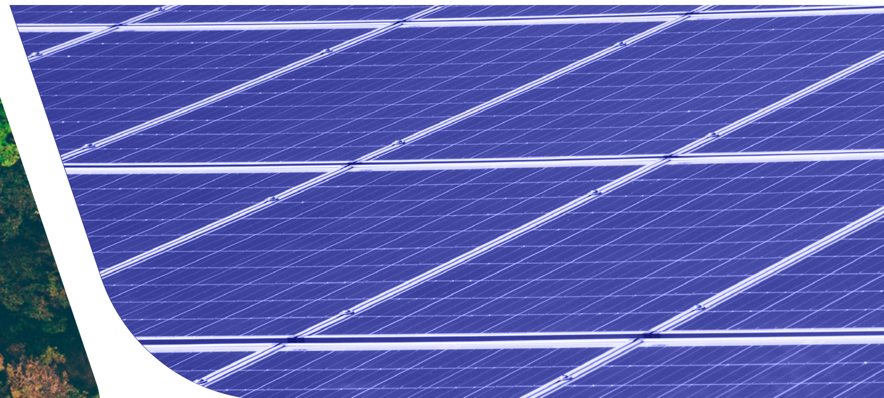
GUIDEBOOK ON QUANTIFYING GREENHOUSE GAS REDUCTIONS AT THE PROJECT LEVELS



PARTNERS FOR CLIMATE PROTECTION PROGRAM

ICLEI Local Governments for Sustainability

FCM FEDERATION OF CANADIAN MUNICIPALITIES FÉDÉRATION CANADIENNE DES MUNICIPALITÉS

PARTNERS FOR **CLIMATE** PROTECTION

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Introduction

The Partners for Climate Protection (PCP) program is a network of Canadian municipal governments that have committed to reducing greenhouse gases (GHGs) and acting on climate change. Delivered by the Federation of Canadian Municipalities (FCM) and ICLEI - Local Governments for Sustainability, the PCP program provides tools and resources to support municipalities in achieving their climate mitigation goals and reducing GHG emissions. Launched in 1994, the program is now a network of over 400 municipalities with over 180 local climate change action plans.

This resource provides the principles and methods for quantifying GHG reductions from municipal climate change projects, along with examples. It is designed for municipal staff who are looking to quantify and report on GHG or energy reductions for municipal mitigation projections. Quantifying the GHG benefits for specific projects, programs and policies can help:

- Celebrate the success of a project
- Demonstrate a project's effectiveness to stakeholders, funders and council
- Generate support and funds for future projects
- Refine and readjust efforts or inform the level of ambition required to meet climate mitigation goals and targets
- Inform decision-making and priority setting

This guidebook begins with an overview of how to quantify GHG emissions generally, then reviews the basic approach for calculating emission reductions at the project level. The following sections present step-by-step instructions for different mitigation projects at both the corporate and community levels, such as building retrofit projects, transportation policies and waste diversion programs, among others. The last section discusses challenges and provides further resources.

Overview of GHG accounting

The basics of measuring GHG emissions

The greenhouse gases

In the context of climate change, we consider three main greenhouse gases (GHGs):

carbon dioxide (CO_2)
methane (CH_4)
nitrous oxide (N_2O)

Although other gases, such as hydrofluorocarbon gases, perfluorocarbon gases and sulphur hexafluoride, are important GHGs, they represent a very small proportion of emissions in the municipal context and are not included here.

Each greenhouse gas's impact on climate change depends on its atmospheric lifetime and its heat-trapping potential, or global warming potential. The global warming potential (GWP)[1] of each gas determines how much heat it traps in the atmosphere in a specific time frame, usually 100 years (Appendix A). We use GWP to convert methane and nitrous oxide to carbon dioxide equivalents (CO_2e). Although it is sometimes necessary to calculate and report on all GHGs individually, the rest of this resource only looks at CO_2e and uses CO_2e emission factors to keep things simple.

The calculation

Calculating emissions can seem complicated and overwhelming, but the basic premise of measuring emissions is straightforward. GHG emissions are measured by multiplying the activity level or rate (e.g. fuel use) by its respective emission factor.

$$\text{activity (A)} \times \text{emission factor (EF)} = \text{emissions}$$

An emission factor represents the rate or quantity of GHG emissions that are released as a result of that activity. We recommend using emission factors from Environment and Climate Change Canada's National Inventory Report[2], which are specific to Canada or to each province and updated annually.

[1] GWP is sourced from the Intergovernmental Panel on Climate Change (IPCC)'s Fourth Assessment Report (AR4) and uses 100-year timelines.
[2] Environment and Climate Change Canada. *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada*. Canada's Submission to the United Nations Framework Convention on Climate Change. Electricity coefficients are found in tables at the end of Part 3; emission factors for other fuel sources are found throughout Part 2.

Example: calculating the GHGs emitted from consuming 500 L of diesel in one year

activity (A) × emission factor (EF) = emissions

activity (fuel consumption): 500 L

emission factor for diesel[3]: 0.002757 tonnes/L

A × EF = 500 L × 0.002757 tonnes/L = 1.379 tonnes

The basics of quantifying GHG emissions at the project level

Quantifying GHG emissions at the project level is more complex than measuring emissions for a GHG inventory. Project-level GHG accounting quantifies the amount of GHGs that are reduced as a result of the implementation of a project, such as replacing gasoline-powered cars with electric vehicles or retrofitting buildings to be more energy efficient. In this resource, a project refers to any action, initiative, policy, program, or bylaw implemented by a municipality that reduces emissions. This section describes the basic approach to quantifying project-level GHGs with example calculations for different types of projects.

[3] Sourced from Environment and Climate Change Canada's *National Inventory Report 2018*.

