GREENHOUSE GAS PROTOCOL

GLOBAL PROTOCOL FOR COMMUNITY-SCALE GREENHOUSE GAS EMISSION INVENTORIES (GPC)

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1.0 Introduction

1.1 Cities and climate change

Cities are the global centers of communication, commerce and culture. They are also a significant, and growing, source of energy consumption and greenhouse gas (GHG) emissions. With 90 percent of the world's urban areas situated on coastlines, cities are also particularly vulnerable to global environmental change, such as rising sea levels and coastal storms. Therefore, cities play a key role in tackling climate change.

A city's ability to take effective action on climate change, and monitor progress, depends on having access to good quality data on GHG emissions. Planning for climate action begins with developing a GHG inventory. An inventory enables cities to measure their GHG emissions and understand the contribution that different activities in the city make. Measurement allows cities to determine where to best direct mitigation efforts, create a strategy to reduce GHG emissions, and track their progress. Many cities have already developed GHG inventories, and use them to set reduction targets and inform their climate action plans.

In addition, a city-scale GHG inventory can help cities meet legal and voluntary requirements to measure and report GHG emissions data. A growing number of cities are choosing to disclose GHG emissions data through voluntary reporting platforms, such as carbon*n* Cities Climate Registry (cCCR) and the Carbon Disclosure Project (CDP), to enhance transparency and give stakeholders easier access to their results. Furthermore, it is often a requirement or prerequisite from city project funders and donors that cities measure their GHG emissions using best practice standards.

However, the inventory methods that cities have used to date vary in terms of what emission sources and GHGs are included in the inventory; how emissions sources are defined and categorized; and how transboundary emissions are treated. This inconsistency makes comparisons between cities difficult, raises questions around data quality, and limits the ability to aggregate local, subnational, and national government GHG emissions data.

To allow for more credible reporting, meaningful benchmarking and aggregation of climate data, greater consistency in GHG accounting is required. The Global Protocol for Community-Scale GHG Emissions (GPC) responds to this challenge, offering a robust and clear framework that builds on existing methodologies for calculating and reporting city-scale GHG emissions.

1.2 Purpose of the GPC

The GPC sets out requirements and provides guidance for calculating and reporting city-scale GHG inventories, consistent with the 2006 IPCC Guidelines for National GHG Inventories. The GPC seeks to:

- Help cities develop a comprehensive and robust GHG inventory in order to support climate action planning through a thorough understanding of their GHG impacts.
- Ensure consistent and transparent measurement and reporting of GHG emissions between cities, following internationally recognized GHG accounting and reporting principles.
- Enable city inventories to be aggregated at subnational and national levels.

- Demonstrate the important role that cities play in tackling climate change, and facilitate insight through benchmarking – and aggregation – of comparable data.

1.3 Using the GPC

The GPC can be used by anyone assessing the GHG emissions of a geographically defined area. Although the GPC is primarily designed for cities, the accounting framework can also be used for boroughs or wards within a city, towns, districts, counties, prefectures, provinces, and states. In this document, the term "city" is used to refer to all these jurisdictions, unless otherwise specified. (Furthermore, the GPC does not define what geographic boundary constitutes a "city".)

1.4 Relationship to other protocols and standards

The GPC builds upon the knowledge, experiences, and practices of existing standards used by cities to measure city-scale GHG emissions. A brief overview of these resources is provided in Table 1.1 below. Further detail on how GPC requirements and boundaries relate to these standards is provided in Appendix A.

Table 1.1 Existing standards on GHG accounting and reporting

Author	Title	Description
IPCC	IPCC Guidelines for National Greenhouse Gas Inventories	Detailed guidance on GHG accounting for national inventories
ICLEI[1]	International Local Government GHG Emissions Analysis Protocol	Standards for community-level, and local government operations, GHG emissions
UNEP, UN Habitat and World Bank[2]	International Standard for Determining Greenhouse Gas Emissions for Cities	Simplified approach, with reference to other standards, such as IPCC Guidelines
ICLEI-USA	U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions	Provides U.S.-specific data sources, calculation approaches and reporting frameworks, from geographic to consumption based
WRI and WBCSD[3]	GHG Protocol Standards	Family of standards for GHG measurement and reporting for a variety of audiences and purposes (e.g., corporate, cities, projects)
The Covenant of Mayors Initiative	Baseline Emissions Inventory / Monitoring Emissions Inventory methodology	Measures CO_2 emissions resulting from non-EU ETS (emissions trading system) covered final energy consumption
British Standards Institute	PAS 2070: Specification for the assessment of a city's greenhouse gas emissions	Measures GHG emissions using a direct plus supply chain, and consumption-based approach

[1] ICLEI: Local Governments for Sustainability
[2] United Nations Environment Program (UNEP); United Nations Human Settlements Program (UN Habitat).
[3] World Resources Institute (WRI) and World Business Council for Sustainable Development (WBCSD)

Upon publication, the GPC will supersede the provisions related to community GHG emissions of International Local Government GHG Emissions Analysis Protocol, and the International Standard for Determining GHG Emissions for Cities.

