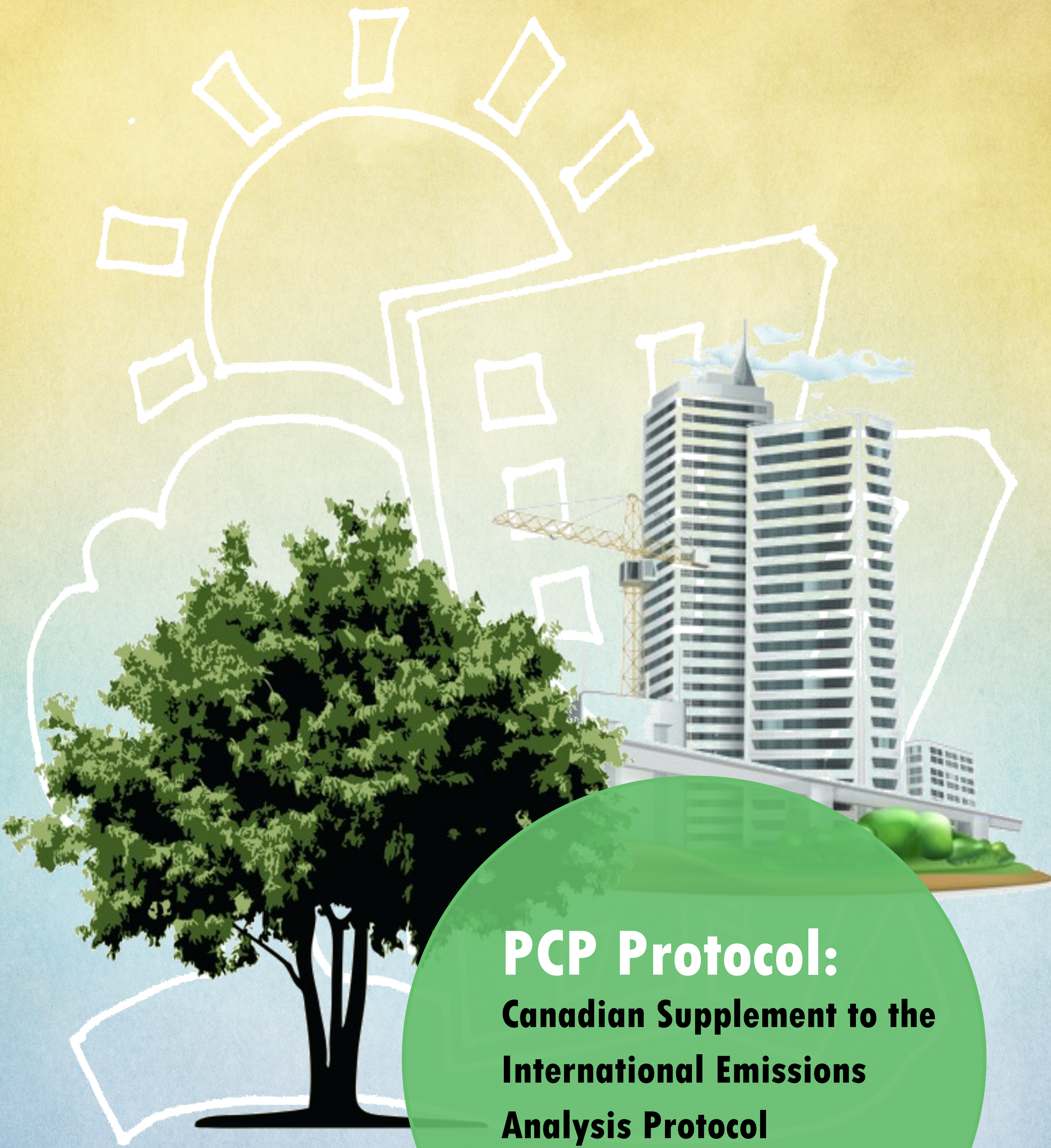

PCP Protocol:

Canadian Supplement to the International Emissions Analysis Protocol

All across the country, municipal governments are taking action to reduce GHG emissions and mitigate the effects of climate change. The Partners for Climate Protection (PCP) program is a network of these Canadian municipalities that are working together to create tangible changes in their local communities while together tackling a global concern.

Learn more about the PCP program and milestone framework on the PCP website.

ICLEI Local Governments for Sustainability

FCM FEDERATION OF CANADIAN MUNICIPALITIES FÉDÉRATION CANADIENNE DES MUNICIPALITÉS

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Introduction

The PCP program is based on the premise that in order to effectively manage GHG emissions, local governments must first measure and report. Accurate and reliable GHG measurement enables local governments to identify energy and emissions-intensive activities with their communities and provides policy and decision-makers with a set of verifiable metrics upon which targeted and prioritized action can be based. Community-wide GHG measurement also provides local government and community stakeholders with the necessary baseline information to monitor, evaluate, and compare performance over time. For these reasons, GHG inventorying is often seen as the foundation of a climate change or community energy strategy.

Purpose of Protocols

The purpose of the PCP Protocol is to provide municipalities with a set of clear accounting and reporting guidelines for developing corporate and community-level GHG inventories within the context of the PCP program. These standards have been developed to meet the following objectives:

- Clarify the corporate and community inventory requirements so that PCP municipalities have a clear sense of which emissions sources must be reported and those that are optional;
- Clarify the relationship between the corporate and community-scale inventories to address overlapping emission sources and activity sectors, such as municipal landfills and public transit systems;
- Provide detailed accounting and quantification guidelines, including recommended best practices and alternate approaches, for each of the required reporting sectors; and
- Clarify the relationship between PCP and other GHG inventory protocols so that municipalities can plan and coordinate their reporting according to their own needs and priorities.

History of Protocols in the PCP Program

The field of GHG accounting and reporting has evolved considerably since the PCP program began in 1997. Improvements in data accessibility and quantification methodologies are leading to more robust inventory practices, and are helping local governments across Canada gain a better understanding of the sources that generate emissions within their communities. These developments have been accompanied and supported by a number of new protocols and GHG inventory standards released at the international level.

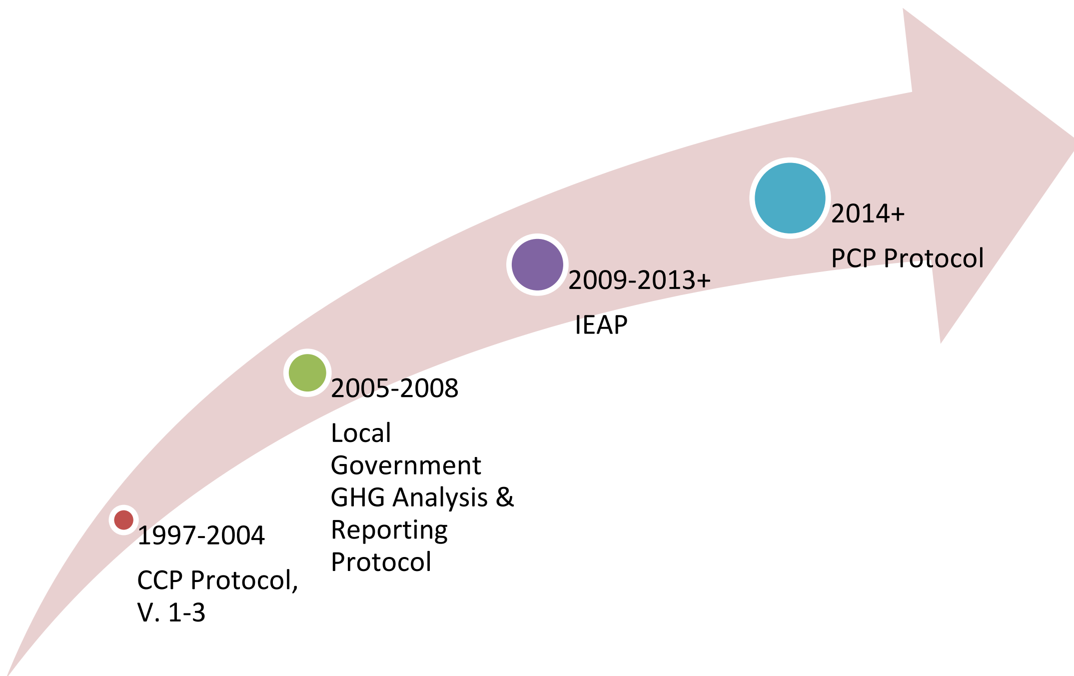


Figure A: History of Protocols in the PCP

When the PCP Program began, the protocol that guided local governments in their GHG emission accounting was called the Cities for Climate Protection (CCP) Protocol, a reference to the fact that it was also used by the members of the global CCP Campaign. This document was the first of its kind to introduce and outline the issue of GHG accounting at the local government level. In under 20 pages it was the first to touch on issues of sectors, scope, boundaries, and levels of control. The CCP Protocol was the main guidance document for the PCP program from 1997 to 2004.

In 2005, the global CCP Campaign deepened and broadened the support document through consultation and testing with participating local governments and municipal GHG experts. GHG emissions accounting had become more mainstream, more complex and better understood, as was reflected in the growth of the guidance document from less than 20 pages to over 50. The Local Government GHG Analysis and Reporting Protocol was the main guidance document used by PCP members from 2005 to 2008.

In 2009, the International Emissions Analysis Protocol (IEAP) came into force. The IEAP was based on a multi-year global consultation process with key peer and expert organizations including United Nations Environment Program, World Resources Institute, International Energy Agency, California Climate Action Registry, Federation of Canadian Municipalities and Center for Neighborhood Technologies. The IEAP represents the most complex, thorough, and widely-used guidance for local governments conducting GHG emissions accounting. The PCP has been using the IEAP as a guiding reference document for GHG accounting since 2009.

In 2014, the PCP Protocol was released as a Canadian supplement to the IEAP. Where the IEAP describes the high-level principles and approach to municipal GHG accounting, the Canadian supplement describes the procedures and methodology in the context of the PCP Program. Used in tandem they are comprehensive and detailed, however PCP members can follow the PCP Protocol alone and be assured their work follows globally recognized standards.

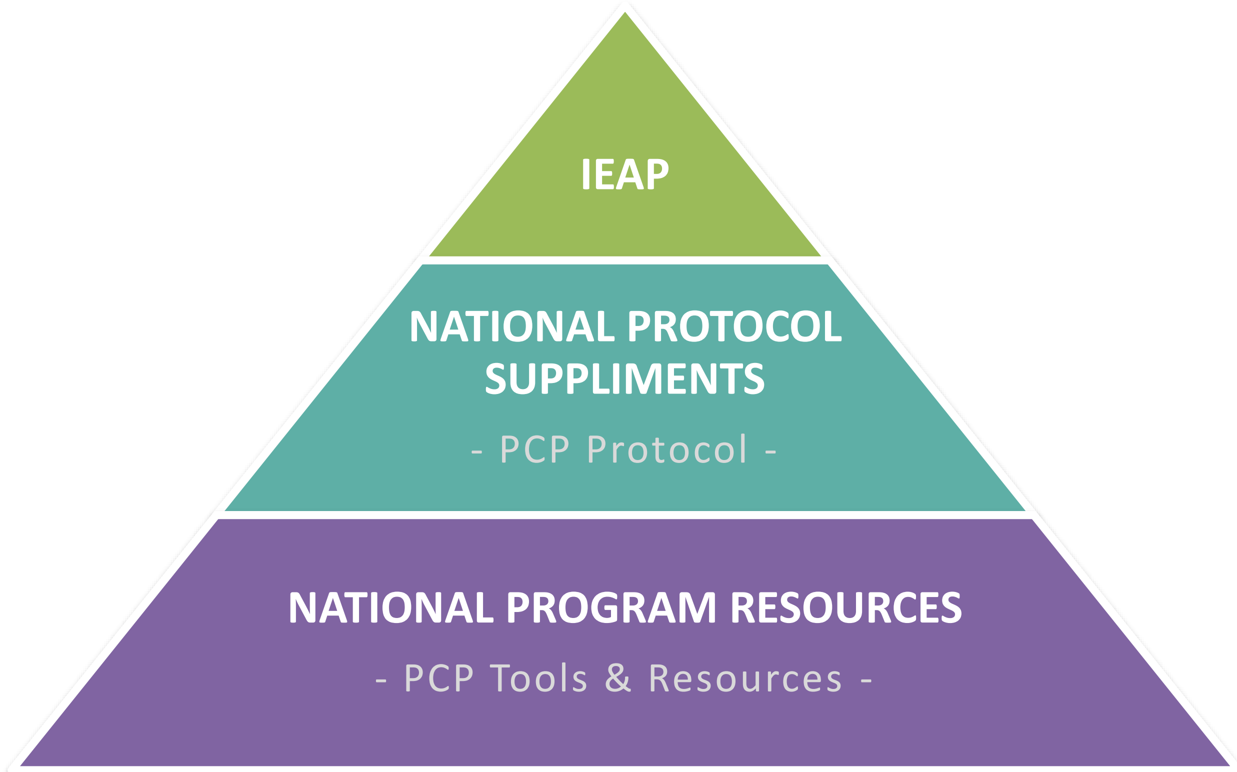


Figure B: Protocol Resource Relationship Pyramid

Figure B illustrates where the IEAP and PCP Protocol fit within the plethora of resources offered by the PCP. The IEAP can be visualized as the top of the pyramid, setting the conceptual framework for municipal GHG accounting. The PCP Protocol provides the detail on how to implement the IEAP in the Canadian context, and the many PCP tools and resources help with implementation, analysis delivery, and reporting.

Accounting and reporting of GHG emissions at the local level is an established yet continuously evolving field. As access to data and quantification methodologies improve, there are opportunities for local governments to expand the scope of their GHG reporting and to develop more robust inventory practices. The PCP program will continue to monitor these developments, and will strive to update the accounting and reporting guidelines outlined in this document on an ongoing basis. Local governments can support this process by submitting detailed GHG inventory reports, inventory data management manuals and other relevant methodological documents to the PCP Secretariat for review.

PCP Protocol Audience

The PCP Protocol was developed to support municipal practitioners working through the milestones on the PCP program. It is most relevant in completing the first PCP milestone, a GHG emissions inventory, but is also important to align with milestones two through five (setting an emissions target, developing a local action plan, implementation, and monitoring and verification).

The PCP Protocol is technical in nature, containing many complex formulas and calculations. Ideal users will have some technical background in engineering, math and science or be comfortable learning new methodological concepts. The PCP Protocol aligns with the online PCP Milestone Tool, making it easy to follow the methodology and record and analyze the GHG inventory results.

Field of Protocols

The PCP Protocol exists within a growing field of GHG reporting standards used by local governments, each with specific merits and functions. This protocol was formulated to address the unique situation of local governments working voluntarily to reduce GHG emissions within their operations and broader community. Other standards and protocols exist for different reasons, such as compliance with provincial acts and regulations, funding arrangements, or recognition programs. Since function dictates form, the protocols and standards can vary greatly.

Figure C illustrates a sample of the variety of organizations and protocols that are involved in Canadian local government GHG emissions accounting. Blue represents the organizations involved in the field while green represents the protocols or standards in use. The PCP Secretariat helps members with the complexity of the field by assisting those that report against multiple standards to simplify and streamline reporting. The PCP has created several alignment documents to identify variances between some of the more commonly used protocols.

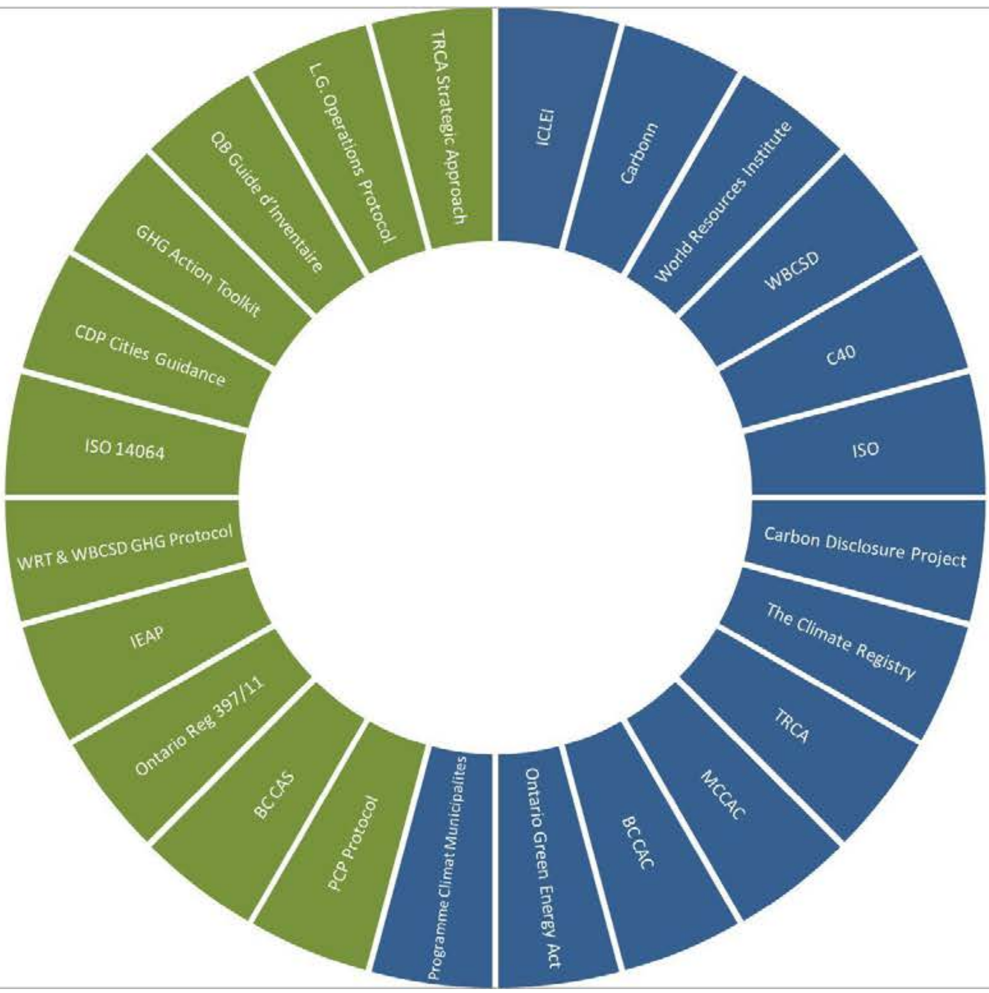


Figure C: Complexity of GHG Protocols & Standards Field

Inventory Parameters

The parameters established for local government GHG emissions inventories and reporting are established and defined by the IEAP. However, parameters addressing boundaries, operational control and contracted services are reiterated in the PCP Protocol due to the rate at which they are raised and the complexity of the discussion. Any other issues of inventory parameters not dealt in the PCP Protocol are addressed in the IEAP.

Setting Inventory Boundaries

The PCP program distinguishes between two types of local-level GHG inventories, each with its own emission sources and activity sectors. A corporate or municipal GHG inventory outlines the GHG emissions generated as a result of a local government's operations and services. As the name suggests, a corporate inventory is an organization-level GHG inventory akin to those developed by businesses or corporations. Its purpose is to identify the GHG emissions within a local government's direct control or influence, and for which the local government is accountable as a corporate entity.

The community GHG inventory, in contrast, is a much larger inventory that estimates GHG emissions generated within the community as a whole. Although a local government may have only limited control or influence over certain community activities, the purpose of the community GHG inventory is to document, as accurately as possible, the GHG emissions arising from all significant activities occurring within the territorial boundaries of a community. This includes emissions generated by activities such as residential energy consumption and on-road transportation as well as emissions generated by the local government itself.