Define the boundary and scope

The first step is to define the boundary for which the GHG benefits will be accounted. The boundary can be physical, organizational or jurisdictional. For corporate-level mitigation actions, the boundary is usually the corporation itself. For community-level actions, the boundary is usually defined by the jurisdictional boundary of the municipality but may be restricted to a neighbourhood or district. For instance, a building policy for municipally owned buildings will have a boundary of all buildings and facilities owned by the municipal corporation. The boundary for a new organics diversion program will be the entire area served by the municipality's waste management services. The boundary for a new district energy system will be the neighbourhood or district that the energy system serves.

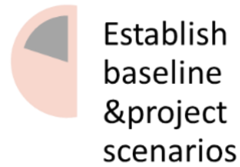
The boundary may not just be geographical. For instance, when looking at a waste diversion project, methane emissions from the waste decomposition at the landfill would fall within the project boundary. But what's less clear, and what must be determined in advance, is whether transportation emissions from waste collection trucks, or emissions from energy consumption within the waste treatment facility, are included. Defining the boundary should be done as a first step and will depend on data availability, the purpose and goals of the project, and the scope of the evaluation.

Emissions are categorized into three scopes:

- Scope 1: Emissions that physically occur within the municipality
- Scope 2: Emissions that occur from the use of electricity supplied by grids which may or may not cross municipal boundaries
- Scope 3: Emissions from activities occurring outside of the municipality as a result of activities of residents and businesses within the municipality (e.g. emissions from the production, manufacturing and distribution of goods)

In the municipal context, emissions accounting focuses primarily on scopes 1 and 2, while scope 3 emissions are typically not included. Scope 3 emissions are not included in this report, in part due to a lack of commonly accepted methodologies and lack of available data sources.

Establish the baseline and project scenarios



The second step in assessing the outcome and GHG reduction of a project is to establish a baseline scenario and a project scenario. The baseline scenario, or business-as-usual reference case, forms the basis for comparison. For example, to assess the benefits of a facility's energy retrofit, one must first determine the amount of energy consumed by the facility prior to the retrofit. Then the energy and emissions generated after the retrofit (the project scenario) can be compared against the facility's baseline to determine the annual energy and GHG savings achieved through the facility upgrade.

Sometimes, the baseline is an actual point in time with real measurable data, while other times it is a theoretical business-as-usual scenario that captures what *would* have occurred had the project not been completed. The theoretical scenario is usually used when assessing the benefits of a new development, such as the construction of a high-performance facility or a district energy system at a new residential subdivision. In these cases, an actual project baseline does not exist, so the project's environmental benefits are compared against a counterfactual business-as-usual scenario (e.g. the high-performance facility is instead built to building code, or the subdivision is developed without district energy with each home heated individually).

Collect usage and activity data

Once the boundary and scope have been defined and the baseline and project scenarios have been established, data must be collected to calculate the emissions for both scenarios. This is often the most challenging part of GHG accounting.

The most accurate, localized data should be prioritized, but if unavailable, more easily accessible regional averages or provincial/territorial/federal data can be used instead. Typically, activity data involves energy consumption or waste generation estimates. For projects relating to buildings or transportation, this is usually electricity, natural gas, gasoline and other fuel consumption in a given year. Renewable energy projects require data related to the energy generated by solar panels, wind turbines, etc. For projects targeting waste emissions, required data typically includes tonnes of waste sent to landfill or diverted, and the composition of the waste. There may be situations where other data is also required, such as information on the length of a vehicle trip. Each example in the next section provides a brief discussion of data requirements.

Apply emission factors

Once the appropriate data has been collected for the baseline and project scenarios, the respective emission factors must be applied to calculate the emissions for each scenario. As discussed previously, emissions are calculated by multiplying activity data (e.g. fuel consumption) by the appropriate emission factor.

Calculate and report GHG reductions

Once the emissions have been calculated for the baseline scenario and the project scenario, the GHG reduction can be calculated. Reductions are usually measured as annual reductions.

$$\text{GHG emission reduction} = \text{baseline emissions} - \text{project emissions}$$

Once the GHG reductions have been quantified, it is recommended to assess the reasonableness of one's calculation. Ask yourself the following questions:

- Does the emission reduction align with other similar projects elsewhere?
- Is the percent reduction calculated typical for projects like this?
- Does it make sense relative to the GHG inventory (fraction of tonnes reduced)?
- Are the units consistent between activity data and emission factors (L, km, kWh, m^3, etc.)?

Example calculations for select projects

This section uses six mitigation project examples to demonstrate how to quantify GHG reductions. They serve as references to guide and inform PCP members on how to quantify the benefits of their own projects, which will likely be different in scale, scope or application, but will follow the same general approach.

- Stationary energy:
    - Example 1: Residential building retrofit program
    - Example 2: Newly constructed, high-efficiency municipal building
    - Example 3: LED streetlight conversion project
- Transportation:
    - Example 4: Replacement of a conventional gas-powered vehicle with an electric vehicle
- Waste:
    - Example 5: Waste diversion program and gas capture at a municipally owned landfill
- Renewable energy:
    - Example 6: Rooftop solar PV installation

Each example follows the same format:

- A description of the example project
- An overview of the steps required to quantify the GHG reduction
- A list of required data and sources
- The step-by-step calculation of the baseline and project scenarios, plus the GHG reduction, using real numbers
- If relevant, alternative calculations
- A list of other projects that could use a similar approach

Stationary energy

Example 1: Residential building retrofit program

A town in Ontario is planning to implement a deep energy home retrofit program. The program will target single-family homes and aims to achieve energy savings of 50% for all participating houses. There are 100,000 homes in the community, and the town plans to retrofit 30%.