1.5 How this standard was developed

The GPC is the result of a collaborative effort between the World Resources Institute (WRI), C40 Cities Climate Leadership Group (C40), and ICLEI – Local Governments for Sustainability (ICLEI). See Table 1.2 for a short description of each organization.

Table 1.2 GPC authors

Organization	Description
WRI	The GHG Protocol is a partnership of businesses, non-governmental organizations, governments, and others convened by WRI and the World Business Council for Sustainable Development. The mission of the GHG Protocol is to develop internationally accepted GHG accounting and reporting standards and tools, and promote their adoption.
C40	The C40 Cities Climate Leadership Group (C40) is a network of the world's megacities committed to addressing climate change. Established in 2005, C40 offers cities an effective forum where they can collaborate, share knowledge and drive meaningful, measurable and sustainable action on climate change.
ICLEI	ICLEI is a leading association of cities and local governments dedicated to sustainable development. ICLEI represents a movement of over 1,000 cities and towns in 86 countries. ICLEI promotes local action for global sustainability and supports cities to become sustainable, resilient, resource-efficient, biodiverse, and low-carbon.

Development of the GPC began in Sao Paulo in June 2011 as a result of a Memorandum of Understanding between C40 and ICLEI. In 2012, the partnership expanded to include WRI and the Joint Work Programme of the Cities Alliance between the World Bank, UNEP, and UN-HABITAT.

An early draft (Version 0.9) was released in March 2012 for public comment. The GPC was then updated (Version 1.0) and tested with 35 cities worldwide. This GPC Version 2.0 incorporates the feedback from the pilot testing and is slated for publication at the end of 2014.

Table 1.3 Development process of GPC

Date		**Milestones**
2011	June	Memorandum of Understanding between C40 and ICLEI
2012	March	GPC Pilot (Version 0.9) released for public comment
	May	GPC Pilot (Version 1.0) released
2013		Pilot testing with 35 cities worldwide
2014	July	GPC Draft (Version 2.0) released for public comment
	December	GPC (Version 2.0) published

In 2015 the GPC authors will begin developing an expanded version, which will provide additional guidance on identifying and quantifying GHG emissions occurring outside the city boundary associated with cities activities (e.g., scope 3 emissions). This will allow cities to take a broader and more holistic approach to measuring their GHG impact, as well as identify opportunities for realizing more efficient urban supply chains. The authors anticipate launching this expanded version at the end of 2015.

1.6 Local government operations

In addition to compiling a city-scale GHG inventory, local governments may also want to measure GHG emissions from their own municipal operations via a local government operations, or LGO, inventory. A subset of a city-scale inventory, an LGO highlights the GHG emission sources over which city leadership has direct control, such as municipal buildings and facilities, and street lighting.

An LGO inventory allows local governments to identify GHG reduction opportunities across their estate and demonstrate leadership in taking action. This GPC requires that an LGO inventory be reported separately from the city-scale inventory. Appendix B provides further information on developing an LGO inventory.

Box 1.1 Case study: Measuring GHG emissions – New York City, U.S.

New York City aims to reduce GHG emissions by 30% below 2005 levels by 2030, and 80% by 2050. To help determine where to best direct mitigation efforts, as well as track the effectiveness of actions taken and measure progress, the city conducts and publishes an annual assessment and analysis of GHG emissions. The plan states:

"*Regular, accurate data allow us to assess the impact of policy measures, infrastructure investments, consumer behavior, population and weather on GHG emissions, and focus our programs to ensure that we are implementing the most effective GHG mitigation strategies.*"

In 2012, GHG emissions were 19% lower than in 2005. The reduced carbon intensity of the city's electricity supply proved to be the main driver. Next, New York City plans to expand their inventory to map neighborhood-level emissions to better target policies and provide communities with information to help them reduce their GHG emissions.

Source: PlaNYC website www.nyc.gov/html/planyc

2.0 Accounting and Reporting Principles

In addition to outlining accounting and reporting principles for city-scale GHG emissions, this chapter introduces notation keys, which shall be used to indicate any GHG emission sources not reported in an inventory but which are included as requirements in the GPC. This helps to facilitate assessment of the completeness of an inventory.