The corporate inventory is a subsector of the community inventory, as illustrated in Figure D. In most cases, corporate emissions fall entirely within the sphere of the community inventory. Occasionally emissions from corporate operations fall outside of the community inventory, i.e. when waste is managed outside of the geographical boundary of the community or when air travel is factored into a corporate GHG inventory and management plan. In general, the corporate inventory is like any other large commercial or institutional sources within a community, but it is singled-out for a separate and contained inventory under the PCP Protocol by virtue of the fact that local governments can control and influence these emissions.

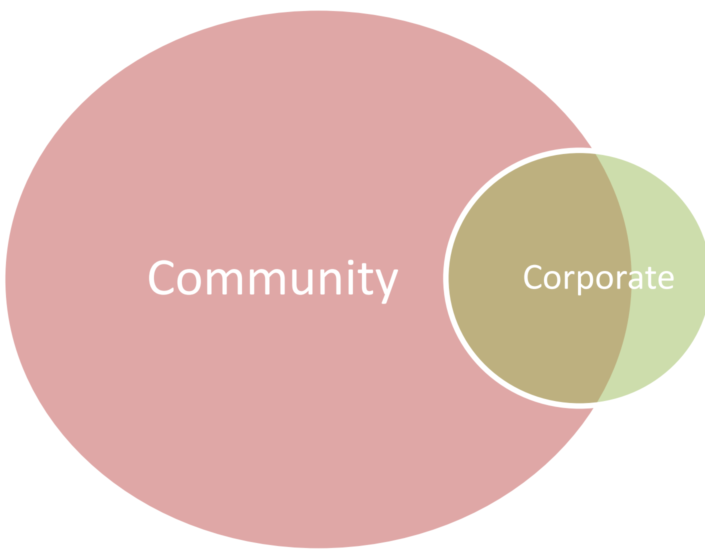


Figure D: Community & Corporate Inventory Relationship

Corporate Inventory Boundary

The roles and responsibilities of Canadian local governments can vary considerably from one jurisdiction to another. In some jurisdictions services such as public transit and solid waste disposal are owned and operated directly by the local government, while in other jurisdictions these services are offered by a private-sector third party, a neighbouring municipality or a regional government. Within the context of the PCP program, the boundary of the corporate inventory is determined using an approach known as *operational control*, which requires the local government to report 100 per cent of the emissions from operations over which it has control.

Text Box: Operational Control

According to the *Local Government Operations Protocol* developed by ICLEI USA and partners, a local government is considered to have operational control over a facility or operation if it has the full authority to introduce and implement operating policies at the operation. Operational control is typically established by one of the following conditions:

- The local government wholly owns the operation, facility or source; or
- The local government has full authority to implement operational and health, safety and environmental policies (including both GHG- and non-GHG-related policies). In most cases, holding an operator's license is an indication of an organization's authority to implement operational and HSE policies.

It should be noted that having operational control does not necessarily mean that a local government has the authority to make all decisions concerning an operation. Large capital investments, for example, may require approval from other partners with joint financial control. For more information on the concept of operational control, see Section 3.1.1 of the *Local Government Operations Protocol*.

GHG Emissions from Contracted Services

In Canada, it is not uncommon for a local government to contract certain services out to a private-sector organization or third party. Contracted services can encompass a variety of activities, ranging from road maintenance and custodial services to water system operations and solid waste disposal. Determining whether to report the GHG emissions from these types of contracted services can present local governments with unique reporting challenges. Once a service or activity has been contracted out, for example, a local government may feel as though it no longer has the authority to introduce policies or operating procedures governing the contracted service. However, if the service provided by the contractor is a traditional local government service, omitting this emission source from the corporate GHG inventory can undermine the inventory's relevance and completeness, and can limit efforts to draw accurate comparisons with other local governments.

To determine whether to report the GHG emissions from a contracted service, local governments are encouraged to follow the guidelines outlined in the *International Local Government GHG Emissions Analysis Protocol* (IEAP).[1] According to the IEAP, local governments must report the GHG emissions from a contracted service in cases where:

[1] ICLEI. (2009). International Local Government GHG Emissions Analysis Protocol, Version 1.0. Page 16.

1. The service provided by the contractor is a service that is traditionally provided by local government;

2. Emissions from the contracted service were reported in an earlier local government GHG inventory; and/or

3. Emissions generated by the contractor are a source over which the local government exerts significant influence.

When reporting emissions from a contracted service, the intention is to capture the GHG emissions *directly* related to the service provided by the contractor. For example, if a local government has contracted out its snow removal or solid waste collection services, it should report the direct emissions from motor fuel used by the snow removal or waste collection vehicles. In most cases, it is not necessary to report the indirect emissions generated at the contractor's administrative or corporate office buildings.

Text Box: Traditional Local Government Services[2]

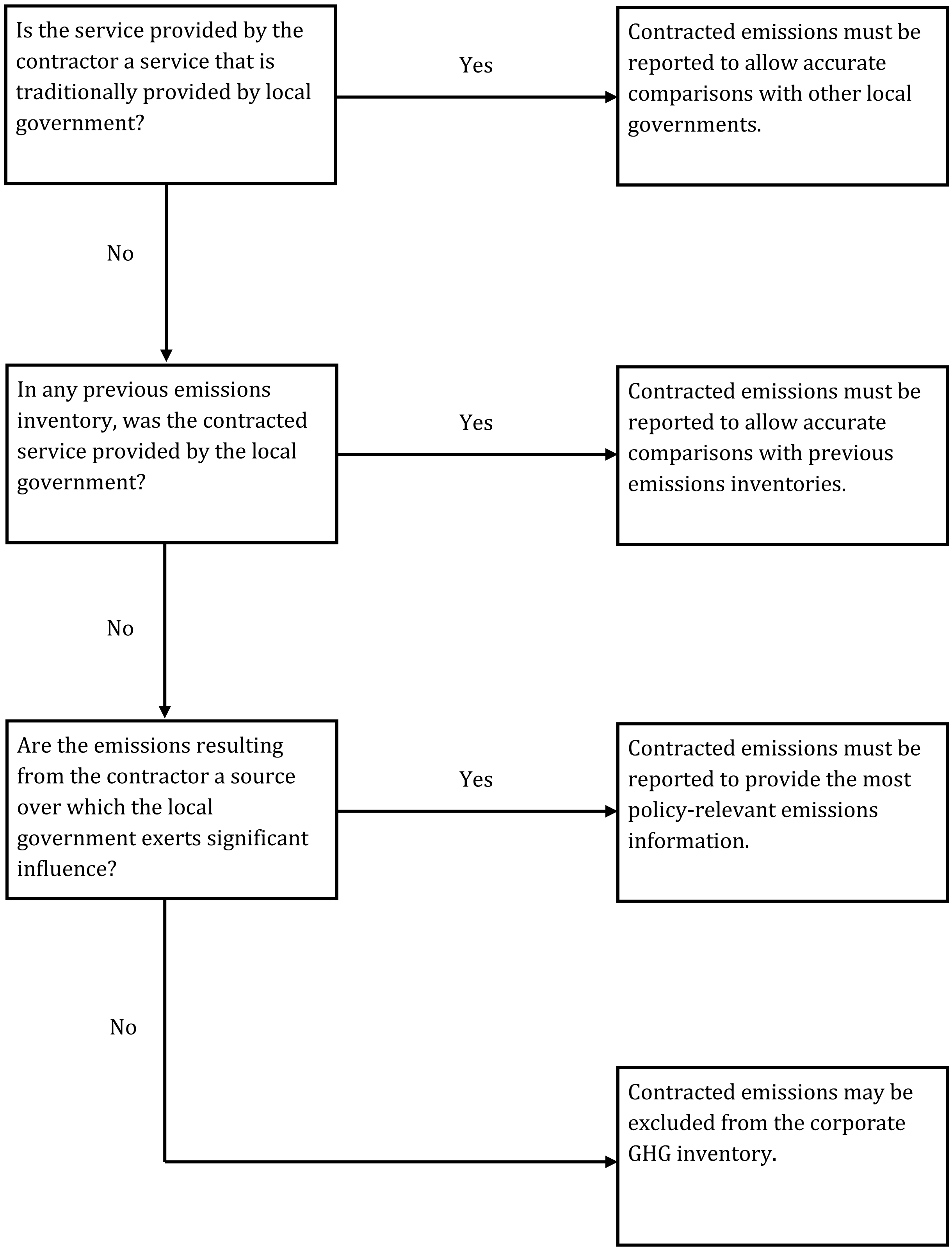
As signatories to the provincial *Climate Action Charter*, local governments in British Columbia committed to becoming carbon neutral in their operations by 2012. To ensure equity among local governments, the provincial government developed a standard for corporate (municipal) GHG inventories based on six "traditional services" commonly provided by the majority of local governments. These six traditional local government services include:

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

For more information on the traditional services model adopted by the Province of British Columbia, see *The Workbook: Helping Local Governments Understand How to be Carbon Neutral in their Corporate Operations*.

[2] Government of British Columbia. (2012). *The Workbook: Helping Local Governments Understand How to be Carbon Neutral in their Corporate Operations*.

Figure E: Contracted Services Decision Tree



Community Inventory Boundary

The community GHG inventory measures emissions generated by key activities within the territorial boundary of the local government. It includes direct sources of emissions within the community, such as the combustion of natural gas or fuel oil for space heating, as well as certain trans-boundary emission sources generated as a result of community activities. In theory, a community GHG inventory should aim to capture emissions generated by all significant activities and sources within the jurisdictional boundary of the community. In practice, however, local governments often do not have the resources or access to data that is necessary to generate a complete and comprehensive account of their community's GHG emissions.

Consider, for example, hydrofluorocarbon (HFC) emissions resulting from the use of refrigeration and air-conditioning equipment. To accurately quantify emissions from this source a local government would need to determine the quantity of refrigerant used in new and existing equipment within the community, as well as the quantity of refrigerant recovered from retired equipment. Although this type of analysis is possible, it requires access to data that is not likely available in many communities.

For these reasons, standards for developing community-scale GHG inventories typically outline a minimum reporting threshold based on a set of common and generally well-understood community activities, such as energy consumption in buildings, on-road transportation and generation of solid waste. As access to data and quantification methodologies improve over time, minimum reporting requirements will likely expand to include more complex community emission sources previously considered to be optional. This process of continual improvement can be seen in the recent Global Protocol for Community-Scale GHG Emissions (GPC), which challenges local governments to expand the scope of their GHG reporting to include additional community emission sources, such as industrial processes and off-road transportation (see Relationship to Global Protocol for Community-Scale GHG Emissions).

Quantification Guidelines for Corporate GHG Inventories

To be considered in compliance with PCP protocol, corporate GHG inventories must include emissions from the following **five** activity sectors:

- Buildings and Facilities;
- Fleet Vehicles;
- Streetlights and Traffic Signals;
- Water and Wastewater; and
- Solid Waste.

A detailed description of each sector is provided in this section along with the recommended best practices for GHG quantification.

Buildings and Facilities

The corporate buildings sector tracks GHG emissions associated with the use of energy in corporate buildings and facilities. Emissions in this sector can be produced directly from stationary combustion of fuels (e.g. natural gas used in boilers and furnaces) or indirectly from the use of grid electricity or district energy.

Inclusion Protocol

Report all direct and indirect emissions generated by the use of energy at corporate buildings and facilities. Include all buildings and facilities owned and/or operated by the local government, including those leased to a person or other legal entity (e.g. municipally-owned housing units, daycare facilities, etc.).

Exclusion Protocol

Exclude energy consumed by water and wastewater infrastructure (e.g. lift stations, treatment plants, etc.); emissions generated by these facilities are accounted for in the water and wastewater sector.

Carbon dioxide (CO_2) emissions associated with the combustion of biomass and biomass-based energy sources (e.g. wood, wood residuals, pellets, etc.) are considered to be of biogenic origin and may be excluded from the GHG inventory. However, methane (CH_4) and nitrous oxide (N_2O) emissions from biomass combustion are anthropogenic and must be reported in the GHG inventory.

Reporting Guidelines

As a best practice, energy and emissions data should be sufficiently disaggregated so as to enable comparisons of individual buildings or groups of buildings of similar type or function (e.g. city housing, administrative buildings, sports and recreation centres, etc.). Reporting energy and emissions data at the individual facility level allows for more detailed comparisons of performance over time, and can reveal opportunities to invest in energy efficiency or renewable energy initiatives. If disaggregated reporting is not possible, local governments should report the total energy consumption and corresponding GHG emissions for each energy source used (e.g. natural gas, electricity, fuel oil, etc.).

Accounting Guidelines

Emissions from energy consumed in buildings can be calculated using the following steps:

1. For each energy source, determine the total amount of energy consumed by each corporate building and facility during the inventory year.
2. Identify the corresponding emission factors for CO_2, CH_4 and N_2O (values provided).
3. Multiply energy consumption activity data by the corresponding emission factors and their global warming potential (GWP) to determine total CO_2e emissions.

Step 1: For each energy source, determine the total amount of energy consumed by each corporate building and facility during the inventory year.

Recommended	Obtain actual consumption data for each energy source consumed. This information can be determined by reading individual meters located at fuel input points or by using fuel receipts and purchase records.
Alternate	If actual energy consumption data are not available for the analysis year, local governments can estimate energy consumption based on energy consumed at the facility during the following or previous year (proxy year data). Note that this approach should only be used for one or a few minor facilities, and should not be used as a substitute for significant groups of buildings.
Alternate	If actual consumption data are not available, local governments can estimate a facility's annual energy consumption based on the facility's total floor area and average energy intensity values. Energy intensity values estimate a facility's annual energy consumption per area of floor space (e.g. GJ/m^2). A list of energy intensity values for commercial/institutional facilities is provided in the *Comprehensive Energy Use Database* published by Natural Resources Canada's Office of Energy Efficiency.[3]

Step 2: Identify the corresponding emission factors for CO_2, CH_4 and N_2O (values provided).

Use province/territorial or utility-specific emission factors for stationary fuel combustion and electricity consumption. Environment Canada's *National Inventory Report* provides emission factors for a variety of emissions-generating activities, including stationary combustion of fuels (Annex 8) and consumption of grid electricity (Annex 13).

Note that emission factors for electricity consumption are updated annually based on the energy sources used to generate electricity in each province or territory. Emission factors for stationary combustion of fuels, such as natural gas or fuel oil, are influenced primarily by the carbon content of the fuel, and as such do not vary considerably between inventory years (see table 1 and 2 below).

Table 1: CO_2, CH_4 and N_2O Emission Factors for Natural Gas[4]

Province	Emission Factors (g/m^3)			
	CO2	CH4	N2O	CO_2e
Newfoundland and Labrador	1,891	0.037	0.035	1,903
Nova Scotia	1,891	0.037	0.035	1,903
New Brunswick	1,891	0.037	0.035	1,903
Quebec	1,878	0.037	0.035	1,890
Ontario	1,879	0.037	0.035	1,891
Manitoba	1,877	0.037	0.035	1,889

[3]Natural Resources Canada Office of Energy Efficiency. (2011). [Comprehensive Energy Use Database](#).
[4]Adapted from Environment Canada's *National Inventory Report 1990-2011: Greenhouse Gas Sources and Sinks in Canada*, Part 2, Annex 8, pp.193-194.

Saskatchewan	1,820	0.037	0.035	1,832
Alberta	1,918	0.037	0.035	1,930
British Columbia	1,916	0.037	0.035	1,928
Yukon	1,891	0.037	0.035	1,903
Northwest Territories	2,454	0.037	0.035	2,466

*CH_4 and N_2O emission factors are specific to the residential, commercial and institutional sectors.

Table 2: CO_2, CH_4 and N_20 Emission Factors for Other Stationary Fuels[5]

Fuel Type	Emission Factors (g/L)			
	CO2	CH4	N2O	CO_2e
Light fuel oil	2,725	0.026	0.031	2,735
Heavy fuel oil	3,124	0.057	0.064	3,145
Kerosene	2,534	0.026	0.031	2,544
Propane	1,507	0.024	0.108	1,541
Diesel	2,663	0.133	0.4	2,790

*CH_4 and N_2O emission factors are specific to the commercial and institutional sector.

Step 3: Multiply energy consumption data by the corresponding emission factors and their global warming potential (GWP) to determine total CO_2e emissions.

For each energy source, multiply the amount of energy consumed by the corresponding emission factors for CO_2, CH_4 and N_2O. Use global warming potentials to convert CH_4 and N_20 emissions into units of CO_2 equivalent (CO_2e).

$$CO_2e_a = (x_a \bullet CO_2EF_a) + (x_a \bullet N_2OEF_a \bullet GWP_{N2O}) + (x_a \bullet CH_4EF_a \bullet GWP_{CH4})$$

OR

For each energy source, multiply the amount of energy consumed by the corresponding emission factor for CO_2 equivalent.

$$CO_2e_a = (x_a \bullet CO_2eEF_a)$$

Description			Value
CO_2e_a	=	Total CO_2e emissions produced from a building consuming energy source 'a' in the inventory year	Computed
x_a	=	Amount of energy source 'a' consumed in one year	User input
CO_2EF_a	=	The CO_2 emission factor for energy source 'a'	User input
CH_4EF_a	=	The CH_4 emission factor for energy source 'a'	User input
N_2OEF_a	=	The N_2O emission factor for energy source 'a'	User input

[5]Adapted from Environment Canada's *National Inventory Report 1990-2011: Greenhouse Gas Sources and Sinks in Canada*, Part 2, Annex 8, pp.195.

CO_2eEFa	=	The CO_2 equivalent emission factor for energy source 'a'	User input
a	=	Energy source (e.g. electricity, natural gas, fuel oil, etc.)	
GWP_{N2O}	=	Global warming potential of N_2O	310
GWP_{CH4}	=	Global warming potential of CH_4	21

Fleet Vehicles

The corporate fleet sector tracks GHG emissions generated by the use of corporate vehicles and equipment. Emissions in this sector can be produced directly from the use of fuels, such as gasoline and diesel, or indirectly from the use of grid electricity (e.g. plug-in electric vehicles).

Inclusion Protocol

Report all direct and indirect emissions generated by the use of motor fuels (including electricity) in corporate vehicles and equipment. Include all on- and off-road vehicles owned and/or operated by the local government, including all corporate-owned public transit (i.e. local rail and bus systems). Use the *Contracted Services Decision Tree* (Figure E) to determine whether to report emissions generated by the use of contracted vehicles and equipment.

Exclusion Protocol

In certain instances, it may not be possible to distinguish electricity consumed in vehicles and equipment from electricity consumed by a building or facility. In these cases, indirect emissions from electricity consumed by vehicles may be reported in the corporate buildings sector.

Carbon dioxide (CO_2) emissions associated with the combustion of biomass and biomass-based energy sources (e.g. biomass used in ethanol and biodiesel blends) are considered to be of biogenic origin and may be excluded from the GHG inventory. However, methane (CH_4) and nitrous oxide (N_2O) emissions from biomass combustion are anthropogenic and must be reported in the GHG inventory.

Reporting Guidelines

As a best practice, energy and emissions data should be sufficiently disaggregated so as to enable comparisons of individual vehicles or groups of vehicles and equipment of similar type or function (e.g. parking services, waste management, emergency services, etc). If disaggregated reporting is not possible, local governments should report the total energy consumption and corresponding GHG emissions for each energy source used (e.g. gasoline, diesel, compressed natural gas, electricity, etc.).

