Factor (kg CO2e / km)	÷	Travel Mode's **Cost per kilometer** (\$ / km)	=	Travel Mode's **Spend-Based** Emission Factor (kg CO2e/ \$)
0.22 kg CO2e/km	÷	\$2.30/km	=	**0.0956 kg CO_2e / \$**

4.1.2 Transit

Employees who travel on a city bus, the Skytrain, or Seabus must select "Transit" within the iExpenses system. For this reason, the spend-based emission factor for the Transit travel mode was calculated as a weighted average of the city bus, Skytrain and Seabus factors, weighted by the number of trips recorded in SMARTTEC/iExpenses linked database for the period 2008-2016.

CITY BUS

The spend-based emission factor for City Bus was estimated using Equation 2 which requires:

- Average City Bus cost per trip; and
- Average City Bus emissions per trip

Average Cost Per Trip
A standard trip on a city bus costs \$2.50 in Victoria and \$2.75 in Vancouver. Fares tend to be cheaper in the rest of the province. Therefore, \$2.50 was used as the standard price of one bus trip.

[90] \$3.32 is the typical flag fee, but this may change slightly on a case by case basis.

Average Emissions Per Trip

BC Transit's Carbon Neutral Action Report provides data on the total emissions from BC Transit operations: 64,582 tonnes, or 64,582,000 kilograms, of CO_2e in 2015[91]. BC Transit reports approximately 50 million rides annually[92], which leads to the following average emissions per trip:

$$64{,}582{,}000 \; / \; 50{,}000{,}000 \; = 1.29 \text{ kg } CO_2e \text{ per trip}$$

Spend-Based City Bus Emission Factor

Using Equation 2 and the information above, the spend-based emission factor for City Bus travel is calculated as follows

Travel Mode's **Emissions per Trip** (kg CO2e / trip)	÷	Travel Mode's **Cost per Trip** ($ / trip)	=	Travel Mode's **Spend-Based** Emission Factor (kg CO2e/ trip)
1.29 kg CO2e/trip	÷	$2.50/trip	=	**0.5200 kg CO_2e / $**

SKYTRAIN

The spend-based emission factor for Skytrain was estimated using Equation 2 which requires:

- Average Skytrain cost per trip; and
- Average Skytrain emissions per trip.

Average Skytrain Cost Per Trip

Skytrain fares depend on the number of zones travelled (1, 2 or 3). Many different possibilities exist for trip distance within each zone. This estimate uses the price for a 2 zone trip ($4.00) combined conservatively with the longest distance logged in the system over the lifespan of SMARTTEC, approximately 45 kilometers.

Average Skytrain Emissions Per Trip

Using the 45 kilometer distance per trip noted above, and the distance-based emission factor of 0.002334 kg CO_2e/km (refer to Table 28), a standard trip will generate 0.105 KG of CO_2e.

Spend-Based Skytrain Emission Factor

Using Equation 2 and the information above, the spend-based emission factor for Skytrain travel is calculated as follows:

Travel Mode's **Emissions per Trip** (kg CO_2e / trip)	÷	Travel Mode's **Cost per Trip** ($ / trip)	=	Travel Mode's **Spend-Based** Emission Factor (kg CO_2e / trip)
0.105 kg CO_2e /trip	÷	$4.00/trip	=	**0.0260 kg CO_2e / $**

91 https://bctransit.com/servlet/documents/1403646319880

92 https://bctransit.com/*/about/sustainability, Ridership number confirmed via phone call March 2017

SEABUS

The spend-based emission factor for Seabus was estimated using Equation 2 which requires:

- Average Seabus cost per trip; and
- Average Seabus emissions per trip.

Average Seabus Cost Per Trip

A one-way trip on the Seabus costs $2.75.

Average Seabus Emissions Per Trip

Based on 3.25 km distance for a one-way Seabus trip, and the distance-based emission factor of 0.1547 kg CO_2e/km (refer to Table 28), a one-way Seabus trip will generate 0.502 kg CO_2e per passenger.

Spend-Based Seabus Emission Factor

Using Equation 2 and the information above, the spend-based emission factor for Seabus travel is calculated as follows:

Travel Mode's **Emissions per Trip** (kg CO_2e / trip)	÷	Travel Mode's **Cost per Trip** ($ / trip)	=	Travel Mode's **Spend-Based** Emission Factor (kg CO_2e/ trip)
0.502 kg CO_2e /trip	÷	$2.75/trip	=	**0.1830 kg CO_2e / $**

WEIGHTED AVERAGE - TRANSIT

The spend-based emission factor for the Transit travel mode was calculated as a weighted average of the City Bus, Skytrain and Seabus factors, weighted by the number of trips recorded in SMARTTEC/iExpenses linked database for the period 2008-2016. According to the data, there were 378 City Bus trips, 1,471 Skytrain trips, and 51 Seabus trips. Using these values as relative weights, the Transit spend-based emission factor is:

$$\frac{378(0.5200)+1{,}471(0.0260)+51(0.1830)}{378+1471+51} = 0.128 \text{ kg } CO_2e \text{ / \$}$$

4.1.3 Public Transport: Other

Employees who travel by rail and inter-city buses must select "Other" under Public Tranport within the iExpenses system. For this reason, the spend-based emission factor for the Transit travel mode was calculated as a weighted average of the factors for these two modes of travel, weighted by the number of trips recorded in SMARTTEC/iExpenses linked database for the period 2008-2016.