2.1 Accounting and reporting principles

Accounting and reporting for city-scale GHG emissions is based on the following principles adapted from the GHG Protocol Standards[4] in order to represent a fair and true account of emissions:

Relevance: The reported GHG emissions shall appropriately reflect emissions occurring as a result of activities and consumption within the city boundary. The inventory will also serve the decision-making needs of the city, taking into consideration relevant local, subnational, and national regulations. The principle of relevance applies when selecting data sources, and determining and prioritizing data collection improvements.

Just 10km from the city center, the airport serving Arendal, Norway is located outside of the city's municipal boundaries. Since the airport serves the Arendal area, and the majority of the regional population lives in the city, the city of Arendal includes the emissions activities of the airport in their GHG inventory.

Completeness: All emissions sources within the inventory boundary shall be accounted for according to the GPC requirements. Any exclusion of emission sources shall be justified and clearly explained. Notation keys shall be used when an emission source is excluded, and/or not occurring (see 2.2).

The city of Adelaide, Australia, has two electric vehicle charging stations, but because of limited use and a lack of reliable data, the Adelaide inventory does not include emissions from electric vehicles. The city's inventory methodology report provides justifications and the exclusion is clearly indicated with a notation key (NE, not estimated).

Consistency: Emissions calculations shall be consistent in approach, boundary, and methodology. Using consistent methodologies for calculating GHG emissions enables meaningful documentation of emission changes over time, trend analysis, and comparisons between cities. Accounting of emissions shall follow the standardized methodologies provided by the GPC. Any deviation from the preferred methodologies shall be justified and disclosed.

Transparency: Activity data, emission sources, emission factors, and accounting methodologies require adequate documentation and disclosure to enable verification. The information should be sufficient to allow individuals outside of the inventory process to use the same source data and derive the same results. All exclusions shall be clearly identified and justified.

[4] See GHG Protocol *Corporate Standard*, 2004.

Accuracy: The calculation of GHG emissions should not systematically overstate or understate actual GHG emissions. Accuracy should be sufficient enough to give decision makers and the public reasonable assurance of the integrity of the reported information. Uncertainties in the quantification process should be reduced to the extent that it is possible and practical.

Guidance on using principles: Within the requirements of this standard, a city will need to make important decisions in terms of setting the inventory boundary, choosing calculation methods, deciding whether to include additional scope 3 sources, etc. Tradeoffs between the five principles may be required in making these decisions. For example, achieving a complete inventory may at times require using less accurate data. Over time, as both the accuracy and completeness of GHG data increase, the need for tradeoffs between these accounting principles will likely diminish.

Data limitations created a challenge for the city of Kampala, Uganda when it undertook its first GHG inventory in 2013. Data from different years and sources were scaled or combined in order to complete their inventory. Commercial activities, for example, were estimated based on older data provided by the Uganda Investment Authority while residential data was based on a household survey from the inventory year. This is an example of tradeoff between completeness and accuracy.

2.2 Notation keys

Data collection is an integral part of developing and updating a GHG inventory. Data will likely come from a variety of sources and will vary in quality, format, and completeness and, in many cases, will need to be adapted for the purposes of the assessment. The GPC recognizes these challenges and sets out good practice data collection principles in Chapter 5.0. It also provides guidance on gathering existing data, generating new data, and adapting data for inventory use.

To accommodate limitations in data availability and differences in emission sources between cities, the GPC encourages the use of notation keys, as recommended in IPCC Guidelines, and an accompanying explanation to justify exclusion or partial accounting of GHG emission source categories.

Table 2.1 Use of notation keys (adapted from 2006 IPCC Guidelines, Chapter 8)[5]

Notation key	Definition	Explanation
IE	Included Elsewhere	GHG emissions for this activity are estimated and presented in another category of the inventory. That category should be noted in the explanation.
NE	Not Estimated	Emissions occur but have not been estimated or reported; justification for exclusion should be noted.

[5] IPCC Guidelines also includes the notation keys "C - Confidential" for GHG emissions which could lead to the disclosure of confidential information, and "NA – Not Applicable" for activities that occur but do not result in emissions of specific GHG emissions. For the purposes of the GPC, the notation key "NE" should be used for GHG emissions that cannot be reported for reasons of data confidentiality or aggregated with another category, whilst the notation key "NA" does not apply because the use of notation keys in the GPC is focused on GHG emission source categories, rather than specific gases and does not require the same level of disaggregation as national inventories.

NO	Not Occurring	An activity or process does not occur or exist within the city.