Accounting Guidelines

Emissions from energy consumed by vehicles and equipment can be calculated using the following steps:

1. For each energy source, determine the total amount of energy consumed by corporate vehicles and equipment during the inventory year.
2. Identify the corresponding emission factors for CO_2, CH_4 and N_2O (values provided).
3. Multiply energy consumption data by the corresponding emission factors and their global warming potential (GWP) to determine total CO_2e emissions.

Step 1: For each energy source, determine the total amount of energy consumed by corporate vehicles and equipment during the inventory year.

<table>
<tr><td>Recommended</td><td>Obtain actual fuel consumption data for each fuel type consumed. This information can be obtained through direct measurement of fuel use (official logs of vehicle fuel gauges or storage tanks), collected fuel receipts, or purchase records for bulk storage fuel purchases.</td></tr>
<tr><td>Alternate</td><td>If actual fuel consumption data are unavailable, energy consumption can be estimated based on the vehicle or equipment's fuel efficiency and annual usage data (e.g. distance traveled). Vehicle fuel efficiency is usually expressed in units of volume per distance traveled (e.g. L/100 km) or kilowatt-hours per distance traveled in the case of plug-in electric vehicles. Fuel consumption ratings for cars and light trucks can be assessed using the Natural Resources Canada website.[6] Energy efficiency information for equipment and machinery can typically be sourced to the product manufacturer or retailer.

To estimate energy consumption using this approach, follow the formula below:

$x_a = FE_a \bullet U$

Description | Value
x_a = Amount of energy source 'a' consumed in inventory year | Computed
FE_a = Fuel or energy efficiency of vehicle or equipment (e.g. L/100 km, etc.) | User input
U = Vehicle kilometres traveled or equipment usage in inventory year | User input
a = Energy source (e.g. gasoline, diesel, electricity, etc.)</td></tr>
<tr><td>Alternate</td><td>If actual fuel consumption and vehicle usage data are unavailable, energy consumption can be estimated based on annual expenditure (i.e. dollars spent) for fuel. Sources of annual dollars spent include fuel receipts and purchase records for fuel station accounts. Given the fluctuating price of transportation fuels, this approach should only be used in the case of one or a few vehicles.

To estimate fuel consumption using this approach, follow the formula below:

$x_a = M_a \div P_a$

Description | Value
x_a = Amount of energy source 'a' consumed in inventory year | Computed
M_a = Amount of money spent on fuel source 'a' in inventory year | User input
P_a = Average price of energy source in inventory year (e.g. 140 cents/L) | User input</td></tr>
</table>

[6] Natural Resources Canada. (2008). Fuel Consumption Ratings.

	a = Energy source (e.g. gasoline, diesel, electricity, etc.)
Alternate	If fuel use data cannot be obtained for the analysis year, local governments can estimate fuel consumption using proxy year fuel use data (i.e. using fuel use data from the following or previous year). Note that this approach should only be used for one or a few vehicles, and should not be used as a substitute for a significant group of fleet vehicles or the entire vehicle fleet sector.

Step 2: Identify the corresponding emission factors for CO_2, CH_4 and N_2O (values provided).

CO_2 emissions from the combustion of transportation fuels are predominantly dependent on the type of fuel combusted, whereas N_2O and CH_4 emissions are dependent on both the type of fuel combusted and the characteristics of the vehicle (e.g. vehicle emission control technologies).

Use emission factors specific to the vehicle type (e.g. light-duty vehicle, heavy-duty vehicle, etc.), model year, and fuel type. Environment Canada's National Inventory Report provides a comprehensive listing of transportation-related emission factors, broken-down by vehicle type, fuel type, and technology penetration (Annex 8). These emission factors have been adapted in Table 3 below.

Table 3: CO_2e Emission Factors for Mobile Energy Combustion Sources[7]

Light-Duty Vehicles[1] (tonnes CO2e/unit fuel)									
	Fuel Type								
Inventory Year	**Gasoline**	**Diesel**	**Propane**	**CNG [4]**	**E10**	**E85**	**B5**	**B10**	**B20**
1990-1999	0.002500	0.002730	0.001513	0.003023	0.002271	0.000555	0.002597	0.002464	0.002197
2000	0.002500	0.002730	0.001513	0.003023	0.002271	0.000555	0.002597	0.002464	0.002197
2001	0.002500	0.002730	0.001513	0.003023	0.002271	0.000555	0.002597	0.002464	0.002197
2002	0.002440	0.002730	0.001513	0.003023	0.002211	0.000494	0.002597	0.002464	0.002197
2003	0.002440	0.002732	0.001513	0.003023	0.002211	0.000494	0.002599	0.002466	0.002199
2004	0.002440	0.002732	0.001513	0.003023	0.002211	0.000494	0.002599	0.002466	0.002199
2005	0.002440	0.002732	0.001513	0.003023	0.002211	0.000494	0.002599	0.002466	0.002199
2006	0.002440	0.002732	0.001513	0.003023	0.002211	0.000494	0.002599	0.002466	0.002199
2007	0.002440	0.002732	0.001513	0.003023	0.002211	0.000494	0.002599	0.002466	0.002199
2008	0.002440	0.002732	0.001513	0.003023	0.002211	0.000494	0.002599	0.002466	0.002199
2009	0.002440	0.002732	0.001513	0.003023	0.002211	0.000494	0.002599	0.002466	0.002199
2010	0.002440	0.002732	0.001513	0.003023	0.002211	0.000494	0.002599	0.002466	0.002199
2011	0.002299	0.002732	0.001513	0.003023	0.002070	0.000353	0.002599	0.002466	0.002199
2012	0.002299	0.002732	0.001513	0.003023	0.002070	0.000353	0.002599	0.002466	0.002199
2013	0.002299	0.002732	0.001513	0.003023	0.002070	0.000353	0.002599	0.002466	0.002199
Light-Duty Trucks[2] (tonnes CO2e/unit fuel)									
	Fuel Type								

[7] Adapted from Environment Canada's *National Inventory Report 1990-2011: Greenhouse Gas Sources and Sinks in Canada*, Part 2, Figure A2-2 (p. 43) and Table A8-11 (p.198).

Inventory Year	Gasoline	Diesel	Propane	CNG (kg) [4]	E10	E85	B5	B10	B20
1990-1999	0.002498	0.002730	0.001513	0.003023	0.002269	0.000552	0.002597	0.002464	0.002197
2000	0.002498	0.002730	0.001513	0.003023	0.002269	0.000552	0.002597	0.002464	0.002197
2001	0.002498	0.002730	0.001513	0.003023	0.002269	0.000552	0.002597	0.002464	0.002197
2002	0.002474	0.002730	0.001513	0.003023	0.002245	0.000528	0.002597	0.002464	0.002197
2003	0.002474	0.002733	0.001513	0.003023	0.002245	0.000528	0.002600	0.002467	0.002200
2004	0.002474	0.002733	0.001513	0.003023	0.002245	0.000528	0.002600	0.002467	0.002200
2005	0.002474	0.002733	0.001513	0.003023	0.002245	0.000528	0.002600	0.002467	0.002200
2006	0.002474	0.002733	0.001513	0.003023	0.002245	0.000528	0.002600	0.002467	0.002200
2007	0.002474	0.002733	0.001513	0.003023	0.002245	0.000528	0.002600	0.002467	0.002200
2008	0.002474	0.002733	0.001513	0.003023	0.002245	0.000528	0.002600	0.002467	0.002200
2009	0.002474	0.002733	0.001513	0.003023	0.002245	0.000528	0.002600	0.002467	0.002200
2010	0.002474	0.002733	0.001513	0.003023	0.002245	0.000528	0.002600	0.002467	0.002200
2011	0.002299	0.002733	0.001513	0.003023	0.002070	0.000353	0.002600	0.002467	0.002200
2012	0.002299	0.002733	0.001513	0.003023	0.002070	0.000353	0.002600	0.002467	0.002200
2013	0.002299	0.002733	0.001513	0.003023	0.002070	0.000353	0.002600	0.002467	0.002200
Heavy-Duty Vehicles[3] (tonnes CO2e/unit fuel)									
	Fuel Type								
Inventory Year	**Gasoline**	**Diesel**	**Propane**	**CNG [4]**	**E10**	**E85**	**B5**	**B10**	**B20**
1990-1999	0.002310	0.002691	0.001513	0.003023	0.002081	0.000364	0.002558	0.002425	0.002158
2000	0.002310	0.002691	0.001513	0.003023	0.002081	0.000364	0.002558	0.002425	0.002158
2001	0.002310	0.002691	0.001513	0.003023	0.002081	0.000364	0.002558	0.002425	0.002158
2002	0.002310	0.002691	0.001513	0.003023	0.002081	0.000364	0.002558	0.002425	0.002158
2003	0.002310	0.002691	0.001513	0.003023	0.002081	0.000364	0.002558	0.002425	0.002158
2004	0.002310	0.002691	0.001513	0.003023	0.002081	0.000364	0.002558	0.002425	0.002158
2005	0.002352	0.002712	0.001513	0.003023	0.002123	0.000407	0.002579	0.002446	0.002179
2006	0.002352	0.002712	0.001513	0.003023	0.002123	0.000407	0.002579	0.002446	0.002179
2007	0.002352	0.002712	0.001513	0.003023	0.002123	0.000407	0.002579	0.002446	0.002179
2008	0.002352	0.002712	0.001513	0.003023	0.002123	0.000407	0.002579	0.002446	0.002179
2009	0.002352	0.002712	0.001513	0.003023	0.002123	0.000407	0.002579	0.002446	0.002179
2010	0.002352	0.002712	0.001513	0.003023	0.002123	0.000407	0.002579	0.002446	0.002179
2011	0.002352	0.002712	0.001513	0.003023	0.002123	0.000407	0.002579	0.002446	0.002179
2012	0.002352	0.002712	0.001513	0.003023	0.002123	0.000407	0.002579	0.002446	0.002179
2013	0.002352	0.002712	0.001513	0.003023	0.002123	0.000407	0.002579	0.002446	0.002179
Off-road Vehicles/Equipment* (tonnes CO2e/unit fuel)									
	Fuel Type								
Inventory Year	**Gasoline**	**Diesel**	**Propane**	**CNG [4]**	**E10**	**E85**	**B5**	**B10**	**B20**
1990-1999	0.002361	0.003007	0.001513	0.003023	0.002132	0.000416	0.002874	0.002741	0.002474
2000	0.002361	0.003007	0.001513	0.003023	0.002132	0.000416	0.002874	0.002741	0.002474
2001	0.002361	0.003007	0.001513	0.003023	0.002132	0.000416	0.002874	0.002741	0.002474
2002	0.002361	0.003007	0.001513	0.003023	0.002132	0.000416	0.002874	0.002741	0.002474

2003	0.002361	0.003007	0.001513	0.003023	0.002132	0.000416	0.002874	0.002741	0.002474
2004	0.002361	0.003007	0.001513	0.003023	0.002132	0.000416	0.002874	0.002741	0.002474
2005	0.002361	0.003007	0.001513	0.003023	0.002132	0.000416	0.002874	0.002741	0.002474
2006	0.002361	0.003007	0.001513	0.003023	0.002132	0.000416	0.002874	0.002741	0.002474
2007	0.002361	0.003007	0.001513	0.003023	0.002132	0.000416	0.002874	0.002741	0.002474
2008	0.002361	0.003007	0.001513	0.003023	0.002132	0.000416	0.002874	0.002741	0.002474
2009	0.002361	0.003007	0.001513	0.003023	0.002132	0.000416	0.002874	0.002741	0.002474
2010	0.002361	0.003007	0.001513	0.003023	0.002132	0.000416	0.002874	0.002741	0.002474
2011	0.002361	0.003007	0.001513	0.003023	0.002132	0.000416	0.002874	0.002741	0.002474
2012	0.002361	0.003007	0.001513	0.003023	0.002132	0.000416	0.002874	0.002741	0.002474
2013	0.002361	0.003007	0.001513	0.003023	0.002132	0.000416	0.002874	0.002741	0.002474

[1]Light duty vehicles are cars with a gross vehicle weight rating (GVWR) of less than or equal to 3,900 kg. Assumes average light-duty vehicle on the road in any given year is 7 years old. [2]Light-duty trucks are pickups, minivans, SUVs, etc. with a GVWR of less than or equal to 3,900 kg. Assumes average light-duty truck on the road in any given year is 7 years old. [3]Heavy-duty vehicles are vehicles with a GVWR above 3,900 kg. Assumes average heavy-duty truck on the road in any given year is 9 years old. [4]Emission factors for natural gas vehicles are measured in g/kg of fuel.

Step 3: Multiply energy consumption data by the corresponding emission factors and their global warming potential (GWP) to determine total CO_2e emissions.

For each energy source, multiply the amount of energy consumed by the corresponding emission factors for CO_2, CH_4 and N_2O. Use global warming potentials to convert CH_4 and N_20 emissions into units of CO_2 equivalent (CO_2e).

$$CO_2e_a = (x_a \bullet CO_2EF_a) + (x_a \bullet N_2OEF_a \bullet GWP_{N2O}) + (x_a \bullet CH_4EF_a \bullet GWP_{CH4})$$

OR

For each energy source, multiply the amount of energy consumed by the corresponding emission factor for CO_2 equivalent.

$$CO_2e_a = (x_a \bullet CO_2eEF_a)$$

Description			Value
CO_2e_a	=	Total CO_2e emissions produced from a vehicle or piece of equipment consuming energy source 'a' in the inventory year	Computed
x_a	=	Amount of energy source 'a' consumed in one year	User input
CO_2EF_a	=	CO_2 emission factor for energy source 'a'	User input
CH_4EF_a	=	CH_4 emission factor for energy source 'a'	User input
N_2OEF_a	=	N_2O emission factor for energy source 'a'	User input
CO_2eEF_a	=	The CO_2 equivalent emission factor for energy source ‘a’	User input
a	=	Energy source (e.g. gasoline, diesel, ethanol, etc.)	
GWP_{N2O}	=	Global warming potential of N_2O	310

GWP_{CH4}	=	Global warming potential of CH_4	21

Streetlights and Traffic Signals

The streetlights and traffic signals sector tracks GHG emissions generated by the use of energy for streetlights, traffic signals and other types of outdoor public lighting, such as park and recreational area lighting. Emissions in this sector are typically produced indirectly from the use of grid electricity.

Inclusion Protocol

Report all indirect emissions generated from the use of electricity for outdoor lighting. Take into account all outdoor lighting (e.g. streetlights, traffic signals, park lighting, etc.) owned and/or operated by the local government, including lighting systems that are leased to a private management company or utility.

Exclusion Protocol

GHG emissions from streetlights owned and operated by a regional or neighbouring municipality may be excluded from the corporate GHG inventory.

Reporting Guidelines

As a best practice, energy and emissions data should be sufficiently disaggregated so as to enable comparisons of defined streetlight grids or different lighting types (e.g. park lights, traffic signals, etc.). Reporting energy and emissions data according to defined streetlight grids enables more detailed comparisons based on the average performance of fixtures in a select group of lights (e.g. tonnes CO_2e/fixture), and can reveal opportunities to invest in energy efficiency initiatives. If disaggregated reporting is not possible, local governments should report the total electricity consumption and corresponding GHG emissions for all outdoor lighting.

Accounting Guidelines

Emissions from electricity consumed by outdoor lighting can be calculated using the following steps:

1. Determine the total amount of electricity consumed by municipal lighting systems during the inventory year.
2. Identify the corresponding emission factors for CO_2, CH_4 and N_2O.
3. Multiply energy consumption data by the corresponding emission factors and their global warming potential (GWP) to determine total CO_2e emissions.

Step 1: Determine the total amount of electricity consumed by municipal lighting systems during the inventory year.

Recommended	Obtain actual electricity consumption data for each lighting system. The preferred sources for determining annual electricity use are monthly electric bills or electric meter records. Both sources provide the number of kilowatt-hours (kWh) or megawatt-hours (MWh) of electricity consumed, giving a measure of the energy used by an electric load. Local governments should make note of any accounts that are not metered (i.e. the account is billed at a flat rate), as the data from these accounts may not reflect actual energy consumption.
Alternate	If actual energy consumption data is not available, local governments can estimate the amount of electricity used in streetlights based on the total installed wattage

	and average daily operating hours of the lighting system. Total installed wattage is determined based on the number and wattage of all fixtures in the lighting system. Municipal streetlight systems can range from high-wattage mercury vapour (MV) or high-pressure sodium (HPS) fixtures (e.g. 250-400 W/fixture) to energy-efficient light-emitting diode (LED) fixtures (e.g. 56 W/fixture). Average daily operating hours for streetlight systems can vary depending on daylight hours and a municipality's management practices, but are typically between 10 and 13 hours per day. To estimate electricity consumption using this approach, follow the formula below: $x = \frac{(W \bullet O \bullet 365\ days/year)}{1000\ watts/kwh}$ Description — Value x = Estimated annual electricity use (kWh) — Computed W = Total installed wattage (watts) — User input O = Average annual daily operating hours (hours/day) — User input

Step 2: Identify the corresponding emission factors for CO_2, CH_4 and N_2O.

Use provincial/territorial or utility-specific emission factors for electricity consumption. Environment Canada's National Inventory Report outlines historic emission factors for electricity by province and calendar year (see Annex 13). These emission factors (also known as electricity grid "intensities") are updated annually based on the types of primary energy sources used to generate electricity in each province or territory.

Step 3: Multiply electricity consumption data by the corresponding emission factors and their global warming potential (GWP) to determine total CO_2e emissions.

Multiply the amount of electricity consumed by the corresponding emission factors for CO_2, CH_4 and N_2O. Use global warming potentials to convert CH_4 and N_20 emissions into units of CO_2 equivalent (CO_2e).

$$CO_2e_a = (x_a \bullet CO_2EF_a) + (x_a \bullet N_2OEF_a \bullet GWP_{N2O}) + (x_a \bullet CH_4EF_a \bullet GWP_{CH4})$$

OR

Multiply the amount of electricity consumed by the corresponding emission factor for CO_2 equivalent.

$$CO_2e_a = (x_a \bullet CO_2eEF_a)$$

Description			Value
CO_2e_a	=	Total CO_2e emissions produced by outdoor lighting group consuming electricity in the inventory year	Computed
x_a	=	Amount of electricity consumed by lighting system during inventory year	User input

CO_2EF_a	=	CO_2 emission factor for electricity	User input
CH_4EF_a	=	CH_4 emission factor for electricity	User input
N_2OEF_a	=	N_2O emission factor for electricity	User input
CO_2eEF_a	=	The CO_2 equivalent emission factor for electricity	User input
a	=	Electricity	
GWP_{N2O}	=	Global warming potential of N_2O	310
GWP_{CH4}	=	Global warming potential of CH_4	21

Water and Wastewater

The water and wastewater sector tracks energy consumption and the corresponding GHG emissions generated by municipal water and wastewater infrastructure, such as lift and pumping stations, reservoirs and storage tanks, and treatment facilities. Emissions in this sector can be produced directly from the combustion of fuels (e.g. natural gas used in boilers and furnaces) or indirectly from the use of grid electricity or district energy.

Inclusion Protocol

Report all direct and indirect emissions associated with the use of energy by municipal water and wastewater infrastructure. Include all infrastructure owned and/or operated by the local government, including infrastructure that is leased to a utility or private management company.

Exclusion Protocol

GHG emissions from infrastructure owned and operated by a regional authority or neighbouring municipality may be excluded from the corporate GHG inventory.