RAIL

The spend-based emission factor for Rail was estimated using Equation 1 which requires:

- Average cost of Rail per kilometer; and
- Average Rail emissions per kilometer.

Average Cost of Rail Per Kilometer
SMARTTEC/iExpenses data for the period 2008-2016 shows 36 rail trips at an average cost of \$0.31/km.

Average Rail Emissions Per Kilometer
The distance-based emission factor for Rail is 0.1215 kg CO_2e/km (Refer to Table 28).

Spend-Based Rail Emission Factor
Using Equation 1 and the information above, the spend-based emission factor for Rail travel is calculated as follows:

Travel Mode's **Distance-Based** Emissions Factor (kg CO_2e / km)	÷	Travel Mode's **Cost per Kilometer** (\$ / km)	=	Travel Mode's **Spend-Based** Emission Factor (kg CO_2e/ \$)
0.1215 kg CO_2e /km	÷	\$0.31/km	=	**0.3919 kg CO_2e / \$**

INTERCITY BUS

In the absence of reliable cost data, the spend based emission factor City Bus of **0.5200 kg of CO_2e /\$** has been applied to Inter-City Buses. This is a conservative approach given that Table 11 of NRCan (2015)[93] shows Inter-City Buses emit approximately half the emissions of City Buses.

WEIGHTED AVERAGE – PUBLIC TRANSPORT, OTHER

The spend-based emission factor for the "Other" public transport mode was calculated as a weighted average of the Rail and Intercity Bus factors, weighted by the number of trips recorded in SMARTTEC/iExpenses linked database for the period 2008-2016. According to the data, there were 36 Rail trips and 748 Inter-City Bus trips. Using these values as relative weights, the "Other" spend-based emission factor is:

$$\frac{(36\times0.4300)+(748\times0.5200)}{36+748} = .51 \ \textbf{kg CO}_2\textbf{e / \$}$$

[93] NRCan (2015). Comprehensive Energy Use Database, 1990-2012

4.1.4 Travel Vouchers: "Other Modes"

A small percentage (approximately 7%) of total expenditures on business travel are attributed to employees use of travel vouchers, which provide a paper-forms approach for employees to obtain reimbursement for their travel expenses, and therefore unable to use iExpenses. This option is available to employees without access to a computer. Employees generally submit completed forms to their finance staff for entry into the government's accounting system.

In this case, the travel involved can include all forms of public transport: ferry, bus, taxi, personal vehicles, transit and accommodations. However, the accounting system provides no details about such travel other than approximate destinations based on the following sub-accounts[94]:

- Victoria/Vancouver;
- in-province;
- out-of-province; and
- out-of-country.

The estimation of the emission factor for these subaccounts was based on a highly simplified approach, using an estimated total value for business travel emissions based on emission values from previous years:

$$\frac{\text{Estimated Total Business Travel Emissions (kg CO2e)}}{\text{"Other Modes" Business Travel Expenditures (\$)}} = 0.2900 \text{ kg CO2e / \$}$$

In the future, this factor will be used to estimate the emissions from the other, non-standard, business travel expenses.

[94] The account numbers for these subaccounts are as follows:

- Victoria/Vancouver: 5701, 5720, 5730
- In-province: 5702, 5731
- Out-of-province: 5704, 5722, 5735, 5703, 5721, 5732, 5705, 5706
- Out-of-country: 5735

ANNEX 6: Selected References

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ANNEX 7: Document Version Control

Reporting Year	Page(s)	Updates Include:
2018	Section 1	Updated dates from 2017 to 2018
2018	9, 12	Updated Carbon.Neutralapps@gov.bc.ca to Carbon.Neutral@gov.bc.ca
2018	7, 8, 29	Changed *Greenhouse Gas Reductions Target Act* (GGRTA) to *Climate Change Accountability Act* (CCAA)
2018	Section 3.2	Removed reference to the conversion of compressed natural gas to litres of gasoline and diesel as the web references are no longer valid
2018	Annex 1	Updated Glossary of Terms and Acronyms
2017	TOC	Removed Section 1.5 Structure of Best Practices Guide
2017	Section 1.3	Reference to the National Inventory Report: Greenhouse Gas Sources and Sinks in Canada updated from 1990-2013 to 1990-2014
2017	Table 1, Table 2	Marine Diesel Emission Faction for CH4, N2O and CO2e updated
2017	Table 1, Table 2	Wood Fuel - Residential emission factor for BioCo2, CH4, N2O and CO2e updated
2017	Section 2.2	Electricity emission factors for Quebec and Nova Scotia added
2017	Table 3	Emission factors updated for BC Hydro, Kyoquot Power, Hemlock Valley, Alberta, Ontario, United Kingdom, India, Japan, China, Hong Kong, Nova Scotia, Quebec
2017	Table 4	Added Table 4: Historical Emission Factors for Purchased Electricity
2017	Table 7	Updated Emission Factors for Fleet: Off-Road Vehicle (Diesel), Marine (Gasoline), Marine (Diesel)
2017	Section 4	Updated Business Travel reporting methods
2017	Table 22	Fixed EIU Factors updated for all Building Classifications
2017	Annex 5	Business Travel Methodology Added

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