When collecting emissions data, the first step is identifying whether or not an activity occurs in a city. If it does not, the notation key "NO" is used for the relevant GHG emission source category. For example, a landlocked city with no transport by water would use the notation key "NO" to indicate that GHG emissions from water transport do not occur. If the activity *does* occur in the city – and data are available – then the emissions should be estimated. However, if the data are also included in another emissions source category or cannot be disaggregated, the notation key "IE" would be used to avoid double counting, and the category in which they are included should be identified. For example, emissions from waste incineration would use "IE" if these emissions are also reported under generation of energy for use in buildings. If the data are not available and, therefore, the emissions are not estimated, the notation key "NE" would be used.

3.0 Setting the Assessment Boundary

An assessment boundary identifies the gases, emission sources, geographic area, and time span covered by a GHG inventory. It also helps give the city a comprehensive understanding of where emissions are coming from as well as an indication of where it can take action or influence change.

Requirements in this chapter:

The assessment boundary of a city-wide GHG inventory shall include all seven Kyoto Protocol GHG's occurring within the geographic boundary of the city, as well as specified emissions occurring out-of-boundary as a result of city activities. The inventory shall cover a continuous 12-month period.

3.1 Geographic boundary

Cities shall establish a geographic boundary that identifies the spatial dimension or physical perimeter of the inventory's assessment boundary. Any geographic boundary may be used for an inventory assessment boundary. Depending on the purpose of the inventory, the boundary can align with the administrative boundary of a local government, a ward or borough within a city, a combination of administrative divisions, or another geographically identifiable entity.

3.1.1 Scopes terminology

Activities taking place in a city can generate GHG emissions inside the city boundary as well outside the city boundary. To recognize this distinction, GHG emissions are categorized as scope 1, scope 2 or scope 3 emissions based on an application of the scopes framework used in the *GHG Protocol Corporate Standard.*[6] The scopes framework also gives some indication of the level of control or influence cities are likely to have over GHG emission sources, though this varies by city.

Based on the geographic boundary established, the scopes framework is designed to help cities classify in-boundary, out-of-boundary, and transboundary emissions. Transboundary emissions are those produced by activities that cross the geographic boundary, but which may not be distinguishable as entirely in- or out-of-boundary. Table 3.1 lists definitions of each scope as applied to city inventories.

Table 3.1 Scopes

Scope	Definition
Scope 1	All GHG emissions from sources located within the boundary of the city
Scope 2	All GHG emissions occurring as a consequence of the use of grid-supplied electricity, heating and/or cooling within the city boundary
Scope 3	All other GHG emissions that occur outside the city boundary as a result of activities within the city's boundary

[6] See Appendix A for a comparison of how the scopes framework is applied in corporate GHG inventories compared to city GHG inventories

The scopes framework is derived from the *GHG Protocol Corporate Standard,* where the scopes are considered operational boundaries in which to categorize emissions. Local government operations (LGO) inventories will follow the *GHG Protocol Corporate Standard* framework for the scopes. Cities conducting an LGO inventory should take note of the differences between how the scopes are defined for city-wide vs. LGO inventories (see Appendix B for more information).

3.2 Time period of assessment

The GPC is designed to account for city GHG emissions in a single reporting year. The inventory should cover a continuous period of 12 months, ideally aligning to either a calendar year or a financial year, consistent with the time periods most commonly used by relevant statistical agencies and data sources.

Calculation methodologies in the GPC generally quantify emissions released during the reporting year. In certain cases, however, the most appropriate methodology may also estimate the future emissions that result from activities conducted within the reporting year (see waste emissions accounting in Chapter 8.0).

3.3 Greenhouse gases

Cities shall account for emissions of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen triflouride (NF_3).[7] These are the seven gases currently required for national GHG inventory reporting according to the IPCC following the Kyoto Protocol.

CO_2 emissions arising from biologically sequestered carbon (e.g., CO_2 from burning biomass/biofuels) shall be reported separately from all other GHG emissions – according to reporting requirements set out in Chapter 4.0 – and excluded from emission totals, except where the CO_2 arises from land-use change.

Emissions sequestered by CO_2 capture and storage systems shall be excluded from emissions totals for applicable sectors.