Carbon dioxide (CO_2) emissions associated with the combustion of biomass and biomass-based energy sources (e.g. wood, wood residuals, pellets, etc.) are considered to be of biogenic origin and may be excluded from the GHG inventory. However, methane (CH_4) and nitrous oxide (N_2O) emissions from biomass combustion are anthropogenic and must be reported in the GHG inventory.

Reporting Guidelines

As a best practice, energy and emissions data should be sufficiently disaggregated so as to enable comparisons of individual water and wastewater infrastructure or groups of infrastructure of similar type or function (e.g. lift and pumping stations, reservoirs and storage tanks, treatment facilities, etc.). Reporting energy and emissions data at the individual facility level allows for more detailed comparisons of performance over time, and can reveal opportunities to invest in energy efficiency or renewable energy initiatives. If disaggregated reporting is not possible, local governments should report the total energy consumption and corresponding GHG emissions for each energy source used (e.g. natural gas, electricity, fuel oil, etc.).

Accounting Guidelines

Emissions from energy consumed by water and wastewater infrastructure can be calculated using the following steps:

1. For each energy source, determine the total amount of energy consumed by water and wastewater facilities during the inventory year.
2. Identify the corresponding emission factors for CO_2, CH_4 and N_2O.
3. Multiply energy consumption data by the corresponding emission factors and their global warming potential (GWP) to determine total CO_2e emissions.

Step 1: For each energy source, determine the total amount of energy consumed by water and wastewater facilities during the inventory year.

Recommended	Obtain actual consumption data for each energy source consumed. This information can be determined by reading individual metres located at fuel input points or by using fuel receipts and purchase records.
Alternate	If actual energy consumption data are not available for the analysis year, local governments can estimate energy consumption based on energy consumed at the facility during the following or previous year (proxy year data). Note that this approach should only be used for one or a few minor facilities, and should not be used as a substitute for significant groups of water and wastewater infrastructure.

Step 2: Identify the corresponding emission factors for CO_2, CH_4 and N_2O (defaults provided).

Use provincial/territorial or utility-specific emissions factors for stationary combustion and electricity consumption. Environment Canada's *National Inventory Report* provides emission factors for a variety of emissions-generating activities, including stationary combustion of fuels (Annex 8) and consumption of grid electricity (Annex 13).

Note that emission factors for electricity consumption are updated annually based on the energy sources used to generate electricity in each province or territory. Emission factors for stationary combustion of fuels, such as natural gas or fuel oil, are influenced primarily by the carbon content of the fuel, and as such do not vary considerably between inventory years.

Step 3: Multiply energy consumption data by the corresponding emission factors and their global warming potential (GWP) to determine total CO_2e emissions.

For each energy source, multiply the amount of energy consumed by the corresponding emission factors for CO_2, CH_4 and N_2O. Use global warming potentials to convert CH_4 and N_20 emissions into units of CO_2 equivalent (CO_2e).

$$CO_2e_a = (x_a \bullet CO_2EF_a) + (x_a \bullet N_2OEF_a \bullet GWP_{N2O}) + (x_a \bullet CH_4EF_a \bullet GWP_{CH4})$$

OR

For each energy source, multiply the amount of energy consumed by the corresponding emission factor for CO_2 equivalent.

$$CO_2e_a = (x_a \bullet CO_2eEF_a)$$

Description			Value
CO_2e_a	=	Total CO_2e emissions produced from water or wastewater infrastructure consuming energy source 'a' in the inventory year	Computed

x_a	=	Amount of energy source 'a' consumed during inventory year	User input
CO_2EF_a	=	CO_2 emission factor for energy source 'a'	User input
CH_4EF_a	=	CH_4 emission factor for energy source 'a'	User input
N_2OEF_a	=	N_2O emission factor for energy source 'a'	User input
CO_2eEF_a	=	The CO_2 equivalent emission factor for energy source 'a'	User input
a	=	Energy source (e.g. electricity, natural gas, fuel oil, etc.)	
GWP_{N2O}	=	Global warming potential of N_2O	310
GWP_{CH4}	=	Global warming potential of CH_4	20

Corporate Solid Waste

The corporate solid waste sector tracks methane (CH_4) emissions that enter the air directly as waste decomposes at landfills as well as CH_4, nitrous oxide (N_2O) and non-biogenic carbon dioxide (CO_2) emissions associated with the combustion of solid waste at incineration facilities.

When solid waste is landfilled, its organic components (e.g. paper, food and yard waste, etc.) decompose over time into simpler carbon compounds by bacteria in an anaerobic (oxygen poor) environment generating CH_4 and CO_2 emissions. The CO_2 emissions associated with the decomposition of the organic waste are considered to be of biogenic origin and are excluded from the GHG inventory. Landfill emissions are unique in that the disposed solid waste generates emissions over many years.

When solid waste is incinerated, both its organic and non-organic (e.g. plastic, metal, etc.) components generate CH_4, N_2O, and CO_2 emissions when combusted. The CO_2 emissions released from the combustion of the organic waste are considered to be of biogenic origin and are excluded from the GHG inventory, but the non-biogenic CO_2 emissions associated with combustion of non-organic waste must be accounted for.

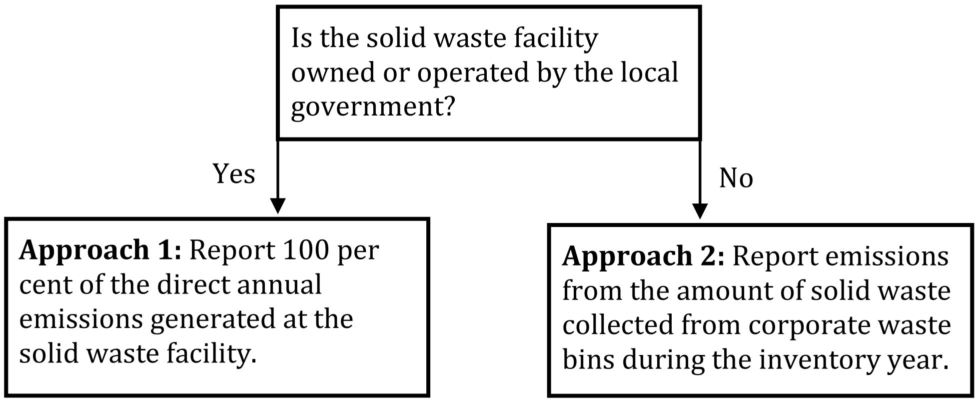
Local governments must report emissions from this sector using one of two approaches:

Approach 1: Emissions from Municipally-Owned Waste Disposal Facilities
If a local government owns or operates its own solid waste facility, it must estimate the direct GHG emissions generated from all the waste disposed at the corporate-owned landfill(s) and incineration facility(s) during the inventory year. Under this approach, the local government accounts for 100 per cent of the direct annual emissions generated at its solid waste disposal sites, regardless of where the solid waste originates. Accounting for the direct emissions from corporate-owned landfills and incineration facilities is consistent with the concept of operational control, which requires the local government to report 100 per cent of the emissions from operations over which it has control (see the Corporate Inventory Boundary section on page 6 for more details).

Approach 2: Emissions from Corporate Solid Waste Generation
If a local government does not own or operate its own solid waste facility, it must estimate GHG emissions based on the amount of solid waste collected from corporate waste bins during the inventory year that is landfilled or incinerated. Under this approach, the local government accounts

for the downstream annual emissions generated from the solid waste collected from corporate waste bins, regardless of where the solid waste is disposed.

Figure G: Corporate Solid Waste Sector Approach Decision Tree



Inclusion Protocol

Approach 1: Emissions from Municipally-Owned Waste Disposal Facilities
Report the direct emissions associated with the landfilling or incineration of waste disposed at corporate-owned landfills and waste incineration facilities during the inventory year. Include any waste disposed at the facilities that originate from outside the municipality.

Approach 2: Emissions from Corporate Solid Waste Generation
Report the total downstream emissions associated with the landfilling or incineration of waste generated by the local government's operations during the inventory year. Include waste generated at all corporate-owned buildings and facilities as well as parks and public receptacles.

Exclusion Protocol

Exclude waste that is diverted through composting or recycling initiatives.

Do not include GHG emissions generated by waste disposal vehicles; these emissions are accounted for in the corporate fleet sector.

CO_2 emissions associated with the decomposition or combustion of organic waste (e.g. paper, food and yard waste, etc.) are considered to be of biogenic origin and may be excluded from the GHG inventory.

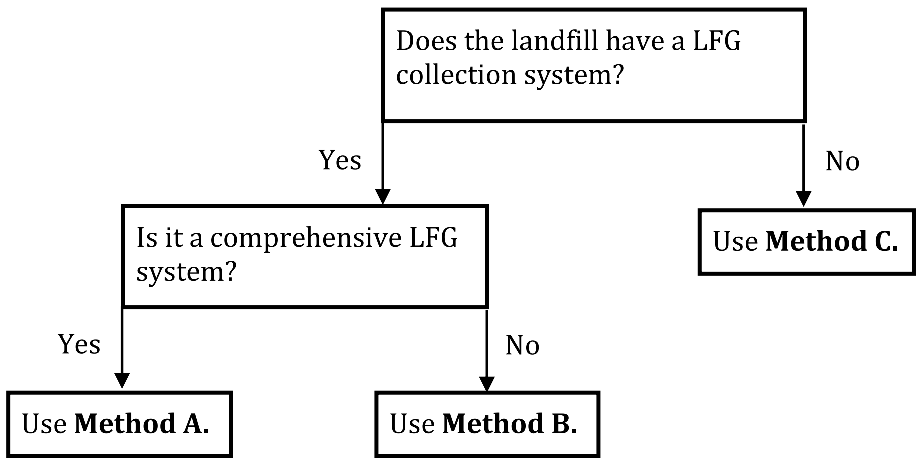
Reporting Guidelines

As a best practice, waste and emissions data should be sufficiently disaggregated so as to enable comparisons of municipal solid waste generating buildings or facilities (e.g. corporate offices, parks, recreation centres, etc.) or by individual solid waste disposal facilities. Reporting emissions data at the individual building or facility level allows for more detailed comparisons of waste generation over time, and can reveal opportunities to implement waste reduction measures. If disaggregated reporting is not possible, local governments should report the total GHG emissions generated by the corporate solid waste sector.

Accounting Guidelines I: Estimating GHG Emissions from Landfilled Waste

Emissions from solid waste deposited at a landfill can be calculated using one of three methods depending on if the landfill has a comprehensive landfill gas (LFG) collection system, partial LFG collection system, or no LFG collection system.

Figure H: Landfilled Waste GHG Emissions Quantification Decision Tree



Method A: Landfills with Comprehensive LFG Collection Systems

The U.S. Environmental Protection Agency defines a "comprehensive" LFG collection system as "a system of vertical wells and/or horizontal collectors providing 100 percent collection system coverage of all areas with waste within one year after the waste is deposited."[8] To estimate GHG emissions from a landfill with a comprehensive LFG collection system, follow the formula[9] below:

$$CO_2e = LFG \bullet F \bullet [(1\text{-}DE) + (\frac{1-CE}{CE}) \bullet (1\text{-}OX)] \bullet \text{unit conversion} \bullet GWP$$

Description			*Value*
CO_2e	=	Direct GHG emissions (methane) from a landfill with comprehensive LFG collection (t CO_2e/year)	Computed
LFG	=	Annual landfill gas collected by the collection system (measured in m^3 at STP)	User input
F	=	Fraction of methane in landfill gas	User input (default value of 0.5)
DE	=	CH_4 destruction efficiency based on type of combustion/flare system	User input (default value of 0.99)
CE	=	Collection efficiency of the LFG system	User input (default value of 0.75)
OX	=	Oxidation factor	A value of 0.1 is justified for well-managed landfills

[8] U.S. EPA. (2010). LFG Energy Project Development Handbook, Chapter 2: Landfill Gas Modeling.

[9] ICLEI-USA. (2010). *Local Government Operations Protocol*, Chapter 9.

Unit Conversion	=	Applies when converting million standard cubic feet of methane into metric tons of methane (volume units to mass units)	19.125
GWP	=	Global warming potential of CH_4	21

Method B: Landfills with Partial LFG Collection Systems

Partial landfill gas collection systems are designed to capture some of the CH_4 gas emitted from the decomposition of waste. To estimate GHG emissions from a landfill with a comprehensive LFG collection system, follow the formula[10] below:

$$CO_2e = \text{LFG} \bullet \text{F} \bullet \{(1\text{-DE}) + [(\frac{1}{CE}) \bullet (\frac{1}{OX})] \bullet [(\text{AF} + (1\text{-CE})]\} \bullet \text{unit conversion} \bullet \text{GWP}$$

Description			*Value*
CO_2e	=	Direct GHG emissions (methane) from a landfill with partial LFG collection (t CO_2e/year)	Computed
LFG	=	Annual landfill gas collected by the collection system (measured in m^3 at STP)	User input
F	=	Fraction of methane in landfill gas	User input (default value of 0.5)
DE	=	CH_4 destruction efficiency based on type of combustion/flare system	User input (default value of 0.99)
CE	=	Collection efficiency of the LFG system	User input (default value of 0.75)
OX	=	Oxidation factor	A value of 0.1 is justified for well-managed landfills
AF	=	Uncollected area factor (uncollected surface area divided by collected surface area under the influence of LFG collection system).	User input (ratio of uncollected surface area to collected surface area)
Unit Conversion	=	Applies when converting million standard cubic feet of methane into metric tons of methane (volume units to mass units)	19.125
GWP	=	Global warming potential of CH_4	21

Method C: Landfills with No LFG System

Emissions from solid waste disposed at a landfill without a LFG system can be estimated using either a 'methane commitment' or 'waste-in-place' model.

[10] ICLEI-USA. (2010). *Local Government Operations Protocol*, Chapter 9.

The methane commitment model (also known as 'total yield gas') estimates the total downstream methane (CH_4) emissions generated over the course of the waste's decomposition i.e. future CH_4 generation is attributed to the inventory year in which the solid waste was generated and disposed. This approach is typically the simplest for local governments in terms of data collection requirements and methodology. It is also the most comparable approach.

The waste-in-place model (also known as 'fist order decay') is an exponential equation that estimates the amount of CH_4 that will be generated in a landfill based on the amount of waste in the landfill in the inventory year (i.e. the "waste-in-place"), the capacity of that waste to generate CH_4, and a CH_4 generation rate constant which describes the rate at which waste in the landfill is expected to decompose and produce CH_4. To use this model, local governments will need to know the amount of waste historically deposited at the landfill, the composition of the landfilled waste, and the general climatic conditions at the landfill site. This method is the recommended approach to estimate CH_4 from a landfill without a LFG system because it best models CH_4 release from landfilled waste; the model assumes CH_4 from solid waste peaks shortly after it is placed in the landfill and then decreases exponentially as the organic material in the waste decomposes.

Option 1: Methane Commitment Model

Emissions from solid waste disposed at a landfill without a LFG system can be calculated with the methane commitment model using the following steps:

1. Determine the quantity (mass) of solid waste landfilled during the inventory year.
2. Determine the composition of the waste stream (defaults provided).
3. Calculate the degradable organic carbon (DOC) content of the waste stream (formula provided).
4. Calculate the methane generation potential of the landfilled waste (formula provided).
5. Calculate emissions of CO_2e using the information determined in steps 1-4.

Step 1: Determine the quantity (mass) of solid waste landfilled during the inventory year.
The recommended and alternative quantification guidelines are different for this step depending on if the local government owns or operates its own solid waste facility (Approach 1) or does not own or operate its own solid waste facility (Approach 2).

<u>Approach 1: Emissions from Municipally-Owned Waste Disposal Facilities</u>

Recommended	Obtain actual data on the quantity (mass) of solid waste landfilled annually. Solid waste facilities should have records on the total quantity of solid waste disposed in a particular year.
Alternative	If actual waste generation data are unavailable for the inventory year, follow the general formula[11] below: $M_x = P_x \bullet \frac{M_y}{P_y}$ <u>Description</u> <u>Value</u> M_x = Quantity of solid waste disposed in year 'x' Computed x = Year for which solid waste data is not known User input

[11] ICLEI USA, *Local Government Operations Protocol*, Version 1.1 (2010).

	P_x = Total population of jurisdiction(s) disposing waste in year 'x' — User input M_y = Quantity of solid waste disposed in year 'y' — User input y = Year for which solid waste data is known — User input P_y = Total population of jurisdiction(s) disposing waste in year 'y' — User input
Alternative	If actual waste generation data is not available, local governments can extrapolate data from an existing regional or provincial/territorial post diversion study.

Approach 2: Emissions from Corporate Solid Waste Generation

Recommended	Obtain actual data on the quantity (mass) of solid waste generated at corporate buildings and facilities that is landfilled during the inventory year. This may require conducting an internal waste audit or consulting with maintenance staff.
Alternative	If actual waste generation data is not available, local governments can estimate the quantity of solid waste generated at corporate buildings and facilities based on the size of garbage bins used, their average fullness, and the frequency of their pickup. To use this approach, follow the formula below for each garbage bin: $M = B \bullet F \bullet P \bullet 0.178 \bullet 12$ *Description* — *Value* M = Annual quantity of solid waste generated at a building or facility (t) — Computed B = Garbage bin capacity (m^3) — User input F = How full the bin is at pickup (%) — User input P = Frequency of pickup (times/month) — User input *0.178* = Volume to weight conversion factor *12* = Months in one year

Step 2: Determine the composition of the waste stream (defaults provided).

Recommended	Obtain actual data on the composition of the waste stream by undertaking a waste composition study/audit that identifies the types of materials discarded and their portion of the total waste stream.
Alternative	If actual waste composition information is not available, local governments can extrapolate data from an existing regional or provincial/territorial post diversion study.

Alternative	If data from a waste composition study is not available, use the general municipal solid waste composition values for North America[12] below: **Waste Category** / **Percentage** Food: 34% Garden: 0% Paper/Cardboard: 23% Wood Products: 6% Textiles: 4% Plastics, other inert (e.g. glass, metal, etc.): 33%

Waste Category	Percentage
Food	34%
Garden	0%
Paper/Cardboard	23%
Wood Products	6%
Textiles	4%
Plastics, other inert (e.g. glass, metal, etc.)	33%

Step 3: Determine the degradable organic carbon content of the waste stream (formula provided).

The degradable organic carbon (DOC) content represents the amount of organic carbon present in the waste stream that is accessible to biochemical decomposition. Note that only organic waste (e.g. food waste, paper, garden waste, etc.) has DOC. To estimate DOC, follow the formula[13] below:

DOC = (0.15 x A) + (0.2 x B) + (0.4 x C) + (0.43 x D) + (0.24 x E) + (0.15 x F)

Description			Value
DOC	=	Degradable organic carbon (t carbon/t waste)	Computed
A	=	Fraction of solid waste stream that is food	User input
B	=	Fraction of solid waste stream that is garden waste and other plant debris	User input
C	=	Fraction of solid waste stream that is paper	User input
D	=	Fraction of solid waste stream that is wood	User input
E	=	Fraction of solid waste stream that is textiles	User input
F	=	Fraction of solid waste stream that is industrial waste	User input

[12] IPCC. (2006). *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Volume 5 Waste, IPCC Waste Model spreadsheet.

[13] Toronto and Region Conservation. (2010). *Getting to Carbon Neutral: A Guide for Canadian Municipalities*. Adapted from the *Intergovernmental Panel on Climate Change Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories.*

Step 4: Determine the methane generation potential of the landfilled waste (formula provided).