Steps

Step 1: Define boundary

- Boundary: jurisdiction of municipality
- Emissions from use of energy within retrofitted homes

Step 2: Establish baseline and project scenarios

- Baseline scenario: before retrofits occur
- Project scenario: after retrofits completed; target number of houses are retrofitted

Step 3: Collect activity data (for baseline and project scenarios)

- Equation 1: Determine total annual energy consumption of all houses participating in the retrofit program
- Equation 2: Determine energy consumption by fuel source (natural gas, electricity)

Step 4: Apply emission factors (for baseline and project scenarios)

- Equation 3: Determine GHGs per fuel source

Step 5: Calculate GHG reduction

Data and sources

Data	**Value**	**Source**
Number of households	100,000	Internal records Alternative sources: Statistics Canada, local survey data, etc.
Retrofit target	30% of houses (30,000 houses)	
Annual energy consumption per household—before retrofit (baseline)	101 GJ	Comprehensive Energy Use Database, Office of Energy Efficiency, Natural Resources Canada Alternative sources: utilities, local survey data, Statistics Canada, etc.

Data	Value	Source
		Note: This estimate includes energy consumption across all sources. In some cases, it may be available by individual fuel source.
Annual energy consumption per household—after retrofit (scenario) Note: Retrofits aim to achieve energy savings of 50%.	101 − (101 × 50%) = 50.5 GJ	*Calculated*
Average percentage of household energy fueled by natural gas	70%	Comprehensive Energy Use Database, Office of Energy Efficiency, Natural Resources Canada Alternative sources: utilities, local survey data, Statistics Canada, etc.
Average percentage of household energy fueled by electricity	30%	Comprehensive Energy Use Database, Office of Energy Efficiency, Natural Resources Canada Alternative sources: utilities, local survey data, Statistics Canada, etc.
Natural gas conversion factor	26.853 m^3/GJ	Canada Energy Regulator
Electricity conversion factor	277.778 GJ/kWh	Canada Energy Regulator

Baseline scenario (before retrofit)

Equation 1: Determine total annual energy consumption of all houses participating in the retrofit program

Equation 1a: Determine number of houses in retrofit program

Total number of houses in retrofit program:

= total number of houses × goal target %

= 100,000 × 30%

= 30,000 houses retrofitted

Project scenario (after retrofit)

Equation 1: Determine total annual energy consumption of all houses participating in the retrofit program

Equation 1a: Energy consumption of retrofitted households

Annual energy consumption:

= baseline energy consumption × (1 − percentage of the energy reduction after the retrofit)

= 3,030,000 GJ × (1 − 50%)

= 1,515,000 GJ of energy consumed

Baseline scenario (before retrofit)

Equation 1b: Determine annual energy consumption

Annual energy consumption:

= average energy consumption per household per year × number of households

= 101 GJ/year × 30,000 houses

= 3,030,000 GJ (across all fuel sources) of energy consumed

Equation 2: Determine energy consumption by fuel source (natural gas, electricity)

Equation 2a: Natural gas consumption

Total natural gas consumed by all households per year:

= total energy consumption per year × share of power from natural gas

= 3,030,000 GJ/year × 70%

= 2,121,000 GJ of natural gas

Equation 2b: Convert to native units (so fuel units match with emission factor units)

GJ × conversion factor = m^3

= 2,121,000 GJ × 26.853 GJ/m^3

= 56,955,213 m^3 of natural gas/year

Equation 2c: Electricity consumption

Total electricity consumed by all households per year:

= total energy consumption per year × share of power from electricity

= 3,030,000 GJ/year × 30%

= 909,000 GJ of electricity

Equation 2d: Convert to native units (so fuel units match with emission factor units)

GJ × conversion factor = kWh

= 909,000 GJ × 277.778 GJ/kWh

= 252,500,202 kWh of electricity

Project scenario (after retrofit)

Equation 2: Determine energy consumption by fuel source (natural gas, electricity)

Equation 2a: Natural gas consumption

Total natural gas consumed by all households per year:

= total energy consumption per year × share of power from natural gas

= 1,515,000 GJ/year × 70%

= 1,060,500 GJ of natural gas

Equation 2b: Convert to native units (so fuel units match with emission factor units)

GJ × conversion factor = m^3

= 1,060,500 GJ × 26.853GJ/m^3

= 28,477,606.5 m^3 of natural gas/year

Equation 2c: Electricity consumption

Total electricity consumed by all households per year:

= total energy consumption per year × share of power from electricity

= 1,515,000 GJ/year × 30%

= 454,500 GJ of electricity

Equation 2d: Convert to native units (so fuel units match with emission factor units)

GJ × conversion factor = kWh

= 454,500 GJ × 277.778 GJ/kWh

= 126,250,101 kWh of electricity

Baseline scenario (before retrofit)

In summary:

Total amount of fuel used before retrofit:

= **56,955,213 m^3/year of natural gas** and **252,500,202 kWh/year of electricity**

Equation 3: Determine GHGs per fuel source

Emission factor of natural gas	0.0018983 tonnes CO_2e /m^3	Source: National Inventory Report
Emission factor of electricity (province-specific)	0.00004 tonnes CO_2e /kWh	Source: National Inventory Report

Equation 3a: Determine GHGs for natural gas

GHG emissions from natural gas:

= fuel consumption × emission factor = tonnes of CO_2e

= 56,955,213m^3/year of natural gas × 0.0018983 tonnes CO_2e /m^3

= 108,118.08 tonnes CO_2e from natural gas

Equation 3b: Determine GHGs for electricity

GHG emissions from electricity:

= fuel consumption × emission factor = tonnes of CO_2e

= 252,500,202 kWh/year of electricity × 0.00004 tonnes CO_2e /kWh

= 10,100.01 tonnes CO_2e of electricity

In summary:

Households in municipality before the retrofit emitted 108,118.08 tonnes CO_2e from natural gas and 10,100.01 tonnes CO_2e from electricity per year, or **118,218.09 tonnes of CO_2e/year in total.**

Project scenario (after retrofit)

In summary:

Total amount of fuel used after retrofit:

= **28,477,606.5 m^3/year of natural gas** and **126,250,101 kWh/year of electricity**

Equation 3: Determine GHGs per fuel source

Emission factor of natural gas	0.0018983 tonnes CO_2e /m^3	Source: National Inventory Report
Emission factor of electricity (province-specific)	0.00004 tonnes CO_2e /kWh	Source: National Inventory Report