3.4 GHG emission sources

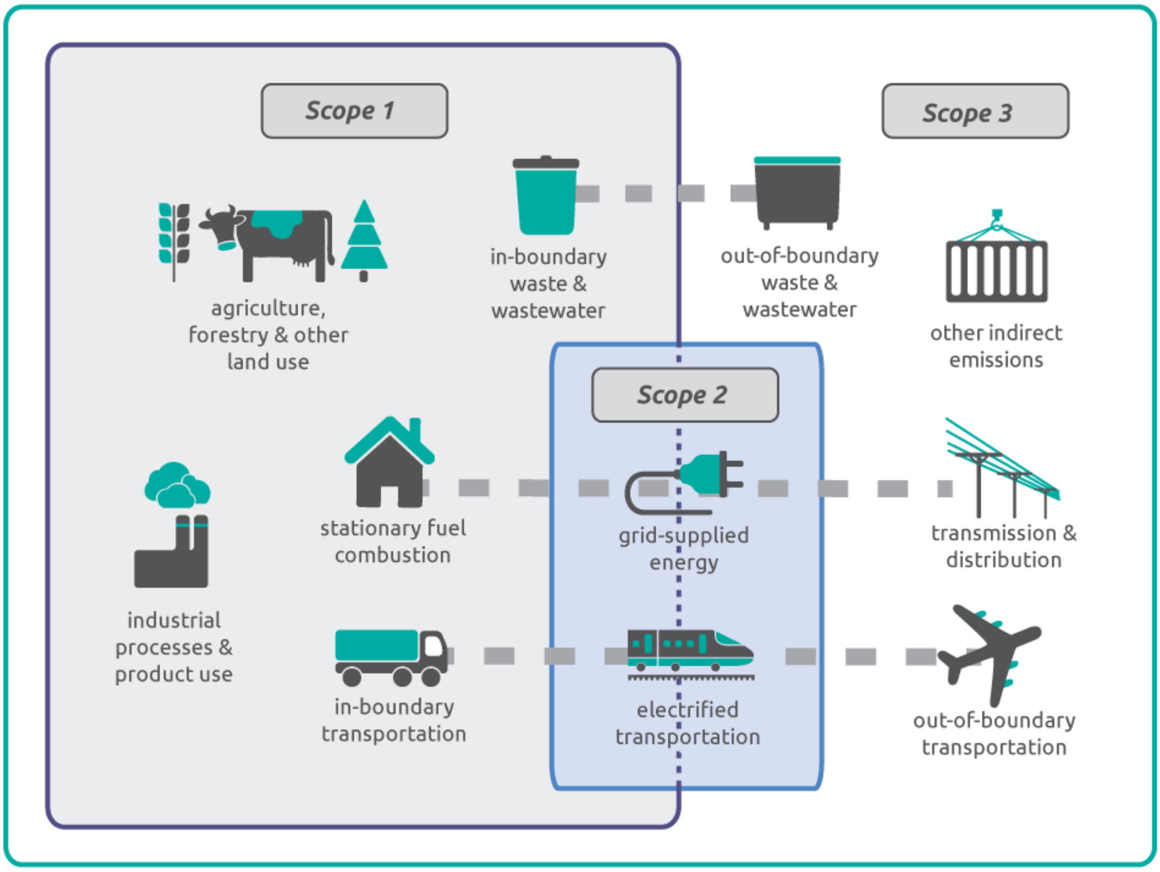
The GPC includes six main emission sectors where emissions are either categorized as scope 1, 2, or 3 depending on where the emissions occur. These sectors include:

- Stationary energy
- Transportation
- Waste
- Industrial processes and product use (IPPU)
- Agriculture, forestry, and other land use (AFOLU)
- Other indirect emissions

[7] NF_3 is the seventh GHG to be added to the international accounting and reporting rules under the UNFCCC/Kyoto Protocol. NF_3 was added to the second compliance period of the Kyoto Protocol, beginning in 2012 and ending in either 2017 or 2020.

Figure 3.1 illustrates how some emission sources may occur solely within a geographic boundary (IPPU, stationary fuel combustion), and some may cross the geographic boundaries established for the inventory. Regional transportation systems, electricity generation and use, waste disposal, and exchanges of goods and services are examples of activities that may be shared between cities.

Figure 3.1 Sources and boundaries of city-scale GHG emissions



4.0 Reporting Requirements

In order to ensure transparent and consistent GHG inventory reports, this chapter identifies GHG reporting requirements and guidance. Cities may report emissions based on relevant local or program-specific requirements, but must also follow the requirements outlined in this chapter to comply with the GPC.

4.1 Shall, Should and May Terminology

The GPC uses precise language to indicate which provisions of the standard are requirements, which are recommendations, and which are permissible or allowable options that cities may choose to follow.

- The term **"shall"** is used throughout this standard to indicate what is required in order for a GHG inventory to be in conformance with the GPC.
- The term **"should"** is used to indicate a recommendation, but not a requirement.
- The term **"may"** is used to indicate an option that is permissible or allowable.

The term "required" is used in the guidance to refer to requirements in the standard. "Needs," "can," and "cannot" may be used to provide guidance on implementing a requirement or to indicate when an action is or is not possible.