The methane generation potential (L_0) is an emission factor that specifies the amount of CH_4 generated per tonne of solid waste landfilled. Its value is dependent on several factors, including the portion of DOC present in the waste and the general characteristics of the landfill. To estimate L_0, follow the IPCC formula[11] below:

$$L_0 = {}^{16}/_{12} \bullet MCF \bullet DOC \bullet DOC_F \bullet F$$

Description			*Value*
L_0	=	Methane generation potential (t CH_4/t waste)	Computed
MCF	=	Methane correction factor	User input: managed = 1.0 unmanaged (≥5 m deep) = 0.8 unmanaged (<5 m deep) = 0.4 uncategorized = 0.6
DOC	=	Degradable organic carbon (t carbon/t waste)	User input
DOC_F	=	Fraction of DOC dissimilated	User input (default value of 0.6)
F	=	Fraction of methane in landfill gas	User input (default value of 0.5)
16/12	=	Stoichiometric ratio between methane and carbon	

Step 5: Calculate emissions of CO_2e using the information determined in steps 1-4.

To estimate emissions of CO_2e, use the formula[14] below:

$$CO_2e = 21 \bullet M \bullet L_0\,(1 - f_{rec})(1 - \mathrm{OX})$$

Description			*Value*
CO_2e	=	Downstream GHG emissions (methane) associated with corporate solid waste sent to landfill (t CO_2e)	Computed
M	=	Quantity of solid waste sent to landfill during inventory year (tonnes)	User input
L_0	=	Methane generation potential (t CH_4/t waste)	User input (see Step 4)
21	=	Global warming potential of CH_4	
f_{rec}	=	Fraction of methane emissions that are recovered at the landfill (e.g. landfill gas collection systems)	User input
OX	=	Oxidation factor	A value of 0.1 is justified for well-managed landfills;

[14] Toronto and Region Conservation. (2010). *Getting to Carbon Neutral: A Guide for Canadian Municipalities*. Adapted from the *Intergovernmental Panel on Climate Change Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories.*

		An average value for unmanaged landfills is closer to zero.

Text Box: Corporate Solid Waste Approach 1 & Option 1 Emissions Quantification Example

In 2010, the municipal corporation of the Town of St. Resilience generated 2,000 tonnes of solid waste. The Town estimates the composition of the waste stream to be approximately 30% paper, 15% food, 10% garden and plant debris, 6% wood and 39% other. The waste is sent to a managed landfill with a partial LFG collection system that recovers approximately 60% of the landfill gas.

Step 1: Determine the quantity (mass) of solid waste generated by corporate operations during the inventory year.

M = 2,000 tonnes

Step 2: Determine the composition of the corporate waste stream.

Waste Category	Percentage of Waste Stream
Paper and Cardboard	30% *("C")*
Food	15% *("A")*
Garden and Plant Debris	10% *("B")*
Wood Products	6% *("D")*
Other	39%

Step 3: Determine the degradable organic carbon content of the waste stream.

$$DOC = (0.15 \times A) + (0.2 \times B) + (0.4 \times C) + (0.43 \times D) + (0.24 \times E) + (0.15 \times F)$$

$$= (0.15 \times 0.15) + (0.2 \times 0.1) + (0.4 \times 0.3) + (0.43 \times 0.06)$$

$$= 0.1883$$

Step 4: Determine the methane generation potential of the landfilled waste.

$$L_0 = {}^{16}/_{12} \bullet MCF \bullet DOC \bullet DOC_F \bullet F$$

$$= {}^{16}/_{12} \bullet 1.0 \bullet 0.1883 \bullet 0.6 \bullet 0.5$$

$$= 0.07532 \text{ t } CH_4/\text{t waste}$$

Step 5: Calculate emissions of CO_2e using the information determined in steps 1-4.

$$CO_2e = 21 \bullet M \bullet L_0\,(1 - f_{rec})(1 - OX)$$

=	21 • 2,000 • 0.07532 • (1 - 0.6) • (1-0.1)
=	1,139 tonnes

Option 2: Waste-In-Place Model

The waste-in-place model is available for use in a variety of user-friendly Excel-based formats, such as the *IPCC Waste Model*, the U.S. EPA's *Landfill Gas Emissions Model (LandGEM)*, and the *Landfill Emissions Tool* developed by the California Air Resources Board. Alternatively, emissions from solid waste deposited at a landfill without a LFG collection system can be calculated with the waste-in-place model using the following steps:

1. Determine the historical quantity (mass) of solid waste landfilled annually (defaults provided).
2. For each year, determine the first-order decay rate at the landfill site (defaults provided).
3. For each year, determine the average methane generation potential of the landfilled waste (defaults provided).
4. Calculate the sum of CH_4 generated from the solid waste landfilled each year using a first-order decay (FOD) model and multiply the total value by its global warming potential (GWP) to determine total CO_2e emissions.

Step 1: Determine the historical quantity (mass) of solid waste landfilled annually (defaults provided).
The recommended and alternative quantification guidelines are different for this step depending on if the local government owns or operates its own solid waste facility (Approach 1) or does not own or operate its own solid waste facility (Approach 2).

<u>Approach 1: Emissions from Municipally-Owned Waste Disposal Facilities</u>

Recommended	Obtain actual data on the quantity (mass) of solid waste landfilled annually. Solid waste facilities should have records on the total quantity of solid waste disposed in a particular year. The calculation of the analysis-year emissions requires at least 30 years of historical data.
Alternative	If actual waste generation data are unavailable for some years, follow the general formula[15] below and repeat it for all the missing years: $M_x = P_x \bullet \frac{M_y}{P_y}$ <u>Description</u> — <u>Value</u> M_x = Quantity of solid waste disposed in year 'x' — Computed x = Year for which solid waste data is not known — User input P_x = Total population of jurisdiction(s) disposing waste in year 'x' — User input M_y = Quantity of solid waste disposed in year 'y' — User input y = Year for which solid waste data is known — User input

[15] ICLEI USA, *Local Government Operations Protocol*, Version 1.1 (2010).

	P_y	=	Total population of jurisdiction(s) disposing waste in year 'y'	User input
Alternative	If actual waste generation data is not available, local governments can extrapolate data from an existing regional or provincial/territorial post diversion study.			

Approach 2: Emissions from Corporate Solid Waste Generation

Recommended	Obtain actual data on the quantity (mass) of solid waste generated at corporate buildings and facilities that is landfilled annually. This may require conducting an internal waste audit or consulting with maintenance staff. The calculation of the analysis-year emissions requires at least 30 years of historical data.
Alternative	If actual waste generation data is not available, local governments can estimate the quantity of solid waste generated at corporate buildings and facilities based on the size of garbage bins used, their average fullness, and the frequency of their pickup. To use this approach, follow the formula below for each garbage bin: $M = B \bullet F \bullet P \bullet 0.178 \bullet 12$ *Description* / *Value* M = Annual quantity of solid waste generated at a building or facility (t) — Computed B = Garbage bin capacity (m^3) — User input F = How full the bin is at pickup (%) — User input P = Frequency of pickup (times/month) — User input *0.178* = Volume to weight conversion factor *12* = Months in one year

Step 2: For each year, determine the first-order decay rate at the landfill site (defaults provided).

The decay rate constant (k), also known as the methane generation constant, represents the first-order rate at which methane is generated after waste has been disposed at the landfill. Its value is affected by moisture content, availability of nutrients, pH, and temperature. The moisture content of the waste within a landfill is one of the most important parameters affecting the landfill gas generation rate. The infiltration of precipitation through the landfill cover, the initial moisture content of the waste, the design of the leachate collection system, and the depth of waste in the site are the primary factors that influence the moisture content of the waste.

Environment Canada's *National Inventory Report 1990-2010: Greenhouse Gas Sources and Sinks in Canada* (2013*)* provides municipal solid waste landfill k estimates for different regions and provinces/territories in Canada for three respective time series: 1941-1975, 1976-1989, and 1990-2007. This information is available in Part 2, Annex 3: Additional Methodologies, Page 155-156.

Step 3: For each year, determine the average methane generation potential of the solid waste landfilled (defaults provided).

The methane generation potential (L_0) is an emission factor that specifies the amount of CH_4 generated per tonne of solid waste landfilled. Its value is dependent on several factors, including the portion of degradable organic carbon (DOC) present in the waste and the general characteristics of the landfill.

Environment Canada's *National Inventory Report 1990-2010: Greenhouse Gas Sources and Sinks in Canada* (2013*)* provides methane generation potential values for each province and territory for three respective time series: 1941-1975, 1976-1989, and 1990-2007. This information is available in Part 2, Annex 3: Additional Methodologies, Page 158.

Step 4: Calculate the sum of CH_4 generated from the solid waste landfilled each year using a first-order decay (FOD) model and multiply the total value by its global warming potential (GWP) to determine total CO_2e emissions.

To estimate analysis-year emissions, follow the formula[16] below and at least 30 years of historical data:

$CO_2e_{\text{NLFG}} = (\sum Q_{T,x} \bullet \text{GWP})$ where $Q_{T,x} = kM_x L_0 e^{-k(T-x)}$

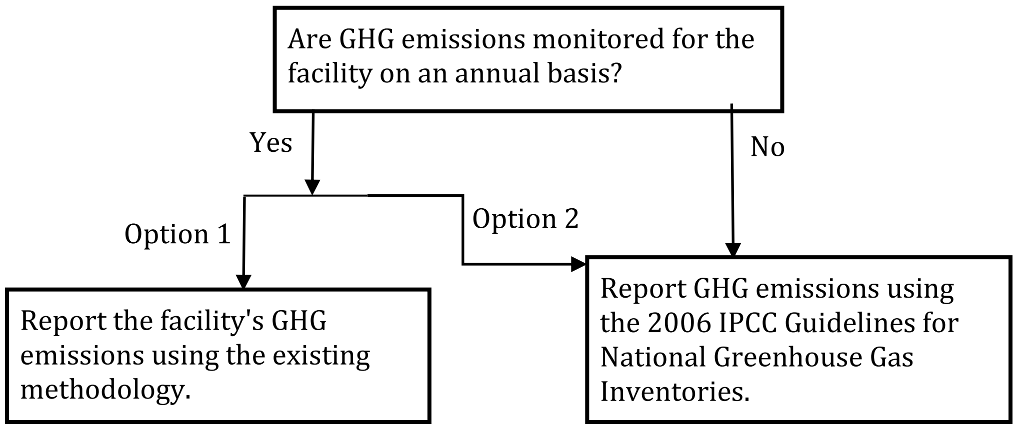
Description			Value
CO_2e_{NLFG}	=	GHG emissions generated in the inventory year from a landfill without a landfill gas system (kt CO_2e/year)	Computed
$Q_{T,X}$	=	Amount of CH_4 generated in the inventory year by waste M_x (kt/CH_4/year)	Computed
T	=	The inventory year	User input
x	=	The year of waste input	User input
k	=	Decay rate constant (yr^{-1})	User input
M_x	=	The amount of waste disposed in year x (Mt)	User input
L_0	=	CH_4 generation potential (kg CH_4/t waste)	User input
GWP	=	Global warming potential of CH_4	21

[16] Environment Canada, *National Inventory Report 1990-2010: Greenhouse Gas Sources and Sinks in Canada,* Part 2 (2012).

Accounting Guidelines II: Estimating GHG Emissions from Waste Incineration

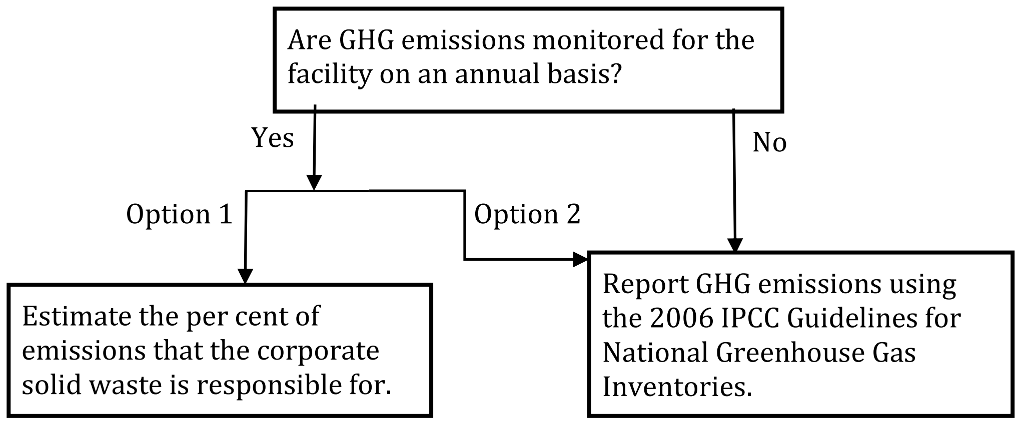
Approach 1: Emissions from Municipally-Owned Waste Disposal Facilities
If a local government owns or operates its own incineration facility for which it monitors GHG emissions on an annual basis (e.g. for Environment Canada's Greenhouse Gas Reporting Program), emissions from solid waste combustion can be reported using the existing methodology. If GHG emissions are not monitored, the 2006 IPCC Guidelines for National Greenhouse Gas Inventories for Incineration[17] must be used to calculate emissions.

Figure I: Approach 1 Emissions Quantification Decision Tree



Approach 2: Emissions from Corporate Solid Waste Generation
If solid waste collected from corporate waste bins during the inventory year are combusted at an incineration facility that monitors GHG emissions on an annual basis (e.g. for Environment Canada's Greenhouse Gas Reporting Program), emissions can be reported by either estimating the per cent of emissions that the corporate solid waste is responsible for or by using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories for Incineration. If GHG emissions are not monitored, the 2006 IPCC Guidelines for National Greenhouse Gas Inventories for Incineration must be used to calculate emissions.

Figure J: Approach 2 Emissions Quantification Decision Tree



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[17] IPCC. (2006). *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Volume 5 Waste, Chapter 5 Incineration and Open Burning of Waste.

Quantification Guidelines for Community GHG Inventories

To be considered in compliance with PCP protocol, community GHG inventories must include emissions from the following **five** activity sectors:

- Residential buildings;
- Institutional and commercial buildings;
- Industrial buildings;
- Transportation; and
- Community solid waste.

A detailed description of each sector is provided below along with the recommended best practices for GHG quantification.

Residential, Institutional and Commercial, and Industrial Buildings

The residential, institutional and commercial, and industrial buildings sectors track GHG emissions associated with the use of energy in buildings and within each sector respectively. Emissions in these sectors can be produced directly from stationary combustion of fuels (e.g. natural gas used in boilers and furnaces) or indirectly from the use of grid electricity or district energy.

Inclusion Protocol

Report all direct and indirect emissions generated by the use of energy at community buildings (e.g. residential dwellings, institutions, commercial establishments, industrial facilities, etc.).

Exclusion Protocol

Carbon dioxide (CO_2) emissions associated with the combustion of biomass and biomass-based energy sources (e.g. wood, wood residuals, pellets, etc.) are considered to be of biogenic origin and may be excluded from the GHG inventory. However, methane (CH_4) and nitrous oxide (N_2O) emissions from biomass combustion are anthropogenic and must be reported in the GHG inventory.

Reporting Guidelines

As a best practice, energy and emissions data should be sufficiently disaggregated so as to enable comparisons of groups of buildings of similar type or function (e.g. single family homes, apartments, etc.). Reporting energy and emissions data at this level allows for more detailed comparisons of performance over time, and can reveal opportunities to develop energy efficiency or renewable energy programs or policies that target specific building types.

If disaggregated reporting is not possible, local governments should report the total energy consumption and corresponding GHG emissions for each energy source used (e.g. natural gas, electricity, fuel oil, etc.).

Accounting Guidelines

Emissions from energy consumed in buildings can be calculated using the following steps:

1. For each energy source, determine the total amount of energy consumed by each building during the inventory year.
2. Identify the corresponding emission factors for CO_2, CH_4 and N_2O (values provided).
3. Multiply energy consumption data by the corresponding emission factors and their global warming potential (GWP) to determine total CO_2e emissions.

Step 1: For each energy source, determine the total amount of energy consumed by each building during the inventory year.

Recommended	Obtain actual consumption data for each energy source consumed. This information may be obtained directly from utility and fuel providers.
Alternate	If actual consumption data are not available, local governments can estimate a building's annual energy consumption based on the building's total floor area and average energy intensity values. Energy intensity values estimate a building's annual energy consumption per area of floor space (e.g. GJ/m^2). A list of energy intensity values for residential, commercial/institutional, and industrial buildings is provided in the *Comprehensive Energy Use Database* published by Natural Resources Canada's Office of Energy Efficiency.[18] Municipal property tax departments typically have data on built space area by building classification.

Step 2: Identify the corresponding emission factors for CO_2, CH_4 and N_2O (values provided).

Use province/territorial or utility-specific emission factors for stationary fuel combustion and electricity consumption. Environment Canada's *National Inventory Report* provides emission factors for a variety of emissions-generating activities, including stationary combustion of fuels (Annex 8) and consumption of grid electricity (Annex 13).

Note that emission factors for electricity consumption are updated annually based on the energy sources used to generate electricity in each province or territory. Emission factors for stationary combustion of fuels, such as natural gas or fuel oil, are influenced primarily by the carbon content of the fuel, and as such do not vary considerably between inventory years (see table 4 and 5 below).

Table 4: CO_2, CH_4 and N_2O Emission Factors for Natural Gas[19]

Province	Emission Factors (g/m^3)			
	CO2	CH4*	N2O*	CO_2e
Newfoundland and Labrador	1,891	0.037	0.035	1,903
Nova Scotia	1,891	0.037	0.035	1,903
New Brunswick	1,891	0.037	0.035	1,903
Quebec	1,878	0.037	0.035	1,890
Ontario	1,879	0.037	0.035	1,891
Manitoba	1,877	0.037	0.035	1,889
Saskatchewan	1,820	0.037	0.035	1,832
Alberta	1,918	0.037	0.035	1,930
British Columbia	1,916	0.037	0.035	1,928
Yukon	1,891	0.037	0.035	1,903
Northwest Territories	2,454	0.037	0.035	2,466

*CH_4 and N_2O emission factors are specific to the residential, commercial and institutional sectors.

[18] Natural Resources Canada Office of Energy Efficiency. (2011). Comprehensive Energy Use Database.
[19] Adapted from Environment Canada's *National Inventory Report 1990-2011: Greenhouse Gas Sources and Sinks in Canada*, Part 2, Annex 8, pp.193-194.

Table 5: CO_2, CH_4 and N_20 Emission Factors for Other Stationary Fuels[20]

Fuel Type	Emission Factors (g/L)			
	CO2	CH4*	N2O*	CO_2e
Light fuel oil	2,725	0.026	0.031	2,735
Heavy fuel oil	3,124	0.057	0.064	3,145
Kerosene	2,534	0.026	0.031	2,544
Propane	1,507	0.024	0.108	1,541
Diesel	2,663	0.133	0.4	2,790

*CH_4 and N_2O emission factors are specific to the commercial and institutional sector.

Step 3: Multiply energy consumption data by the corresponding emission factors and their global warming potential (GWP) to determine total CO_2e emissions.