Equation 3a: Determine GHGs for natural gas

GHG emissions from natural gas:

= fuel consumption × emission factor = tonnes of CO_2e

= 28,477,606.5 m^3/year of natural gas × 0.0018983 tonnes CO_2e /m^3

= 54,059.04 tonnes CO_2e from natural gas

Equation 3b: Determine GHGs for electricity

GHG emissions from electricity:

= fuel consumption × emission factor = tonnes of CO_2e

= 126,250,101 kWh/year of electricity × 0.00004 tonnes CO_2e /kWh

= 5,050 tonnes CO_2e of electricity

In summary:

Households in municipality after the retrofit emitted 54,059.04 tonnes CO_2e from natural gas and 5,050 tonnes CO_2e from electricity per year, or **59,109.04 tonnes of CO_2e/year in total.**

Emissions reduction

Annual GHG emission reduction:

= baseline emissions − project scenario emissions

= 118,218.09 tonnes CO_2e − 59,109.04 tonnes CO_2e

= 59,109.04 tonnes of CO_2e

Alternative data and calculations

A similar approach can be applied if energy intensity (GJ/m_3) and gross floor area are available (for instance for a retrofit of a municipal building).

Once the project is implemented, a comparison of annual pre- and post-retrofit residential energy use and emissions can be done to verify the accuracy of the estimate.

Projects that could use a similar approach

- Retrofits on municipal buildings
- Programs, rebates, etc., that encourage retrofits on any type of building

Example 2: Newly constructed, high-efficiency municipal building

A town in British Colombia has implemented a new corporate building policy that requires high energy performance for all newly constructed buildings. The town is constructing a new building that is expected to go beyond the provincial building code and be 40% more energy efficient than the standard. The standard or “typical” buildings of this type would consume on average 0.79 GJ/m_2. The building energy will be powered and heated by natural gas (50%) and electricity (50%).

Steps

Step 1: Define boundary

- Boundary: new building being constructed
- Emissions from use of energy within building

Step 2: Establish baseline and project scenarios

- Baseline scenario: counterfactual scenario, which assumes the building *would* have been built to standard and *would* have average energy efficiency
- Project scenario: fully constructed building operating at designed efficiency level

Step 3: Collect activity data (for baseline counter-factual scenario and project scenario)

- Equation 1: Determine total annual energy consumption of “typical” building that would have been built without new building policy (counter-factual baseline scenario) and the total annual energy consumption of newly constructed building operating at designed efficiency level
- Equation 2: Determine energy consumption by fuel source (natural gas, electricity)

Step 4: Apply emission factors (for baseline counter-factual scenario and project scenario)

- Equation 3: Determine GHGs per fuel source

Step 5: Calculate GHG reduction

Data and sources

Data	Value	Source
Average energy intensity of “typical” building that would have been built had the new building policy not been implemented	0.79 GJ/m_2	Comprehensive Energy Use Database, Office of Energy Efficiency, Natural Resources Canada Alternative sources: internal records, utilities, local survey data, Statistics Canada, etc.
Improved efficiency level of newly constructed building	40%	Architect Alternative sources: internal estimates, energy audits

Data	Value	Source
Energy intensity of fully constructed building operating at designed efficiency level	0.79 − (0.79 × 40%) = 0.474 GJ/m^2	*Calculated*
Building total floorspace	1,800 m^2	Internal records
Natural gas conversion factor	26.853 m^3/GJ	Canada Energy Regulator
Electricity conversion factor	277.778 GJ/kWh	Canada Energy Regulator

<u>**Baseline scenario**</u>

(Counterfactual scenario, which assumes the building *would* have been build to standard and *would* have had average energy efficiency)

Equation 1: Determine total annual energy consumption of "typical" building that would have been built without new building policy (counter-factual baseline scenario)

Annual energy consumption:

= average energy intensity of "typical" building × total floorspace

= 0.79 GJ/m^2 × 1800 m^2

= 1,422 GJ of energy

Equation 2: Determine energy consumption by fuel source (natural gas, electricity)

Equation 2a: Natural gas consumption

Total natural gas consumed by building per year:

= total energy consumption per year × share of power from natural gas

<u>**Project scenario**</u>

(Fully constructed building operating at designed efficiency level)

Equation 1: Determine total annual energy consumption of newly constructed building operating at designed efficiency level

Annual energy intensity:

The building energy intensity of a "typical" building in the counterfactual scenario was 0.79 GJ/m^2. The new building will be 40% more efficient than "typical" buildings.

= 0.79 − (0.79 × 40%)

= 0.474 GJ/m^2

Annual energy consumption:

= energy intensity of new building × total floorspace

= 0.474 GJ/m^2 × 1800 m^2

= 853.2 GJ of energy

Equation 2: Determine energy consumption by fuel source (natural gas, electricity)

Equation 2a: Natural gas consumption

Total natural gas consumed by building per year:

= total energy consumption per year × share of power from natural gas

<u>Baseline scenario</u> **(Counterfactual scenario, which assumes the building *would* have been build to standard and *would* have had average energy efficiency)**	**<u>Project scenario</u>** **(Fully constructed building operating at designed efficiency level)**
= 1,422 GJ × 50%	= 853.2 GJ × 50%
= 711 GJ of natural gas	= 426.6 GJ of natural gas
Equation 2b: Convert to native units (so units match with emission factors)	*Equation 2b: Convert to native units* (so units match with emission factors)
GJ × conversion factor = m_3	GJ × conversion factor = m_3
= 711 GJ × 26.853 GJ/m_3	= 426.6 GJ × 26.853 GJ/m_3
= 19,092.48 m_3 of natural gas	= 11,455.49 m_3 of natural gas
Equation 2c: Electricity consumption	*Equation 2c: Electricity consumption*
Total electricity consumed by building per year:	Total electricity consumed by building per year:
= total energy consumption per year × share of power from electricity	= total energy consumption per year × share of power from electricity
= 1,422 GJ × 50%	= 853.2 GJ × 50%
= 711 GJ of natural gas	= 426.6 GJ of natural gas
Equation 2d: Convert to native units (so units match with emission factors)	*Equation 2d: Convert to native units* (so units match with emission factors)
GJ × conversion factor = kWh	GJ × conversion factor = kWh
= 711 GJ × 277.778 GJ/kWh	= 426.6 GJ × 277.778 GJ/kWh
= 197,500.16 kWh of electricity	= 118,500.09 kWh of electricity
In summary:	*In summary:*
Energy consumed had a typical building been built:	Energy consumed by new building:
= **19,092.48 m_3/year of natural gas** and **197,500.16 kWh/year of electricity**	= **11,455.49 m_3/year of natural gas** and **118,500.09 kWh/year of electricity**
Equation 3: Determine GHGs per fuel source	**Equation 3: Determine GHGs per fuel source**