4.2 Reporting levels

To accommodate the range of data availability, capacity and inventory purposes, the GPC sets out two levels of reporting requirements that a city can choose for its inventory: BASIC and BASIC+.[8] These levels indicate the emission sources that need to be aggregated together (e.g., a BASIC total, a BASIC+ total). A city should choose the highest level for which it has reliable data and indicate which level it is reporting against in its inventory. Cities reporting additional scope 3 sources beyond the requirements of BASIC + may report these and indicate the methods used for this "expanded" approach.

- **BASIC**:
  This level requires the reporting of all scope 1 sources (except those listed below), all scope 2 sources and waste sector scope 3 sources. Scope 1 emissions not required under BASIC are:

  1. Emissions from energy generation
  2. Emissions from in-boundary disposal and treatment of imported waste
  3. Emissions from IPPU
  4. Emissions from AFOLU

- **BASIC+**:
  This level covers all sources required for BASIC, plus scope 1 emissions from AFOLU and IPPU, and scope 3 emissions from transportation and stationary units. Cities reporting BASIC+ shall indicate any data or reporting gaps (using notation keys) for any of the

[8] The additional emission sources required for BASIC+ reporting were identified as generally less prevalent and/or often lacking in activity data during the GPC pilot test and stakeholder feedback.

sub-sectors within these additional emission sources, and shall have no emissions from BASIC sources that are "Not Estimated."

- **EXPANDED**:
  This level covers an expanded list of scope 3 sources. This methodology is not elaborated in the current version of the GPC, but will be in future publications (see 4.4). Therefore, it is not listed as a formal level in the sample reporting Table 4.2 but cities can note the additional sources they include.

Cities shall report by sector, and where data is available, by sub-sector and sub-category. These designations are explained in Box 4.1.

Box 4.1 Sectors, sub-sectors and sub-categories[9]

Sectors, for GPC purposes, define the topmost categorization of city-level GHG sources, distinct from one another, that together make up the city's GHG producing activities (including waste, transport, stationary energy, etc.).

Sub-sectors are the divisions which together make up a sector (e.g., stationary energy sub-sectors, transport modes, waste streams, industries or product type, or agricultural sub-sectors).

Sub-categories are used to denote an additional level of categorization. Sub-categories provide opportunities to use disaggregated data, improve inventory detail, and help target mitigation actions and policies.

Table 4.1 shows the emission source sub-sectors required for each reporting level, mapped according to scope. Table 4.2 represents a comprehensive template for reporting all emission sources by gas, scope and reporting level, as well as other requirements such as notation keys and data quality assessments.

4.3 Aggregating city inventories

In addition, the GPC has been designed to allow city inventories to be aggregated at subnational and national levels. This can be used to:

- Improve the data quality of a national inventory, particularly where major cities' inventories are reported
- Measure the contribution of city-scale mitigation actions to regional or national GHG emission reduction targets
- Identify innovative transboundary and cross-sectorial strategies for GHG mitigation

The aggregation of city inventories is based on a "territorial" accounting approach, which only measures GHG emissions occurring within the city boundary. This is different to the accounting

[9] 2006 IPCC Guidelines include similar sector breakdowns, described in Volume 1, chapter 8, section 8.2.4 Sectors and categories. Available at: www.ipcc-nggip.iges.or.jp/public/2006gl/vol1

approach required for BASIC or BASIC+ reporting, which also includes out-of-boundary emissions as a result of activities within the city boundary.

When adding GHG emissions data from multiple city inventories, only in-boundary (scope 1) emissions should be aggregated together, excluding all out-of-boundary emissions — these will be included as another city's in-boundary (scope 1) emissions. It is important to ensure that aggregated figures do not double count the same emissions.

To determine "territorial" emissions, all scope 1 emission sources included in BASIC or BASIC+ should be included, in addition to emissions from in-boundary production of grid-supplied energy and in-boundary treatment of waste generated outside the city boundary. These are required for reporting by scopes total in order to ensure inventory completeness and transparency, and for aggregating city inventories. However, they are not included in BASIC or BASIC+ totals in order to avoid double counting. Figure 4.1 provides an illustration.