For each energy source, multiply the amount of energy consumed by the corresponding emission factors for CO_2, CH_4 and N_2O. Use global warming potentials to convert CH_4 and N_20 emissions into units of CO_2 equivalent (CO_2e).

$$CO_2e_a = (x_a \bullet CO_2EF_a) + (x_a \bullet N_2OEF_a \bullet GWP_{N2O}) + (x_a \bullet CH_4EF_a \bullet GWP_{CH4})$$

OR

For each energy source, multiply the amount of energy consumed by the corresponding emission factor for CO_2 equivalent.

$$CO_2e_a = (x_a \bullet CO_2eEF_a)$$

<u>Description</u>			<u>Value</u>
CO_2e_a	=	Total CO_2e emissions produced from a building consuming energy source 'a' in the inventory year	Computed
x_a	=	Amount of energy source 'a' consumed in one year	User input
CO_2EF_a	=	The CO_2 emission factor for energy source 'a'	User input
CH_4EF_a	=	The CH_4 emission factor for energy source 'a'	User input
N_2OEF_a	=	The N_2O emission factor for energy source 'a'	User input
CO_2eEFa	=	The CO_2 equivalent emission factor for energy source 'a'	User input
a	=	Energy source (e.g. electricity, natural gas, fuel oil, etc.)	
GWP_{N2O}	=	Global warming potential of N_2O	310
GWP_{CH4}	=	Global warming potential of CH_4	21

[20]Adapted from Environment Canada's *National Inventory Report 1990-2011: Greenhouse Gas Sources and Sinks in Canada*, Part 2, Annex 8, pp.195.

Transportation

The community transportation sector tracks GHG emissions generated by vehicles traveling within the community. Emissions in this sector can be produced directly from the use of fuels, such as gasoline and diesel, or indirectly from the use of grid electricity (e.g. plug-in electric vehicles).

Local governments may choose to report emissions from this sector using one of three approaches:

Approach 1: Fuel Sales
The fuel sales approach involves obtaining records of the total amount of automotive fuel purchased within the community. Although this approach is typically the simplest for local governments in terms of data collection and replication, fuel sales data may not always be complete as they often exclude commercial card locks, fuel delivered to commercial and industrial operations with fleet fueling stations, and small remote fueling stations. Further, fuel sales may include fuel volumes used by vehicles travelling through the community on major roads that cross local government boundaries.

Approach 2: Vehicle Kilometers Travelled (VKT)
The VKT approach combines data on the total kilometres travelled by vehicles within the community with assumptions about the characteristics and fuel efficiencies of vehicles in the community. VKT is a common measure of roadway use and can be calculated using a number of methods including traffic counts, household activity surveys, odometer reporting programs, and transportation models. Using the VKT approach can be advantageous for municipalities that have a traffic volume counting program.

Approach 3: Vehicle Registration
The vehicle registration approach uses data on the number and type of vehicles registered in the community, fuel efficiencies of individual vehicles, and estimates of the total annual VKT of various vehicle classes. This method can be advantageous because vehicle registration data not only provides details on the type of vehicles present in the community, but it may also have information on the average weighted fuel efficiencies of vehicles classes. It is important to note however that some vehicles do not necessarily operate in the community they are registered in (e.g. companies with large fleets). More detailed information about the Vehicle Registration approach and an example of how it has been put into practice can be found in the Province of British Columbia's *Technical Methods and Guidance Document for 2007-2010 Reports*.[21]

If data is not available to support any of these methods, local governments should consult with transportation specialists to determine how community transportation could otherwise be modeled for the community.

Inclusion Protocol

Report all direct and indirect emissions generated by the use of motor fuels (including electricity) in on-road vehicles and public transit systems. On-road vehicles are designed for transporting people, property, or material on paved roads (e.g. cars, vans, trucks, motorcycles, etc.).

Exclusion Protocol

In certain instances, it may not be possible to distinguish electricity consumed in vehicles from electricity consumed by a building or facility. In these cases, indirect emissions from electricity consumed by vehicles may be reported in the appropriate buildings sector.

[21] Province of British Columbia, Ministry of Environment. (February, 2014). Technical Methods and Guidance Document 2007-2010 Reports. Community Energy and Emissions Inventory (CEEI) Initiative.

Carbon dioxide (CO_2) emissions associated with the combustion of biomass and biomass-based energy sources (e.g. biomass used in ethanol and biodiesel blends) are considered to be of biogenic origin and may be excluded from the GHG inventory. However, methane (CH_4) and nitrous oxide (N_2O) emissions from biomass combustion are anthropogenic and must be reported in the GHG inventory.

Reporting Guidelines

As a best practice, energy and emissions data should be sufficiently disaggregated so as to enable comparisons of groups of vehicles of similar type (e.g. cars, light trucks, heavy trucks, hybrid transit buses, etc.). If disaggregated reporting is not possible, local governments should report the total energy consumption and corresponding GHG emissions for each energy source used (e.g. gasoline, diesel, compressed natural gas, electricity, etc.).

Accounting Guidelines

<u>Approach 1: Fuel Sales</u>

Emissions from energy consumed by vehicles can be calculated with the fuel sales approach using the following steps:

1. For each energy source, determine the total amount of energy consumed by community vehicles during the inventory year.
2. Identify the corresponding emission factors for CO_2, CH_4 and N_2O (values provided).
3. Multiply energy consumption data by the corresponding emission factors and their global warming potential (GWP) to determine total CO_2e emissions.

Step 1: For each energy source, determine the total amount of energy consumed by community vehicles during the inventory year.

Obtain actual consumption data for each energy source consumed. Annual fuel consumption data may be sourced from marketing service companies. If propane data are gathered, ask the data provider to distinguish between automobile propane and propane used for other activities (e.g. barbecues, space heaters, etc.). Electricity is typically monitored at the point of sale, and it is recommended therefore to obtain this data from the utility provider.

Step 2: Identify the corresponding emission factors for CO_2, CH_4 and N_2O (defaults provided).

CO_2 emissions from the combustion of transportation fuels are predominantly dependent on the type of fuel combusted, whereas N_2O and CH_4 emissions are dependent on both the type of fuel combusted and the characteristics of the vehicle (e.g. vehicle emission control technologies).

Use emission factors specific to the vehicle type (e.g. light-duty vehicle, heavy-duty vehicle, etc.), model year, and fuel type. Environment Canada's National Inventory Report provides a comprehensive listing of transportation-related emission factors, broken-down by vehicle type, fuel type, and technology penetration (Annex 8). These emission factors have been adapted in Table 6 below.

Table 6: CO_2e Emission Factors for Mobile Energy Combustion Sources[22]

Light-Duty Vehicles[1] (tonnes CO2e/unit fuel)									
	Fuel Type								
Inventory Year	Gasoline	Diesel	Propane	CNG [4]	E10	E85	B5	B10	B20
1990-1999	0.002500	0.002730	0.001513	0.003023	0.002271	0.000555	0.002597	0.002464	0.002197
2000	0.002500	0.002730	0.001513	0.003023	0.002271	0.000555	0.002597	0.002464	0.002197
2001	0.002500	0.002730	0.001513	0.003023	0.002271	0.000555	0.002597	0.002464	0.002197
2002	0.002440	0.002730	0.001513	0.003023	0.002211	0.000494	0.002597	0.002464	0.002197
2003	0.002440	0.002732	0.001513	0.003023	0.002211	0.000494	0.002599	0.002466	0.002199
2004	0.002440	0.002732	0.001513	0.003023	0.002211	0.000494	0.002599	0.002466	0.002199
2005	0.002440	0.002732	0.001513	0.003023	0.002211	0.000494	0.002599	0.002466	0.002199
2006	0.002440	0.002732	0.001513	0.003023	0.002211	0.000494	0.002599	0.002466	0.002199
2007	0.002440	0.002732	0.001513	0.003023	0.002211	0.000494	0.002599	0.002466	0.002199
2008	0.002440	0.002732	0.001513	0.003023	0.002211	0.000494	0.002599	0.002466	0.002199
2009	0.002440	0.002732	0.001513	0.003023	0.002211	0.000494	0.002599	0.002466	0.002199
2010	0.002440	0.002732	0.001513	0.003023	0.002211	0.000494	0.002599	0.002466	0.002199
2011	0.002299	0.002732	0.001513	0.003023	0.002070	0.000353	0.002599	0.002466	0.002199
2012	0.002299	0.002732	0.001513	0.003023	0.002070	0.000353	0.002599	0.002466	0.002199
2013	0.002299	0.002732	0.001513	0.003023	0.002070	0.000353	0.002599	0.002466	0.002199
Light-Duty Trucks[2] (tonnes CO2e/unit fuel)									
	Fuel Type								
Inventory Year	Gasoline	Diesel	Propane	CNG (kg) [4]	E10	E85	B5	B10	B20
1990-1999	0.002498	0.002730	0.001513	0.003023	0.002269	0.000552	0.002597	0.002464	0.002197
2000	0.002498	0.002730	0.001513	0.003023	0.002269	0.000552	0.002597	0.002464	0.002197
2001	0.002498	0.002730	0.001513	0.003023	0.002269	0.000552	0.002597	0.002464	0.002197
2002	0.002474	0.002730	0.001513	0.003023	0.002245	0.000528	0.002597	0.002464	0.002197
2003	0.002474	0.002733	0.001513	0.003023	0.002245	0.000528	0.002600	0.002467	0.002200
2004	0.002474	0.002733	0.001513	0.003023	0.002245	0.000528	0.002600	0.002467	0.002200
2005	0.002474	0.002733	0.001513	0.003023	0.002245	0.000528	0.002600	0.002467	0.002200
2006	0.002474	0.002733	0.001513	0.003023	0.002245	0.000528	0.002600	0.002467	0.002200
2007	0.002474	0.002733	0.001513	0.003023	0.002245	0.000528	0.002600	0.002467	0.002200
2008	0.002474	0.002733	0.001513	0.003023	0.002245	0.000528	0.002600	0.002467	0.002200
2009	0.002474	0.002733	0.001513	0.003023	0.002245	0.000528	0.002600	0.002467	0.002200
2010	0.002474	0.002733	0.001513	0.003023	0.002245	0.000528	0.002600	0.002467	0.002200
2011	0.002299	0.002733	0.001513	0.003023	0.002070	0.000353	0.002600	0.002467	0.002200
2012	0.002299	0.002733	0.001513	0.003023	0.002070	0.000353	0.002600	0.002467	0.002200
2013	0.002299	0.002733	0.001513	0.003023	0.002070	0.000353	0.002600	0.002467	0.002200
Heavy-Duty Vehicles[3] (tonnes CO2e/unit fuel)									
	Fuel Type								

[22] Adapted from Environment Canada's *National Inventory Report 1990-2011: Greenhouse Gas Sources and Sinks in Canada*, Part 2, Figure A2-2 (p. 43) and Table A8-11 (p.198).

Inventory Year	Gasoline	Diesel	Propane	CNG [4]	E10	E85	B5	B10	B20
1990-1999	0.002310	0.002691	0.001513	0.003023	0.002081	0.000364	0.002558	0.002425	0.002158
2000	0.002310	0.002691	0.001513	0.003023	0.002081	0.000364	0.002558	0.002425	0.002158
2001	0.002310	0.002691	0.001513	0.003023	0.002081	0.000364	0.002558	0.002425	0.002158
2002	0.002310	0.002691	0.001513	0.003023	0.002081	0.000364	0.002558	0.002425	0.002158
2003	0.002310	0.002691	0.001513	0.003023	0.002081	0.000364	0.002558	0.002425	0.002158
2004	0.002310	0.002691	0.001513	0.003023	0.002081	0.000364	0.002558	0.002425	0.002158
2005	0.002352	0.002712	0.001513	0.003023	0.002123	0.000407	0.002579	0.002446	0.002179
2006	0.002352	0.002712	0.001513	0.003023	0.002123	0.000407	0.002579	0.002446	0.002179
2007	0.002352	0.002712	0.001513	0.003023	0.002123	0.000407	0.002579	0.002446	0.002179
2008	0.002352	0.002712	0.001513	0.003023	0.002123	0.000407	0.002579	0.002446	0.002179
2009	0.002352	0.002712	0.001513	0.003023	0.002123	0.000407	0.002579	0.002446	0.002179
2010	0.002352	0.002712	0.001513	0.003023	0.002123	0.000407	0.002579	0.002446	0.002179
2011	0.002352	0.002712	0.001513	0.003023	0.002123	0.000407	0.002579	0.002446	0.002179
2012	0.002352	0.002712	0.001513	0.003023	0.002123	0.000407	0.002579	0.002446	0.002179
2013	0.002352	0.002712	0.001513	0.003023	0.002123	0.000407	0.002579	0.002446	0.002179
Off-road Vehicles/Equipment* (tonnes CO2e/unit fuel)									
	Fuel Type								
Inventory Year	Gasoline	Diesel	Propane	CNG [4]	E10	E85	B5	B10	B20
1990-1999	0.002361	0.003007	0.001513	0.003023	0.002132	0.000416	0.002874	0.002741	0.002474
2000	0.002361	0.003007	0.001513	0.003023	0.002132	0.000416	0.002874	0.002741	0.002474
2001	0.002361	0.003007	0.001513	0.003023	0.002132	0.000416	0.002874	0.002741	0.002474
2002	0.002361	0.003007	0.001513	0.003023	0.002132	0.000416	0.002874	0.002741	0.002474
2003	0.002361	0.003007	0.001513	0.003023	0.002132	0.000416	0.002874	0.002741	0.002474
2004	0.002361	0.003007	0.001513	0.003023	0.002132	0.000416	0.002874	0.002741	0.002474
2005	0.002361	0.003007	0.001513	0.003023	0.002132	0.000416	0.002874	0.002741	0.002474
2006	0.002361	0.003007	0.001513	0.003023	0.002132	0.000416	0.002874	0.002741	0.002474
2007	0.002361	0.003007	0.001513	0.003023	0.002132	0.000416	0.002874	0.002741	0.002474
2008	0.002361	0.003007	0.001513	0.003023	0.002132	0.000416	0.002874	0.002741	0.002474
2009	0.002361	0.003007	0.001513	0.003023	0.002132	0.000416	0.002874	0.002741	0.002474
2010	0.002361	0.003007	0.001513	0.003023	0.002132	0.000416	0.002874	0.002741	0.002474
2011	0.002361	0.003007	0.001513	0.003023	0.002132	0.000416	0.002874	0.002741	0.002474
2012	0.002361	0.003007	0.001513	0.003023	0.002132	0.000416	0.002874	0.002741	0.002474
2013	0.002361	0.003007	0.001513	0.003023	0.002132	0.000416	0.002874	0.002741	0.002474

[1]Light duty vehicles are cars with a gross vehicle weight rating (GVWR) of less than or equal to 3,900 kg. Assumes average light-duty vehicle on the road in any given year is 7 years old. [2]Light-duty trucks are pickups, minivans, SUVs, etc. with a GVWR of less than or equal to 3,900 kg. Assumes average light-duty truck on the road in any given year is 7 years old. [3]Heavy-duty vehicles are vehicles with a GVWR above 3,900 kg. Assumes average heavy-duty truck on the road in any given year is 9 years old. [4]Emission factors for natural gas vehicles are measured in g/kg of fuel.

Step 3: Multiply energy consumption data by the corresponding emission factors and their global warming potential (GWP) to determine total CO_2e emissions.

For each energy source, multiply the amount of energy consumed by the corresponding emission factors for CO_2, CH_4 and N_2O. Use global warming potentials to convert CH_4 and N_20 emissions into units of CO_2 equivalent (CO_2e).

$$CO_2e_a = (x_a \bullet CO_2EF_a) + (x_a \bullet N_2OEF_a \bullet GWP_{N2O}) + (x_a \bullet CH_4EF_a \bullet GWP_{CH4})$$

OR

For each energy source, multiply the amount of energy consumed by the corresponding emission factor for CO_2 equivalent.

$$CO_2e_a = (x_a \bullet CO_2eEF_a)$$

Description			Value
CO_2e_a	=	Total CO_2e emissions produced from vehicles consuming energy source 'a' in the inventory year	Computed
x_a	=	Amount of energy source 'a' consumed in one year	User input
CO_2EF_a	=	CO_2 emission factor for energy source 'a'	User input
CH_4EF_a	=	CH_4 emission factor for energy source 'a'	User input
N_2OEF_a	=	N_2O emission factor for energy source 'a'	User input
CO_2eEF_a	=	The CO_2 equivalent emission factor for energy source 'a'	User input
a	=	Energy source (e.g. gasoline, diesel, ethanol, etc.)	
GWP_{N2O}	=	Global warming potential of N_2O	310
GWP_{CH4}	=	Global warming potential of CH_4	21

Approach 2: Vehicle Kilometers Travelled (VKT)

Emissions from energy consumed by vehicles can be calculated with the VKT approach using the following steps:

1. Determine the total annual VKT for the community.
2. Allocate VKT (in percentages) according to vehicle characteristics and fuel type (defaults provided).
3. Identify vehicle fuel efficiencies for each vehicle type (defaults provided).
4. Determine the amount of each energy source consumed using the information determined in steps 2-3.
5. Identify the corresponding emission factors for CO_2, CH_4 and N_2O (defaults provided).
6. Multiply energy consumption data by the corresponding emission factors and their global warming potential (GWP) to determine total CO_2e emissions.

Step 1: Determine the total annual VKT for the community.

Recommended	The daily VKT for a specific road segment is obtained by multiplying its observed 24-hour traffic volume (obtained using permanent count station, short-period automatic traffic recorders, or turning movement counts[23]) by its centre-line length. The sum of the all the daily VKTs of primary roadways (i.e. roadways with higher capacity and traffic volumes) within a local government's geo-political boarder is the total daily VKT for the community. Multiplying the total daily VKT for the community by a daily-to annual conversion factor provides the total annual VKT for the community. To estimate the total annual VKT for the community using this approach, follow the formula below: $VKT = \sum(S \bullet V) \bullet F$ Description — Value *VKT* = Total annual VKT for the community — Computed *S* = Segment length (km) — User input *V* = Volume on that segment (vehicles per day) — User input *F* = Daily-to-annual conversion factor — User input (default value of 365)
Alternate	If actual traffic count information is not available, local governments can use household activity surveys, odometer reporting programs, or transportation models. More information about these approaches can be found in the Canadian Institute of Transportation Engineer's *Vehicle Kilometres Travelled - Canadian Methodology* publication.[24]
Alternate	VKT travelled by light-duty vehicles within the community can be estimated based on the number of households within the community, the number of vehicles per household, and the average annual distance traveled per vehicle. To estimate the total annual VKT for the community using this approach, follow the formula below and table 7 and 8 for 2000-2009 inventory years: $VKT = H \bullet V \bullet F$ Description — Value *VKT* = Total annual VKT for the community — Computed *H* = Number of households in the community — User input *V* = Number of light-duty vehicles per household — User input *D* = Average annual distance traveled by light-duty vehicles — User input

[23] Canadian Institute of Transportation, Engineers, Technical Liaison Committee. (January 2012). *Vehicle Kilometres Travelled - Canadian Methodology.*

[24] Canadian Institute of Transportation Engineers, Technical Liaison Committee. (January 2012). *Vehicle Kilometres Travelled - Canadian Methodology*.