Baseline scenario

(Counterfactual scenario, which assumes the building *would* have been build to standard and *would* have had average energy efficiency)

Emission factor of natural gas	0.0018983 tonnes CO_2e /m^3	Source: National Inventory Report
Emission factor of electricity (province-specific)	0.0000117 tonnes CO_2e /kWh	Source: National Inventory Report

Equation 3a: Determine GHGs for natural gas

GHG emissions from natural gas:

= fuel consumption × emission factor = tonnes of CO_2e

= 19,092.48 m^3/year of natural gas × 0.0018983 tonnes CO_2e /m^3

= 36.24 tonnes CO_2e

Equation 3b: Determine GHGs for electricity

GHG emissions from electricity:

= fuel consumption × emission factor = tonnes of CO_2e

= 197,500.16 kWh/year of electricity × 0.0000117 tonnes CO_2e /kWh

= 2.31 tonnes CO_2e

In summary:

A "typical" building would have emitted 36.24 tonnes of CO_2e from natural gas and 2.31 tonnes of CO_2e from electricity per year, or **38.55 tonnes of CO_2e/year in total.**

Project scenario

(Fully constructed building operating at designed efficiency level)

Emission factor of natural gas	0.0018983 tonnes CO_2e /m^3	Source: National Inventory Report
Emission factor of electricity (province-specific)	0.0000117 tonnes CO_2e /kWh	Source: National Inventory Report

Equation 3a: Determine GHGs for natural gas

GHG emissions from natural gas:

= fuel consumption × emission factor = tonnes of CO_2e

= 11,455.49 m^3/year of natural gas × 0.0018983 tonnes CO_2e /m^3

= 21.75 tonnes CO_2e

Equation 3b: Determine GHGs for electricity

GHG emissions from electricity:

= fuel consumption × emission factor = tonnes of CO_2e

= 118,500.09 kWh/year of electricity × 0.0000117 tonnes CO_2e /kWh

= 1.39 tonnes CO_2e

In summary:

The new building emits 21.75 tonnes of CO_2e from natural gas and 1.39 tonnes of CO_2e from electricity per year, or **23.13 tonnes of CO_2e/year in total.**

Emissions reduction

Annual GHG reduction:

= baseline emissions − project scenario emissions

= 38.55 tonnes CO_2e − 23.13 tonnes CO_2e

= 15.42 tonnes CO_2e

Alternative data and calculations

One can use other estimates of annual energy consumption (total GJ/building rather than GJ/m^2), or energy consumption by fuel source from internal records.

Compare the emissions reduction estimate with other buildings of similar size and function in your portfolio to verify accuracy.

Projects that could use a similar approach

- New high-efficiency subdivision or development
- Policies and bylaws that encourage or support “beyond building code” construction
- Energy efficiency standards for new buildings

Example 3: LED streetlight conversion project

A municipality in Alberta is planning to replace 3000 high-pressure sodium (HPS) streetlights with energy-efficient LED fixtures as one of the upcoming year’s energy initiatives. HPS streetlights are 250 watts and operate an average of 11 hours a day, while LED streetlights are 100 watts.

Steps

Step 1: Define boundary

- Boundary: all streetlights owned by the municipality
- Emissions from use of electricity to power streetlights

Step 2: Establish baseline and project scenarios

- Baseline scenario: before conversion occurs
- Project scenario: after conversion completed

Step 3: Collect activity data (for baseline and project scenarios)

- Equation 1: Determine total annual energy consumption of HPS and LED streetlights

Step 4: Apply emission factors (for baseline and project scenarios)

- Equation 2: Determine GHGs

Step 5: Calculate GHG reduction

Data and sources

Data	Value	Source
Number of streetlights	3,000	Internal records
Wattage of HPS streetlights	250 watts	Information from manufacturer Alternative sources: internal estimates, energy audits, averages or default values
Wattage of LED streetlights	100 watts	Information from manufacturer Alternative sources: internal estimates, energy audits, averages or default values
Annual operating hours per year	11 hours per day × 365 days = 4,015 hours	Internal records *Calculated*
Emission factor of electricity (province-specific)	0.0009 tonnes CO_2e/kWh	National Inventory Report

Baseline scenario (before conversion)

Equation 1: Determine total annual energy consumption of HPS streetlights

Equation 1a: Determine total wattage of streetlights

Total wattage of streetlights:

= number of streetlights × wattage of HPS streetlights

= 3,000 × 250 watts

= 750,000 watts, or 750 kilowatts

Equation 1b: Determine total kilowatt-hours (total annual consumption) for streetlights

Annual electricity consumption of streetlights:

= total wattage × annual operating hours

= 750 kilowatts × 4,015 hours

Project scenario (after conversion)

Equation 1: Determine total annual energy consumption of LED streetlights

Equation 1a: Determine total wattage of streetlights

Total wattage of streetlights:

= number of streetlights × wattage of LED streetlights

= 3,000 × 100 watts

= 300,000 watts, or 300 kilowatts

Equation 1b: Determine total kilowatt-hours (total annual consumption) for streetlights

Annual electricity consumption of streetlights:

= total wattage × annual operation hours

= 300 kilowatts × 4,015 hours

Baseline scenario (before conversion)