Figure 4.1 Comparison between territorial accounting approach and GPC

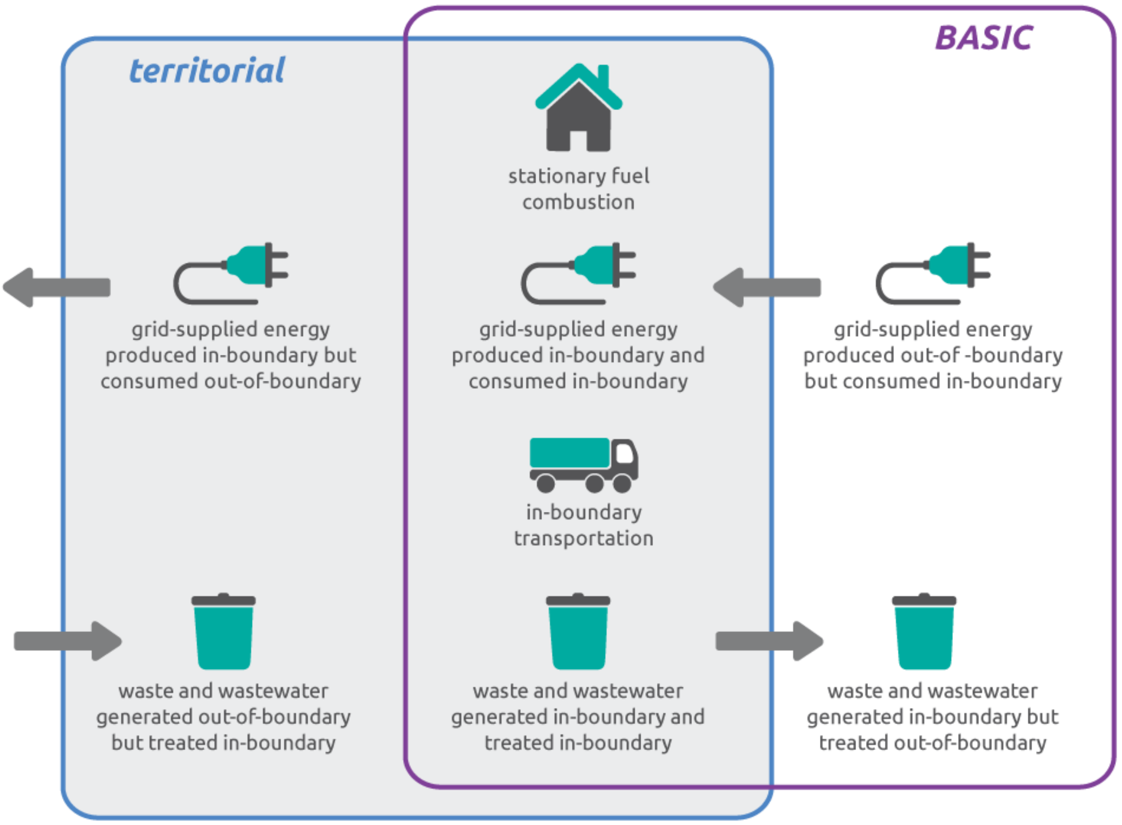


Table 4.1 Sources and scopes required under BASIC, BASIC+ and Expanded

Sectors	Scope 1	Scope 2	Scope 3
STATIONARY ENERGY			
Residential buildings	x	x	x
Commercial buildings	x	x	x
Institutional buildings	x	x	x
Manufacturing industries and construction	x	x	x
Energy industries	x	x	x
Agriculture, forestry, and fishing activities	x	x	x
Non-specified sources	x	x	x
Fugitive emissions from mining, processing, storage, and transportation of coal	x		
Fugitive emissions from oil and natural gas systems	x		
TRANSPORTATION			
On-road	x	x	x
Railways	x	x	x
Waterborne navigation	x	x	x
Aviation	x	x	x
Off-road	x	x	
WASTE			
Solid waste disposal	x		x
Biological treatment of waste	x		x
Incineration and open burning	x		x
Wastewater treatment and discharge	x		x
INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU)			
Industrial processes	x		
Product use	x		
AGRICULTURE, FORESTRY, AND LAND USE (AFOLU)			
Livestock	x		
Land	x		
Other agriculture	x		
OTHER INDIRECT EMISSIONS			x

BASIC =
BASIC+ = **plus BASIC**
EXPANDED = **plus BASIC+**

4.4 Reporting requirements

After a city has chosen its reporting level, the following reporting requirements **shall** apply to all inventories:

4.4.1 Description of the assessment boundary

- A description and map of the geographic boundary, including the rationale used for selecting that boundary.
- An overview of the reporting city including total geographic area, resident population, economic information (GDP, composition of economy), climate, and other relevant information such as land use activities (a land use map is preferable).
- An outline of the activities included in the inventory, and if scope 3 is included, a list specifying which types of activities are covered.
- The reporting period covered.
- The reporting level chosen (BASIC, BASIC+, EXPANDED).