Table 7: Average Light-Duty Vehicle VKT by Province and Year[25]

	Average VKT (km)									
Province	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Newfoundland and Labrador	19,783	17,774	14,305	13,891	14,103	16,398	16,094	15,461	17,877	14,693
Prince Edward Island	16,272	15,954	17,527	17,317	15,293	16,592	12,772	17,341	15,073	15,055
Nova Scotia	16,620	17,377	18,749	18,916	17,462	17,613	18,311	18,270	16,476	17,296
New Brunswick	18,924	17,933	18,657	17,400	16,074	16,823	18,134	16,792	14,778	15,864
Quebec	16,399	16,993	16,199	16,661	15,721	14,412	14,811	14,634	14,137	14,767
Ontario	16,794	16,311	17,293	15,999	16,831	17,033	17,411	16,171	15,833	16,024
Manitoba	15,991	16,327	14,438	18,251	14,351	14,942	16,241	18,405	14,716	14,955
Saskatchewan	16,990	18,140	15,634	17,107	15,639	14,688	14,181	17,146	15,761	15,297
Alberta	18,776	17,637	15,614	16,133	14,885	17,093	16,405	16,239	15,376	15,997
British Columbia	14,975	15,060	16,033	14,166	14,443	13,912	12,173	13,432	13,174	13,005
Yukon	15,150	16,499	15,754	15,392	16,821	14,236	15,975	12,663	14,097	12,986
Northwest Territories	12,539	16,844	13,732	14,387	11,996	13,105	14,810	13,617	13,866	10,993
Nunavut	10,791	15,344	12,527	8,591	8,914	8,696	15,263	9,370	8,792	7,023
Canada	17,152	16,951	16,445	16,584	15,480	15,951	15,653	16,389	15,320	15,295

Table 8: Average Number of Light-Duty Vehicles Per Household by Jurisdiction and Year[26]

	Number of Light-Duty Vehicles per Household									
Province	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Newfoundland and Labrador	1.34	1.32	1.34	1.34	1.32	1.30	1.31	1.34	1.40	1.46
Prince Edward Island	1.49	1.47	1.46	1.46	1.46	1.45	1.44	1.45	1.45	1.48
Nova Scotia	1.49	1.48	1.46	1.46	1.42	1.43	1.39	1.44	1.41	1.41
New Brunswick	1.59	1.58	1.59	1.56	1.54	1.54	1.55	1.57	1.60	1.60
Quebec	1.31	1.30	1.35	1.36	1.36	1.35	1.37	1.38	1.38	1.39
Ontario	1.52	1.52	1.53	1.52	1.51	1.51	1.52	1.52	1.53	1.52
Manitoba	1.42	1.42	1.42	1.41	1.41	1.41	1.41	1.42	1.45	1.46
Saskatchewan	1.75	1.70	1.74	1.72	1.71	1.72	1.72	1.75	1.79	1.80
Alberta	1.67	1.71	1.76	1.75	1.76	1.80	1.86	1.91	1.96	1.95
British Columbia	1.48	1.47	1.47	1.45	1.42	1.38	1.49	1.50	1.51	1.49
Yukon	1.83	1.51	1.93	1.97	1.95	1.99	1.98	2.00	2.03	2.02
Northwest Territories	1.37	1.37	1.43	1.46	1.44	1.48	1.45	1.50	1.53	1.48
Nunavut	0.32	0.36	0.38	0.38	0.38	0.40	0.41	0.39	0.41	0.45
Canada	1.52	1.49	1.54	1.54	1.53	1.53	1.54	1.57	1.59	1.53

[25] Data adapted from Natural Resources Canada's *Canadian Vehicle Survey*.

[26] Data adapted from Natural Resources Canada's *Canadian Vehicle Survey* and census information.

Step 2: Allocate VKT (in percentages) according to vehicle characteristics and fuel type (defaults provided).

Allocate the total VKT for the community in percentages to specific vehicle and fuel types. If a regional or provincial study is not available to extrapolate data from, use the general VKT percentages[27] below:

	Light-Duty Vehicle	Light-Duty Truck	Heavy-Duty Truck	Total
Gasoline	53.17%	32.67%	1.20%	**87.04%**
Diesel	0.15%	0.93%	10.59%	**11.68%**
Propane	1.28%	0%	0%	**1.28%**
Compressed Natural Gas	0%	0%	0%	**0%**
Ethanol Blend (10%)	0%	0%	0%	**0%**
Total	**0.546**	**0.336**	**0.1179**	**100%**

Step 3: Identify vehicle fuel efficiencies for each vehicle type (defaults provided).

Identify vehicle fuel efficiencies that are representative of on-road vehicles during inventory year. If a regional or provincial study is not available to extrapolate data from, use the general fuel efficiencies[28] below:

	Fuel Efficiency (L/100km)		
	Light-Duty Vehicle	**Light-Duty Truck**	**Heavy-Duty Truck**
Gasoline	9	14.7	31.5
Diesel	7.7	12.5	34.5
Propane	14.4	15.3	0
Compressed Natural Gas*	5.4	8.3	0
Ethanol Blend (10%)	8.9	13.2	0

*Fuel Efficiency for compressed natural gas vehicles are measured in kg/100 km

Step 3: Determine the amount of each energy source consumed using the information determined in steps 2-3.

For each energy source consumed, multiply the vehicle and fuel specific VKT by its corresponding vehicle and fuel specific fuel efficiency. Add the resulting amount of fuel consumed from each vehicle type to obtain the total amount of each energy source consumed.

$$x_a = \sum(VKT_{va} \bullet FE_{va})$$

Description			*Value*
x_a	=	Total amount of energy source 'a' consumed in one year	Computed
VKT_{va}	=	Annual VKT for vehicle type 'v' and fuel type 'a'	User input

[27] ICLEI Canada. Inventory Quantification Support Spreadsheet.

[28] Natural Resources Canada's *2007 Canadian Vehicle Survey* and BC Ministry of the Environment's *2011 Methodology for Reporting BC Public Sector Greenhouse Gas Emissions.*

EFv_a	=	Fuel efficiency for vehicle type 'v' and fuel type 'a'	User input
a	=	Energy source (e.g. gasoline, diesel, ethanol, etc.)	
v	=	Vehicle type (e.g. light-duty vehicle, light duty truck, etc.)	

Step 4: Identify the corresponding emission factors for CO_2, CH_4 and N_2O (defaults provided).

Follow the same instructions in step 2 of the Fuel Sales approach in the section above.

Step 6: Multiply energy consumption data by the corresponding emission factors and their global warming potential (GWP) to determine total CO_2e emissions.

Follow the same instructions in step 3 of the Fuel Sales approach in the section above.

Community Solid Waste

The community solid waste sector tracks methane (CH_4) emissions that enter the air directly as waste decomposes at landfills as well as CH_4, nitrous oxide (N_2O) and non-biogenic carbon dioxide (CO_2) emissions associated with the combustion of solid waste at incineration facilities.

When solid waste is landfilled, its organic components (e.g. paper, food and yard waste, etc.) decompose over time into simpler carbon compounds by bacteria in an anaerobic (oxygen poor) environment generating CH_4 and CO_2 emissions. The CO_2 emissions associated with the decomposition of the organic waste are considered to be of biogenic origin and are excluded from the GHG inventory. Landfill emissions are unique in that the disposed solid waste generates emissions over many years.

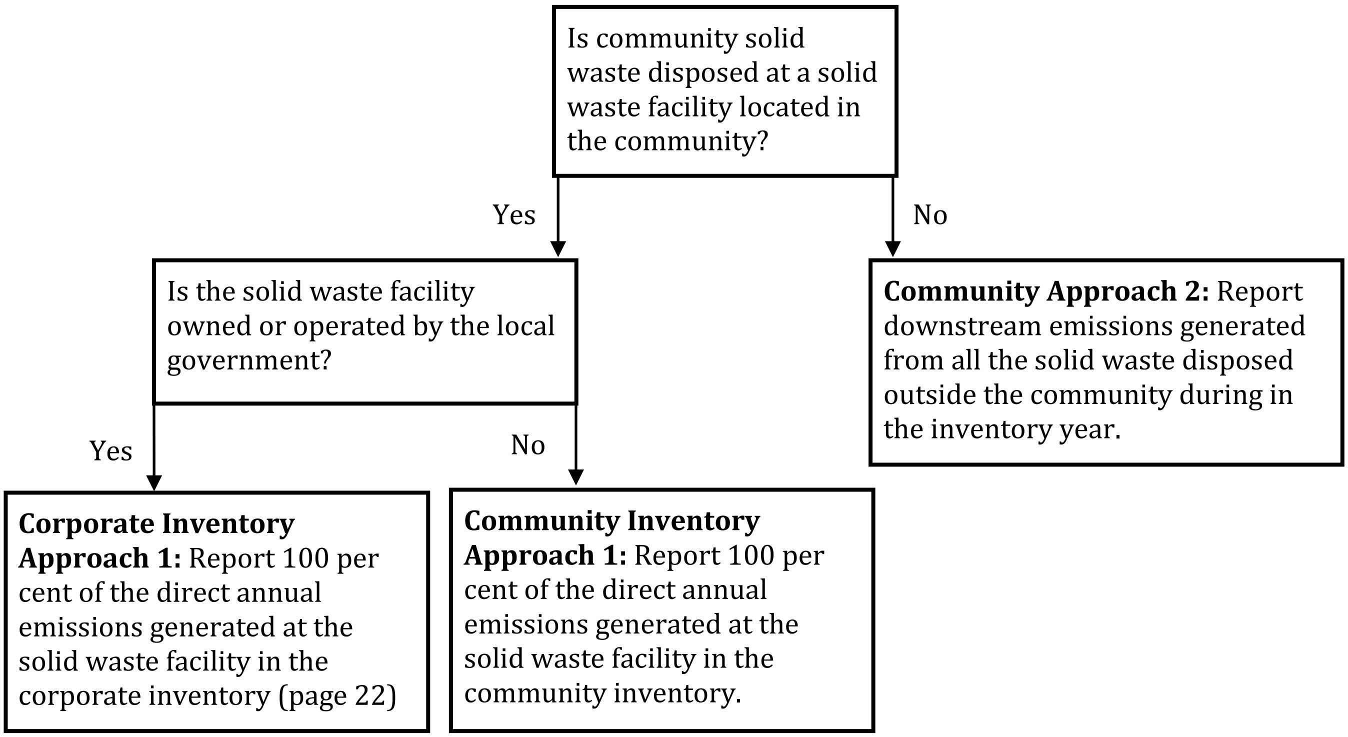
When solid waste is incinerated, both its organic and non-organic (e.g. plastic, metal, etc.) components generate CH_4, N_2O, and CO_2 emissions when combusted. The CO_2 emissions released from the combustion of the organic waste are considered to be of biogenic origin and are excluded from the GHG inventory, but the non-biogenic CO_2 emissions associated with combustion of non-organic waste must be accounted for.

Local governments must report emissions from this sector using one of two approaches:

<u>Approach 1: Emissions from Waste Disposal Facilities in the Community</u>
If a solid waste facility is located within the community, local governments must estimate the direct GHG emissions generated from all the waste disposed at the landfill(s) and/or incineration facility(s) during the inventory year. Under this approach, 100 per cent of the direct annual emissions generated at the solid waste disposal site(s) are accounted for, regardless of where the solid waste originates.

<u>Approach 2: Emissions from Solid Waste Disposed at Facilities Outside the Community</u>
If community solid waste is disposed at a solid waste facility located outside the community, local governments must estimate the downstream emissions generated from the solid waste disposed at the landfill(s) and/or incineration facility(s) that the community generated during the inventory year.

Figure K: Community Solid Waste Sector Approach Decision Tree



Inclusion Protocol

Report all direct emissions generated from all solid waste disposed at landfills and incineration facilities that are in the community as well as downstream emissions from solid waste disposed at solid waste facilities outside the community's geopolitical boarder. If the landfills and incineration facilities are in the community, include any waste disposed at the facilities that originate from outside the municipality.

Exclusion Protocol

The CO_2 emissions associated with the combustion of biomass material (e.g., paper, food, and wood waste) at incineration facilities are considered to be of biogenic origin and may be excluded from the GHG inventory.

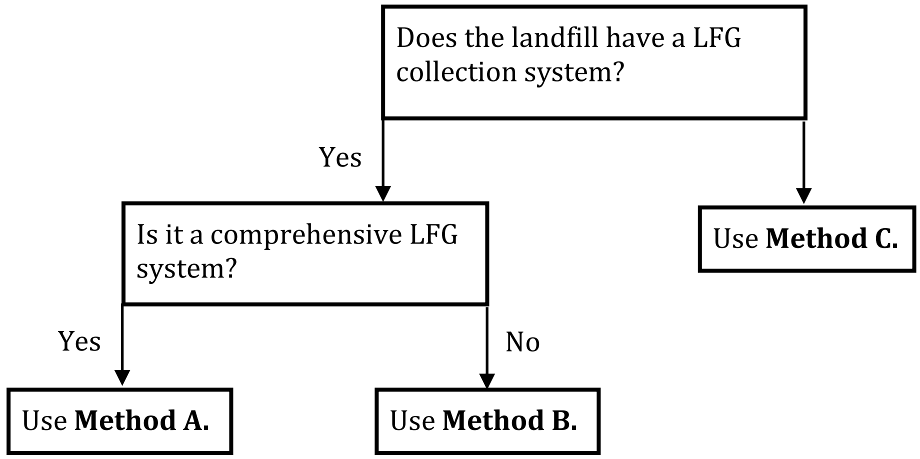
Reporting Guidelines

As a best practice, waste and emissions data should be reported by solid waste facility type i.e. landfill and incineration data should be reported separately. If disaggregated reporting is not possible, local governments should report the total GHG emissions generated by the community solid waste sector.

Accounting Guidelines I: Estimating GHG Emissions from Landfilled Waste

Emissions from solid waste deposited at a landfill can be calculated using one of three methods depending on if the landfill has a comprehensive landfill gas (LFG) collection system, partial LFG collection system, or no LFG collection system.

Figure L: Landfilled Waste GHG Emissions Quantification Decision Tree



Method A: Landfills with Comprehensive LFG Collection Systems

The U.S. Environmental Protection Agency defines a "comprehensive" LFG collection system as "a system of vertical wells and/or horizontal collectors providing 100 percent collection system coverage of all areas with waste within one year after the waste is deposited."[29] To estimate GHG emissions from a landfill with a comprehensive LFG collection system, follow the formula[30] below:

$$CO_2e = \text{LFG} \bullet \text{F} \bullet [(1\text{-DE}) + (\frac{1-CE}{CE}) \bullet (1\text{-OX})] \bullet \text{unit conversion} \bullet \text{GWP}$$

Description			*Value*
CO_2e	=	Direct GHG emissions (methane) from a landfill with comprehensive LFG collection (t CO_2e/year)	Computed
LFG	=	Annual landfill gas collected by the collection system (measured in m^3 at STP)	User input
F	=	Fraction of methane in landfill gas	User input (default value of 0.5)
DE	=	CH_4 destruction efficiency based on type of combustion/flare system	User input (default value of 0.99)
CE	=	Collection efficiency of the LFG system	User input (default value of 0.75)
OX	=	Oxidation factor	A value of 0.1 is justified for well-managed landfills
Unit Conversion	=	Applies when converting million standard cubic feet of methane into metric tons of methane (volume units to mass units)	19.125

[29] U.S. EPA. (2010). LFG Energy Project Development Handbook, Chapter 2: Landfill Gas Modeling.
[30] ICLEI-USA. (2010). *Local Government Operations Protocol*, Chapter 9.

GWP	=	Global warming potential of CH_4	21

Method B: Landfills with Partial LFG Collection Systems

Partial landfill gas collection systems are designed to capture some of the CH_4 gas emitted from the decomposition of waste. To estimate GHG emissions from a landfill with a comprehensive LFG collection system, follow the formula[31] below:

$$CO_2e = \text{LFG} \bullet \text{F} \bullet \{(1\text{-DE}) + [(\frac{1}{CE}) \bullet (\frac{1}{OX})] \bullet [(\text{AF} + (1\text{-CE})]\} \bullet \text{unit conversion} \bullet \text{GWP}$$

Description			*Value*
CO_2e	=	Direct emissions from a landfill with partial LFG collection (t CO_2e/year)	Computed
LFG	=	Annual landfill gas collected by the collection system (measured in m^3 at STP)	User input
F	=	Fraction of methane in landfill gas	User input (default value of 0.5)
DE	=	CH_4 destruction efficiency based on type of combustion/flare system	User input (default value of 0.99)
CE	=	Collection efficiency of the LFG system	User input (default value of 0.75)
OX	=	Oxidation factor	A value of 0.1 is justified for well-managed landfills
AF	=	Uncollected area factor (uncollected surface area divided by collected surface area under the influence of LFG collection system).	User input (ratio of uncollected surface area to collected surface area)
Unit Conversion	=	Applies when converting million standard cubic feet of methane into metric tons of methane (volume units to mass units)	19.125
GWP	=	Global warming potential of CH_4	21

Method C: Landfills with No LFG System

Emissions from solid waste disposed at a landfill without a LFG system can be estimated using either a 'methane commitment' or 'waste-in-place' model.

The methane commitment model (also known as 'total yield gas') estimates the total downstream methane (CH_4) emissions generated over the course of the waste's decomposition i.e. future CH_4 generation is attributed to the inventory year in which the solid waste was generated and disposed. This approach is typically the simplest for local governments in terms of data collection requirements and methodology. It is also the most comparable approach.

[31] ICLEI-USA. (2010). *Local Government Operations Protocol*, Chapter 9.

The waste-in-place model (also known as 'fist order decay') is an exponential equation that estimates the amount of CH_4 that will be generated in a landfill based on the amount of waste in the landfill in the inventory year (i.e. the “waste-in-place”), the capacity of that waste to generate CH_4, and a CH_4 generation rate constant which describes the rate at which waste in the landfill is expected to decompose and produce CH_4. To use this model, local governments will need to know the amount of waste historically deposited at the landfill, the composition of the landfilled waste, and the general climatic conditions at the landfill site. This method is the recommended approach to estimate CH_4 from a landfill without a LFG system because it best models CH_4 release from landfilled waste; the model assumes CH_4 from solid waste peaks shortly after it is placed in the landfill and then decreases exponentially as the organic material in the waste decomposes.

Option 1: Methane Commitment Model

Emissions from solid waste disposed at a landfill without a LFG system can be calculated with the methane commitment model using the following steps:

1. Determine the quantity (mass) of solid waste landfilled during the inventory year.
2. Determine the composition of the waste stream (defaults provided).
3. Calculate the degradable organic carbon (DOC) content of the waste stream (formula provided).
4. Calculate the methane generation potential of the landfilled waste (formula provided).
5. Calculate emissions of CO_2e using the information determined in steps 1-4.

Step 1: Determine the quantity (mass) of solid waste landfilled during the inventory year.

Recommended	Obtain actual data on the quantity (mass) of solid waste landfilled annually. Solid waste facilities should have records on the total quantity of solid waste disposed in a particular year.
Alternative	If actual waste generation data are unavailable for the inventory year, follow the general formula[32] below: $M_x = P_x \bullet \frac{M_y}{P_y}$ Description / Value M_x = Quantity of solid waste disposed in year 'x' — Computed x = Year for which solid waste data is not known — User input P_x = Total population of jurisdiction(s) disposing waste in year 'x' — User input M_y = Quantity of solid waste disposed in year 'y' — User input y = Year for which solid waste data is known — User input P_y = Total population of jurisdiction(s) disposing waste in year 'y' — User input
Alternative	If actual waste generation data is not available, local governments can extrapolate

32 ICLEI USA, *Local Government Operations Protocol*, Version 1.1 (2010).

	data from an existing regional or provincial/territorial post diversion study.

Step 2: Determine the composition of the waste stream (defaults provided).

Recommended	Obtain actual data on the composition of the waste stream by undertaking a waste composition study/audit that identifies the types of materials discarded and their portion of the total waste stream.
Alternative	If actual waste composition information is not available, local governments can extrapolate data from an existing regional or provincial/territorial post diversion study.
Alternative	If data from a waste composition study is not available, use the general municipal solid waste composition values for North America[33] below:

Waste Category	**Percentage**
Food	34%
Garden	0%
Paper/Cardboard	23%
Wood Products	6%
Textiles	4%
Plastics, other inert (e.g. glass, metal, etc.)	33%

Step 3: Determine the degradable organic carbon content of the waste stream (formula provided).