= 3,011,250 kilowatt hours (kWh) of electricity

Equation 2: Determine GHGs

GHG emissions from streetlights:

= annual electricity consumption × emission factor of electricity

= 3,011,250 kWh × 0.0009 tonnes CO_2e/kWh

= 2,710.13 tonnes CO_2e

Project scenario (after conversion)

= 1,204,500 kilowatt-hours (kWh) of electricity

Equation 2: Determine GHGs

GHG emissions from streetlights:

= annual electricity consumption × emission factor of electricity

= 1,204,500 kWh × 0.0009 tonnes CO_2e/kWh

= 1084.05 tonnes CO_2e

Emissions reduction

Annual GHG reduction:

= baseline emissions − project scenario emissions

= 2,710.13 tonnes CO_2e − 1,084.05 tonnes CO_2e

= 1,626.08 tonnes CO_2e

Alternative data and calculations

Total annual kWh consumed by streetlights may be available through internal records.

Projects that could use a similar approach

- Traffic signal conversion
- Lightbulb conversions inside building
- Appliance replacement with more efficient versions

Transportation

Example 4: Replacement of a conventional gas-powered vehicle with an electric vehicle

A mid-sized city in Quebec is looking to replace its aging Toyota Camry with an electric Nissan Leaf. Based on the municipality's internal fuel tracking system, we know the Camry drives an average of 24,000 km each year.

Steps

Step 1: Define boundary

- Boundary: area where car is driven
- Emissions from use of energy to power vehicle

Step 2: Establish baseline and project scenarios

- Baseline scenario: before replacement occurs
- Project scenario: after replacement

Step 3: Collect activity data (for baseline and project scenarios)

- Equation 1: Determine total annual energy consumption of vehicle

Step 4: Apply emission factors (for baseline and project scenarios)

- Equation 2: Determine GHGs

Step 5: Calculate GHG reduction

Data and sources

Data	Value	Source
Annual kilometres travelled	24,000 km	Internal records
Fuel efficiency of gasoline-powered vehicle (Toyota Camry)	0.09 L/km	Fuel Consumption Guide, Natural Resources Canada Alternative sources: internal records
Fuel efficiency of electric-powered vehicle	0.212 kWh/km	Fuel Consumption Guide, Natural Resources Canada Alternative sources: internal records
Emission factor for light duty gasoline vehicle	0.0023258 tonnes CO_2e/L	National Inventory Report
Emission factor of electricity (province-specific)	0.0000017 tonnes CO_2e/kWh	National Inventory Report

Baseline scenario (before replacement)

Equation 1: Determine total annual energy consumption of Toyota Camry

Annual energy consumption:

= kilometres travelled (km) × fuel efficiency (L/km) = L consumed

= 24,000 km × 0.09 L/km

= 2,160 L of gasoline

Equation 2: Determine GHGs

GHG emissions from Toyota Camry:

= annual gasoline consumption × emission factor for gasoline

= 2,160 L × 0.0023258 tonnes CO_2e/L

= 5.024 tonnes CO_2e

Project scenario (after conversion)

Equation 1: Determine total annual energy consumption of Nissan Leaf

Annual energy consumption:

= kilometres travelled (km) × fuel efficiency (kWh/km) = kWh consumed

= 24,000 km × 0.212 kWh/km

= 5,088 kWh of electricity

Equation 2: Determine GHGs

GHG emissions from Nissan Leaf:

= annual electricity consumption × emission factor for electricity

= 5,088 kWh × 0.0000017 tonnes CO_2e/kWh

= 0.00865 tonnes CO_2e

Emissions reduction

Annual GHG reduction:

= baseline emissions − project scenario emissions

= 5.024 tonnes CO_2e − 0.00865 tonnes CO_2e

= 5.02 tonnes CO_2e

Alternative data and calculations

This example is for the replacement of one vehicle, but the same approach can be taken with the replacement of multiple vehicles.

If kilometres travelled is unavailable, but annual fuel consumption is available, use the latter instead. To calculate the distance driven for the electric vehicle, use the fuel consumption (L) and fuel efficiency (L/km) of the gasoline-powered vehicle to calculate km driven. The annual fuel consumption (L) and the kilometres travelled can be solved for interchangeably through this equation:

distance of vehicle travelled (km) × average fuel efficiency of vehicle travel (L/km)
= annual fuel consumption (L)

Projects that could use a similar approach

- Right-sized vehicle purchasing policy
- Vehicle efficiency measures
- Eco driving/anti-idling (apply efficiency factor to L consumption in project scenario, instead calculating kWh)

Waste

Example 5: Waste diversion program and gas capture at a municipally owned landfill

A small municipality in Manitoba produced 9,305 tonnes of solid waste last year. The town aims to reduce the amount of landfilled waste by 30% next year through an advanced waste diversion program. At the same time, the municipality also plans to install a landfill gas capture system at its landfill, which is municipally owned. The system will capture 75% of methane gas.

Steps

Step 1: Define boundary

- Boundary: waste collected within boundary of municipality and sent to municipally owned landfill
- Emissions from the decomposition of waste

Step 2: Establish baseline and project scenarios

- Baseline scenario: before diversion program
- Project scenario: once diversion program is fully in effect

Steps 3: Collect activity data (for baseline and project scenarios)

- Quantity of solid waste landfilled in baseline or project year
- Determine composition of waste stream

Step 4: For baseline and project scenarios, calculate emissions from landfill using methane commitment model[4]

- Equation 1: Determine degradable organic carbon content of waste stream
- Equation 2: Determine methane generation potential of landfilled waste
- Equation 3: Calculate emissions of CO_2e

Step 5: Calculate GHG reduction

[4] Please see PCP Protocol and *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories* (GPC) for more details on the methods to calculate solid waste emissions, including the methane commitment model or other quantification methodologies.

Data and sources

Data	Value	Source
Quantity of solid waste landfilled before waste diversion	9,305 tonnes	Internal records
Quantity of solid waste landfilled after waste diversion (30% diversion)	9,305 tonnes − (9,305 × 30%) = 6,513.5 tonnes	*Calculated*
Composition of waste: below are default values for North America		2006 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 5 Waste (IPCC, 2006) 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 or extrapolate data from existing regional or provincial/territorial waste studies.
Fraction of solid waste that is food **(A)**	34%	
Fraction of solid waste that is garden waste and other plant debris **(B)**	0%	
Fraction of solid waste that is paper **(C)**	23%	
Fraction of solid waste that is wood **(D)**	6%	
Fraction of solid waste that is textiles **(E)**	4%	
Fraction of solid waste that is industrial waste **(F)**	33%	

Baseline scenario (before waste diversion program)

Equation 1: Determine degradable organic carbon content of waste stream

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, use the following formula:

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

= (0.15 × 34%) + (0.2 × 0%) + (0.4 × 23%) + (0.43 × 6%) + (0.24 × 4%) + (0.15 × 33%)

= 0.2279

Project scenario (after conversion)

Equation 1: Determine degradable organic carbon content of waste stream

(same as baseline)

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

= (0.15 × 34%) + (0.2 × 0%) + (0.4 × 23%) + (0.43 × 6%) + (0.24 × 4%) + (0.15 × 33%)

= 0.2279

Equation 2: Determine methane generation potential of landfilled waste

(Baseline and scenario equation and values are the same for Equation 2.)

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 below:

$L_0 = \frac{16}{12} \bullet \text{MCF} \bullet \text{DOC} \bullet DOC_F \bullet \text{F}$

Term	Description	Value
MCF	Methane correction factor (based on type of landfill) • managed = 1.0 • unmanaged (≥5 m deep) = 0.8 • unmanaged (<5m deep) = 0.4 • uncategorized = 0.6	1
DOC	Degradable organic carbon (calculated from Equation 1)	0.2279
DOC_F	Fraction of DOC that is ultimately degraded (reflects the fact that some organic carbon does not degrade)	Default value of 0.6
F	Fraction of methane in landfill gas	Default value of 0.5
$\frac{16}{12}$	Stoichiometric ratio between methane and carbon	

$L_0 = \frac{16}{12} \bullet 1 \bullet 0.2279 \bullet 0.6 \bullet 0.5$

= 0.09116

Baseline scenario (before waste diversion program)

Equation 3: Calculate emissions of CO_2e using methane commitment formula

$CO_2e = MSW_x \bullet L_0 (1 - f_{rec})(1-OX) \bullet GWP$

Term	Description	Value
MSW_x	Quantity of solid waste landfilled in baseline year	9,305 tonnes
L_0	Methane generation potential (Equation 2)	0.091
F_{rec}	Fraction of methane recovered at the landfill. In the baseline year, there is no landfill gas capture system, so no methane is recovered.	0
OX	Oxidation factor (A value of 0.1 is justified for well-managed landfills; an average value for unmanaged landfills is closer to zero.)	0.1
GWP	Global warming potential of CH_4	25

$CO_2e = MSW_x \bullet L_0 (1 - f_{rec})(1-OX) \bullet GWP$

= 9305 tonnes × 0.091 × (1-0) × (1-0.1) × 25

= 19,085.49 tonnes

Project scenario (after conversion)

Equation 3: Calculate emissions of CO_2e using methane commitment formula

$CO_2e = MSW_x \bullet L_0 (1 - f_{rec})(1-OX) \bullet GWP$

Term	Description	Value
MSW_x	Quantity of solid waste landfilled in project year Note: The program aims to achieve diversion rates of 30%.	9,305 tonnes – (9,304 × 30%) = 6,513.5 tonnes
L_0	Methane generation potential (Equation 2)	0.091
F_{rec}	Fraction of methane recovered at the landfill (in project scenario)	0.75
OX	Oxidation factor (A value of 0.1 is justified for well-managed landfills; an average value for unmanaged landfills is closer to zero.)	0.1
GWP	Global warming potential of CH_4	25

$CO_2e = MSW_x \bullet L_0 (1 - f_{rec})(1-OX) \bullet GWP$

= 6,513.5 tonnes × 0.091 × (1-0.75) × (1-0.1) × 25

= 3,339.96 tonnes

Emissions reduction

Annual GHG reduction:

= baseline emissions – project scenario emissions

= 19,085.49 tonnes – 3,339.96 tonnes

= 15,745.53 tonnes CO_2e

Alternative data and calculations

For different methodologies and data requirements for waste GHG calculations, refer to the *PCP Protocol* and/or the *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories* (GPC) for more details, including the methane commitment model, first order of decay model, or other quantification methodologies.

A note on owned vs. shared landfills: This example is for a municipally owned landfill, where all information is attainable and 100% of the waste is generated by local residents and businesses. However, for landfills that are shared, or those managed at another municipality, simply use the share of waste that is generated within your own municipality in the calculations, rather than the total quantity landfilled by all municipalities or regions.

Projects that could use a similar approach

- Landfill gas capture system installation or improvement
- Waste diversion program (organics collection, etc.) (Note that metal recycling programs will not result in GHG reductions as there is no organic material in metal.)

Renewable energy

Example 6: Rooftop solar PV installation

A small, rural municipality in Nova Scotia is planning to install 20 solar photovoltaic (PV) panels on their local schools and community centres. Each solar panel is 1.67m by 0.99m (or an area of 1.65m^2).