The degradable organic carbon (DOC) content represents the amount of organic carbon present in the waste stream that is accessible to biochemical decomposition. Note that only organic waste (e.g. food waste, paper, garden waste, etc.) has DOC. To estimate DOC, follow the formula[34] below:

DOC = (0.15 x A) + (0.2 x B) + (0.4 x C) + (0.43 x D) + (0.24 x E) + (0.15 x F)

Description			Value
DOC	=	Degradable organic carbon (t carbon/t waste)	Computed
A	=	Fraction of solid waste stream that is food	User input
B	=	Fraction of solid waste stream that is garden waste and other plant debris	User input
C	=	Fraction of solid waste stream that is paper	User input
D	=	Fraction of solid waste stream that is wood	User input

[33] IPCC. (2006). *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Volume 5 Waste, IPCC Waste Model spreadsheet.

[34] Toronto and Region Conservation. (2010). *Getting to Carbon Neutral: A Guide for Canadian Municipalities*. Adapted from the *Intergovernmental Panel on Climate Change Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories.*

E	=	Fraction of solid waste stream that is textiles	User input
F	=	Fraction of solid waste stream that is industrial waste	User input

Step 4: Determine the methane generation potential of the landfilled waste (formula provided).

The methane generation potential (L_0) is an emission factor that specifies the amount of CH_4 generated per tonne of solid waste landfilled. Its value is dependent on several factors, including the portion of DOC present in the waste and the general characteristics of the landfill. To estimate L_0, follow the IPCC formula[35] below:

$$L_0 = {}^{16}/_{12} \bullet MCF \bullet DOC \bullet DOC_F \bullet F$$

Description			*Value*
L_0	=	Methane generation potential (t CH_4/t waste)	Computed
MCF	=	Methane correction factor	User input: managed = 1.0 unmanaged (≥5 m deep) = 0.8 unmanaged (<5 m deep) = 0.4 uncategorized = 0.6
DOC	=	Degradable organic carbon (t carbon/t waste)	User input
DOC_F	=	Fraction of DOC dissimilated	User input (default value of 0.6)
F	=	Fraction of methane in landfill gas	User input (default value of 0.5)
16/12	=	Stoichiometric ratio between methane and carbon	

Step 5: Calculate emissions of CO_2e using the information determined in steps 1-4.

To estimate emissions of CO_2e, use the formula[36] below:

$$CO_2e = 21 \bullet M \bullet L_0\ (1 - f_{rec})(1 - \text{OX})$$

Description			*Value*
CO_2e	=	Downstream GHG emissions associated with corporate solid waste sent to landfill (t CO_2e)	Computed
M	=	Quantity of solid waste sent to landfill during inventory year (tonnes)	User input
L_0	=	Methane generation potential (t CH_4/t waste)	User input (see Step 4)
21	=	Global warming potential of CH_4	

[35] IPCC. (2006). *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Volume 5 Waste, Chapter 3, Solid Waste Disposal.

[36] Toronto and Region Conservation. (2010). *Getting to Carbon Neutral: A Guide for Canadian Municipalities*. Adapted from the *Intergovernmental Panel on Climate Change Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories.*

f_{rec}	=	Fraction of methane emissions that are recovered at the landfill (e.g. landfill gas collection systems)	User input
OX	=	Oxidation factor	A value of 0.1 is justified for well-managed landfills; An average value for unmanaged landfills is closer to zero.

Option 2: Waste-In-Place Model

The waste-in-place model is available for use in a variety of user-friendly Excel-based formats, such as the *IPCC Waste Model*, the U.S. EPA's *Landfill Gas Emissions Model (LandGEM)*, and the *Landfill Emissions Tool* developed by the California Air Resources Board. Alternatively, emissions from solid waste deposited at a landfill without a LFG collection system can be calculated with the waste-in-place model using the following steps:

1. Determine the historical quantity (mass) of solid waste landfilled annually (defaults provided).
2. For each year, determine the first-order decay rate at the landfill site (defaults provided).
3. For each year, determine the average methane generation potential of the landfilled waste (defaults provided).
4. Calculate the sum of CH_4 generated from the solid waste landfilled each year using a first-order decay (FOD) model and multiply the total value by its global warming potential (GWP) to determine total CO_2e emissions.

Step 1: Determine the historical quantity (mass) of solid waste landfilled annually (defaults provided).

Recommended	Obtain actual data on the quantity (mass) of solid waste landfilled annually. Solid waste facilities should have records on the total quantity of solid waste disposed in a particular year. The calculation of the analysis-year emissions requires at least 30 years of historical data.
Alternative	If actual waste generation data are unavailable for some years, follow the general formula[37] below and repeat it for all the missing years: $M_x = P_x \bullet \frac{M_y}{P_y}$ Description / Value M_x = Quantity of solid waste disposed in year 'x' — Computed x = Year for which solid waste data is not known — User input P_x = Total population of jurisdiction(s) disposing waste in year 'x' — User input M_y = Quantity of solid waste disposed in year 'y' — User input

[37] ICLEI USA, *Local Government Operations Protocol*, Version 1.1 (2010).

	y	=	Year for which solid waste data is known	User input
	P_y	=	Total population of jurisdiction(s) disposing waste in year 'y'	User input
Alternative	If actual waste generation data is not available, local governments can extrapolate data from an existing regional or provincial/territorial post diversion study.			

Step 2: For each year, determine the first-order decay rate at the landfill site (defaults provided).

The decay rate constant (k), also known as the methane generation constant, represents the first-order rate at which methane is generated after waste has been disposed at the landfill. Its value is affected by moisture content, availability of nutrients, pH, and temperature. The moisture content of the waste within a landfill is one of the most important parameters affecting the landfill gas generation rate. The infiltration of precipitation through the landfill cover, the initial moisture content of the waste, the design of the leachate collection system, and the depth of waste in the site are the primary factors that influence the moisture content of the waste. Environment Canada's *National Inventory Report 1990-2010: Greenhouse Gas Sources and Sinks in Canada* (2013*)* provides municipal solid waste landfill k estimates for different regions and provinces/territories in Canada for three respective time series: 1941-1975, 1976-1989, and 1990-2007. This information is available in Part 2, Annex 3: Additional Methodologies, Page 155-156.

Step 3: For each year, determine the average methane generation potential of the solid waste landfilled (defaults provided).

The methane generation potential (L_0) is an emission factor that specifies the amount of CH_4 generated per tonne of solid waste landfilled. Its value is dependent on several factors, including the portion of degradable organic carbon (DOC) present in the waste and the general characteristics of the landfill. Environment Canada's *National Inventory Report 1990-2010: Greenhouse Gas Sources and Sinks in Canada* (2013*)* provides methane generation potential values for each province and territory for three respective time series: 1941-1975, 1976-1989, and 1990-2007. This information is available in Part 2, Annex 3: Additional Methodologies, Page 158.

Step 4: Calculate the sum of CH_4 generated from the solid waste landfilled each year using a first-order decay (FOD) model and multiply the total value by its global warming potential (GWP) to determine total CO_2e emissions.

To estimate analysis-year emissions, follow the formula[38] below and at least 30 years of historical data:

$CO_2e_{\text{NLFG}} = (\sum Q_{T,x} \bullet \text{GWP})$ where $Q_{T,x} = kM_x L_0 e^{-k(T-x)}$

<u>Description</u>			<u>Value</u>
CO_2e_{NLFG}	=	GHG emissions generated in the inventory year from a landfill without a landfill gas system (kt CO_2e/year)	Computed

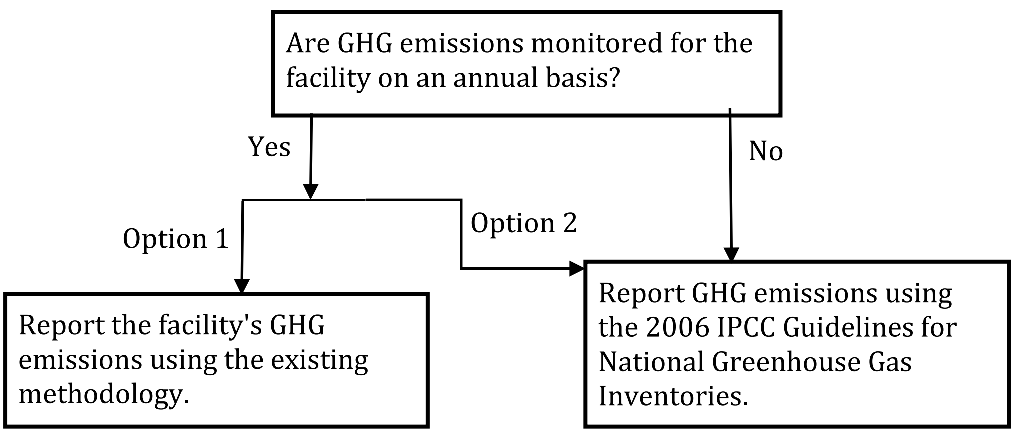
[38] Environment Canada, *National Inventory Report 1990-2010: Greenhouse Gas Sources and Sinks in Canada,* Part 2 (2012).

$Q_{T,X}$	=	Amount of CH_4 generated in the inventory year by waste M_x (kt/CH_4/year)	Computed
T	=	The inventory year	User input
x	=	The year of waste input	User input
k	=	Decay rate constant (yr^{-1})	User input
M_x	=	The amount of waste disposed in year x (Mt)	User input
L_0	=	CH_4 generation potential (kg CH_4/t waste)	User input
GWP	=	Global warming potential of CH_4	21

Accounting Guidelines II: Estimating GHG Emissions from Waste Incineration

Approach 1: Emissions from Waste Disposal Facilities in the Community
If the community solid waste is combusted at an incineration facility that monitors its GHG emissions on an annual basis (e.g. for Environment Canada's Greenhouse Gas Reporting Program), emissions from solid waste combustion can be reported using the existing methodology. If GHG emissions are not monitored, the 2006 IPCC Guidelines for National Greenhouse Gas Inventories for Incineration[39] must be used to calculate emissions.

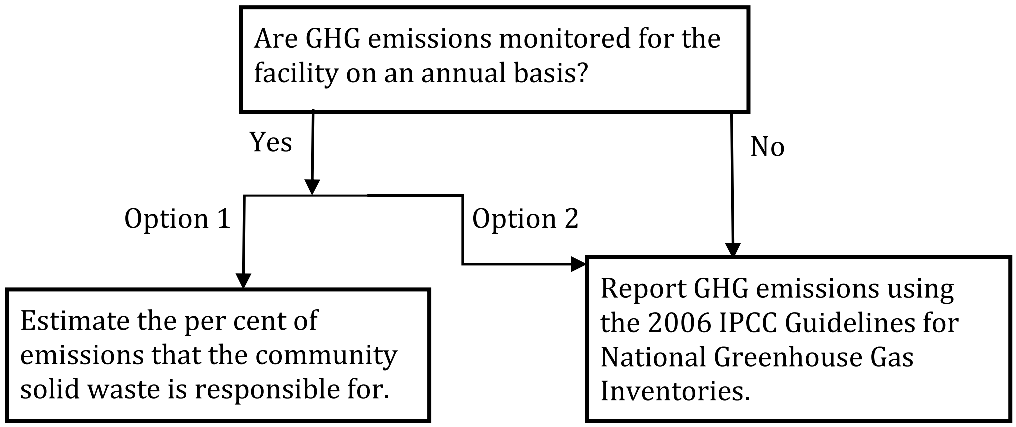
Figure M: Approach 1 Emissions Quantification Decision Tree



Approach 2: Emissions from Solid Waste Disposed at Facilities Outside the Community
If the community solid waste is combusted at an incineration facility that monitors GHG emissions on an annual basis (e.g. for Environment Canada's Greenhouse Gas Reporting Program), emissions can be reported by either estimating the per cent of emissions that the community solid waste is responsible for or by using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories for Incineration. If GHG emissions are not monitored, the 2006 IPCC Guidelines for National Greenhouse Gas Inventories for Incineration must be used to calculate emissions.

[39] IPCC. (2006). *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Volume 5 Waste, Chapter 5 Incineration and Open Burning of Waste.

Figure N: Approach 2 Emissions Quantification Decision Tree



Appendix I: Use of Emission Scopes

The concept of emission “scopes” was developed by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD) to differentiate between direct and indirect emission sources within a corporation’s organizational boundary and to prevent double counting of emissions by two or more organizations. The concept has been incorporated into a variety of GHG programs and standards, including several community-scale protocols, which extend the framework to emissions generated at the community level.

For corporate GHG inventories, the WRI and WBCSD protocol identifies three types of emission sources:

Scope 1: Direct GHG Emissions
The scope 1 category includes GHG emissions generated directly by sources owned or operated by the corporation. Within the context of a municipal operations inventory, the most common sources of scope 1 emissions are the combustion of natural gas or fuel oil at municipal facilities, use of gasoline or diesel fuel in municipal fleet vehicles, and methane generation at municipally-owned landfill sites.

Scope 2: Indirect Emissions from Electricity or District Energy Purchases
The scope 2 category is used exclusively to refer to ‘indirect’ emissions associated with the purchase of grid electricity or district energy. Unlike stationary fuel combustion, which generates GHG emissions directly at the point of energy consumption, emissions associated with the use of grid electricity are produced off-site at a location owned or controlled by another entity. For this reason, the use of grid electricity is always reported as an indirect (Scope 2) source of emissions, regardless of where the generation occurs.

Scope 3: Other Indirect Emissions
The scope 3 category is applied to all other indirect GHG emissions that can be linked to an organization’s activities and operations but that occur from sources owned or controlled by another organization. Sources of scope 3 emissions at the local government level include emissions from employee commuting and staff business travel, upstream and embodied emissions associated with the production of purchased fuel or products, and emissions from contracted services--to name a few.

The concept of emission scopes can be applied similarly to emissions generated at the community level. In this context, the scope 1 category refers to emissions generated directly within the territorial boundary of the community. The definition of scope 2 remains the same and is used exclusively to identify emissions associated with the consumption of grid electricity or district energy. Other community activities that result in indirect GHG emissions outside the territorial boundary of the community are categorized as scope 3.

As noted above, the purpose of emission scopes is mainly to prevent double counting when aggregating data from two or more emissions inventories. GHG programs that have incorporated the scope framework, such as the *Global Protocol for Community-scale GHG Emissions*, typically require local governments to report emissions from each scope category separately. Although use of emission scopes is not a requirement of the PCP program, each of the corporate and community emission sources outlined in this document has been sufficiently disaggregated to enable GHG reporting by scope. A list of corporate and community emission sources and their corresponding scope classification is provided on in Appendix II: PCP Reporting Requirements.

Appendix II: PCP Reporting Requirements

PCP reporting requirements for corporate and community-scale GHG inventories are outlined in the tables below. Emissions from sources marked as 'required' must be reported in order for an inventory to be considered in compliance with PCP protocol. As noted above, these guidelines represent a minimum reporting threshold based on current best practices and the availability of local-level GHG accounting methodologies. Local governments are encouraged to develop more customized GHG inventory reports based on local goals and capacity.

To support PCP members in these efforts, the tables below identify several 'optional' emission sources that can be incorporated into the corporate or community-scale GHG analysis. These optional emission sources represent emerging areas of interest in the field of GHG accounting, and are generally more difficult to measure at the local level. The PCP program is monitoring developments in these areas and will aim to provide more detailed accounting guidelines in future program updates.

Table 1: Corporate Inventory Requirements

Activity Sector/Emission Source	Scope	PCP Reporting Requirements	Recommended Accounting Approach(es)
Buildings and Facilities			
Emissions from stationary fuel combustion (e.g. natural gas, fuel oil, etc.)	Scope 1	Required	Actual consumption data
Emissions from purchased electricity	Scope 2	Required	Actual consumption data
Emissions from purchased steam or district energy	Scope 2	Required	Actual consumption data
Fleet Vehicles (incl. Public Transit Systems)			
Emissions from combustion of motor fuels (gasoline, diesel, CNG, etc.)	Scope 1	Required	Actual consumption data
Emissions from purchased electricity	Scope 2	Required	Actual consumption data
Streetlights and Traffic Signals			
Emissions from purchased electricity	Scope 2	Required	Actual consumption data
Emissions from stationary fuel combustion (off-grid lighting systems, generators, etc.)	Scope 1	Required	Actual consumption data
Water and Wastewater Infrastructure			
Emissions from stationary fuel combustion (e.g. natural gas, fuel oil, etc.)	Scope 1	Required	Actual consumption data
Emissions from purchased electricity	Scope 2	Required	Actual consumption data
Process and fugitive emissions from wastewater treatment and discharge	Scope 1	Optional	*Seeking Input*
Solid Waste			

Projected downstream (future) emissions from disposal of corporate solid waste	Scope 3	Minimum	Methane commitment model
Emissions from corporate-owned landfills, waste-incineration and/or composting facilities	Scope 1	Recommended	Landfill gas collection data or first order decay model
Staff Business Travel			
Emissions from combustion of motor fuels (gasoline, diesel, jet fuel, etc.)	Scope 3	Optional	Distance traveled
Employee Commute			
Emissions from combustion of motor fuels (gasoline, diesel, etc.) by staff during commute to and from work	Scope 3	Optional	Survey

Table 2: Community Inventory Requirements

Activity Sector/Emission Source	Scope	PCP Reporting Requirements	Recommended Accounting Approach(es)
Residential Energy Consumption			
Emissions from stationary fuel combustion (natural gas, fuel oil, etc.)	Scope 1	Required	Actual consumption data
Emissions from purchased electricity	Scope 2	Required	Actual consumption data
Emissions from purchased steam or district energy	Scope 2	Required	Actual consumption data
Commercial/Institutional Energy Consumption			
Emissions from stationary fuel combustion (natural gas, fuel oil, etc.)	Scope 1	Required	Actual consumption data
Emissions from purchased electricity	Scope 2	Required	Actual consumption data
Emissions from purchased steam or district energy	Scope 2	Required	Actual consumption data
Industrial Energy Consumption			
Emissions from stationary fuel combustion (natural gas, fuel oil, etc.)	Scope 1	Required	Actual consumption data
Emissions from purchased electricity	Scope 2	Required	Actual consumption data
Emissions from purchased steam or district energy	Scope 2	Required	Actual consumption data
On-Road Transportation			
Tailpipe combustion emissions from motor vehicles traveling within the community	Scope 1	Required	Retail Fuel Sales or Vehicle Kilometres Traveled or Vehicle Registration

Emissions from electricity used by motor vehicles traveling within the community	Scope 2	Required	
Local Public Transit Systems			
Combustion emissions from local rail and/or bus transit systems	Scope 1	Required	Actual consumption data
Emissions from electricity used in local rail and/or bus transit systems	Scope 2	Required	Actual consumption data
Solid Waste			
Projected downstream (future) emissions from disposal of community solid waste	Scope 3	Minimum	Methane commitment model
Emissions from in-boundary landfills, waste incineration and/or composting facilities	Scope 1	Recommended	Landfill gas collection data or first order decay model
Agriculture			
Methane emissions from enteric fermentation	Scope 1	Optional	Livestock counts
Methane emissions from manure management	Scope 1	Optional	Livestock counts
Industrial Processes			
Non-energy-related emissions from industrial processes (mineral products, chemical industries, metal production, etc.)	Scope 1	Optional	*Seeking Input*
Fugitive Emissions			
Fugitive emissions from the production, processing, transmission, storage and delivery of fossil fuels	Scope 1	Optional	*Seeking Input*