Steps

Step 1: Define boundary

- Municipal boundary: municipally owned buildings where panels will be installed
- Emissions avoided by using solar panels, compared to the emissions that would have been generated by using energy from the electricity grid

Step 2: Establish baseline and project scenarios

- Baseline scenario: before installation
- Project scenario: after installation

Step 3: Collect activity data (for baseline and project scenarios)

- Equation 1: Determine total area of all solar panels
- Equation 2: Calculate annual energy output of solar installation

Step 4: Apply emission factors (for baseline and project scenarios)

- Equation 3: Determine GHGs offset by solar installation

Step 5: Calculate GHG reduction

Data and sources

Data	Value	Source
Solar panel area	1.65m^2	Information from manufacturer
Total number of solar panels	20	

Equation 1: Determine total area of all solar panels

Overall area of the solar panels:

= number of solar panels x area of each panel

= 20 × 1.65 m^2

= 33.066 m^2

Equation 2: Calculate annual energy output of solar installation

Energy output (kWh/year) = A × r × H × PR

Term	Description	Value
A	Solar array area (total)	Output from equation 1 = 33.066 m^2
r	Conversion efficiency of the solar modules	15% (values range from 10% to 20%, depending on the model and technology)
H	Annual solar radiation	1211.8 kWh/m^2 *Natural Resources Canada: Photovoltaic and solar resource maps (values are daily; multiply by 365 to get annual)*
PR	Performance ratio for losses	0.75 (default value, ranges between 0.5 and 0.9)

Energy output (kWh/year) = solar array area × conversion efficiency × annual solar radiation × performance ratio

= 33.066 m^2 × 15% × 1,211.8 kWh /m^2 × 0.75

= 4,507.81 kWh/year

Equation 3: Determine GHGs offset by solar installation

Equation 3 measures the amount of GHGs that would have been emitted from the consumption of grid-supplied electricity. In this case, it calculates the counterfactual baseline GHG emissions. In the project scenario, we assume that that amount of electricity comes from the solar array, which generates no direct emissions within the municipality.

Emission factor of electricity (province-specific)	0.00069 tonnes CO_2e/kWh	Source: National Inventory Report

energy output (kWh/year) × emission factor of electricity = tonnes of GHG offset

= 4,507.81 kWh/year × 0.00069 tonnes CO_2e/kWh

= 3.11 tonnes CO_2e/year

Emissions reduction

Annual GHG reduction:

= baseline emissions − project scenario emissions

= 3.11 tonnes − 0 tonnes

= 3.11 tonnes CO_2e

Projects that could use a similar approach

- Renewable energy projects

Challenges and issues

Project types with challenging quantification

Though it is helpful to understand the GHG benefits of a project, many mitigation activities cannot be quantified, or do not result in direct and measurable reductions. Examples of such projects include:

- The purchase of sustainable, low-impact goods and services: This involves life cycle analysis and the quantification of scope 3 emissions (emissions generated outside the boundary of the municipality but as a result of activities within the municipality). This is a particularly challenging area of GHG quantification, due to a lack of commonly accepted methodologies and availability of data sources. Consumption-based accounting exercises are significant undertakings, as they require full supply chain evaluation.

- Outreach, education and public awareness-raising initiatives: Typically, the GHG benefits for these types of projects are indirect. For example, there may be an associated energy reduction as a result of an educational initiative, but it is likely that many factors contributed to the energy reduction.

- Projects that enhance GHG removal from the atmosphere, such as carbon sequestration through tree planting: The methodologies for these types of calculations are still largely debated and require significant amounts of data (species, conditions and environment, lifespan of each tree, end-of-life use for tree/wood, etc.). Furthermore, in order to attribute these GHG reductions to the action, one must understand the baseline level of carbon stored in trees or other natural assets (e.g. crops), which is also highly data-intensive. In other words, to attribute the GHG reductions, the carbon storage of these natural assets has to have been included in the baseline GHG inventory.

- Many active transportation or public transit initiatives: The data requirements for many of these types of initiatives are significant. Take the example of new bike lanes. To determine the GHG reduction one would need to know the distance everyone using the bike lane travels, what mode of transportation they were using before (car, truck, carpool, bus), how frequently they use the bike lane, etc. It is nearly impossible to collect all this information accurately. Furthermore, it might be challenging to prove that those new bicyclists used the bike lake as a result of the bike lane or if they would have biked regardless, but perhaps using another route. For these reasons, no active transportation examples were included in this resource.

Issues and key considerations

Additionality

A core concept and challenge with any GHG quantification is additionality. It is important to ensure that emission reductions would not have occurred had the project not been implemented. For instance, requiring EV charging stations in all new buildings might encourage the uptake of EVs in the community, but attributing the GHG reductions from all newly purchased EVs afterwards would be incorrect; EVs are increasing due to numerous other factors such as action from other orders of government or consumer trends. In other words, it is important to consider whether changes to the baseline would have occurred had the project not been implemented, due to other external factors or interventions outside the project. Carefully and conservatively establishing the project's baseline scenario can help mitigate additionality concerns.

Interactive effects

It is important to keep in mind that multiple mitigation activities may interact and have an impact on each other's GHG benefits. Take the example of a building retrofit project, where a high-efficiency heater is installed at the same time as a building's insulation is upgraded. The two measures will impact one another's GHG reduction. The heating demands of the building are reduced as less heat is escaping due to better insulation, so the high-efficiency heater need not provide as much heat to the building. Adding the GHG reduction benefit of each individual measure would overestimate the GHG reduction (or in other cases underestimate). Instead, these actions should be quantified together. Before quantifying an action, it is important to carefully consider if there may be any interactive effects.

Resources

For more detailed information on project-level GHG accounting, consult the following:

World Resources Institute. 2014. Global Protocol for Community-Scale Greenhouse Gas Emissions Inventories.

World Resources Institute and World Business Council for Sustainable Development*. 2005. The GHG Protocol for Project Accounting*.

ISO 14064-2:2019. Greenhouse gases—Part 2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements.

For information on the PCP program, including PCP Milestone 5 requirements or measures reporting, visit https://fcm.ca/en/programs/partners-climate-protection.

Appendix A

Global warming potential (GWP) for carbon dioxide, methane and nitrous oxide, provided by the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. The GWP is based on a 100-year time frame.

Greenhouse gases (GHGs)	**Formula**	**GWP**
Carbon dioxide	CO_2	1
Methane	CH_4	25
Nitrous oxide	N_2O	298