4.4.2 Information on emissions

- Emissions by gas: GHG emissions in metric tons by gas (CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, and NF_3) and by CO_2 equivalent (CO_2e). CO_2 equivalent can be determined by multiplying each gas by a global warming potential (GWP), as elaborated in Chapter 5.0.
- Emissions by source: GHG emissions by gas for each sector and sub-sector.
- Emissions by scope: GHG emissions aggregated and reported by scope 1, scope 2, and scope 3 separately, independent of any GHG trades such as sales, purchases, transfers, or banking of allowances.
- CO_2 emissions from biogenic origin, except where CO_2 arises from land-use change, shall be reported as a separate gas under column CO_2(b) in the reporting framework (Table 4.2), but not counted in emissions totals.
- Any specific exclusion of sources, facilities, and/or operations. These shall be identified using notation keys (see Section 2.2), along with a clear justification for their exclusion.

4.4.3 Information on methodologies and data quality

- Methodologies used to calculate or measure emissions, providing a reference or link to any calculation tools used. For each emission source sector, a description of the types and sources of data, including activity data, emission factors, and global warming potential (GWP) values used to calculate emissions, and a description of the data quality of reported emissions data. The 'Explanation' column in the reporting framework (Table 4.2) provides space to indicate the methodology used.

- Data quality for activity data and emission factors used in quantification (AD and EF, respectively, under *data quality* in the GPC accounting and reporting framework), following a High-Medium-Low rating (see Section 5.5).

4.4.4 Information on emission changes

- Year chosen as base year, and an emissions profile over time that is consistent with and clarifies the chosen policy for making base year emissions recalculations.

- Appropriate context for any significant emissions changes that trigger base year emissions recalculation (acquisition of existing neighboring communities, changes in reporting boundaries or calculation methodologies, etc.). See Chapter 11.0 for choosing a base year and recalculation procedures.

Table 4.2 presents the GPC accounting and reporting framework which sets out the reporting levels, emission totals, and other reporting requirements in a comprehensive table. Use of this framework is recommended for all cities. Cities may use an alternate template to present GHG emissions data provided the requirements of the GPC are met. Table 4.2 corresponds to a complementary GPC Excel reporting tool.[10] For each emission source, the corresponding IPCC classification number is provided in Appendix A.

In addition, each sector methodology chapter (6-10) lists a summary of the scope 1, 2, and 3 emissions required for BASIC and BASIC+ reporting. These summary tables correspond to the numbering of Table 4.2.

4.5 Introduction to scope 3

Scope 3 emissions are those that are produced outside the city boundary as a result of activities occurring within the city boundary[11], or from transboundary activities that cross the city boundary.

Cities, by virtue of their size and connectivity, inevitably give rise to GHG emissions beyond their boundary. Measuring these emissions allows cities to take a more holistic approach to tackling climate change by assessing the GHG impact of their supply chains, and identifying areas of shared responsibility for upstream and downstream GHG emissions.

The GPC includes scope 3 accounting for a limited number of emission sources. At the BASIC reporting level, cities must report scope 3 emissions from transmission and distribution losses associated with grid-supplied energy, and waste disposal and wastewater treatment outside the city boundary. The BASIC+ reporting level additionally includes scope 3 accounting for trans-boundary transportation.

Measurement and reporting of other scope 3 categories – such as GHG emissions embodied in fuels, water, food and construction materials – is optional. To support cities in measuring scope 3 emissions in a robust and consistent manner, an expanded version of the GPC is planned for publication in 2015. This will provide additional guidance on identifying and quantifying scope 3 emissions.

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[10] See websites (placeholder for future websites)
[11] The use of grid-supplied energy within the city boundary is reported in scope 2.

Two established approaches for scope 3 emissions include process-based or consumption-based, or a hybrid of the two:

- **Process-based**: This approach seeks to quantify life-cycle based GHG emissions associated with supply chains from the consumption of key goods and services produced outside the city boundary. These emissions may be reported alongside emission sources already covered by the GPC.

- **Consumption-based:** This approach captures life-cycle GHG emissions for all goods and services consumed by residents of a city. GHG emissions from the production of goods and services within the city boundary for export and visitor activities are excluded. While data collection can be challenging, consumption-based inventories typically use an input-output model, which links household consumption patterns and trade flows to energy use and GHG emissions, and their categories cut across those set out in the GPC.

Both methodologies outlined above are complementary and provide different insights into a city's GHG emissions profile. Please see Appendix A for references to existing methodologies used by cities.

Table 4.2 GPC Accounting and Reporting Framework

The following tables A-D highlight key reporting requirements of the GPC and together represent the larger reporting framework.

(A) Description of the assessment boundary

Assessment boundary	
Name of City	
Country	
Inventory year	
City boundary	
Land area (km^2)	
Resident population	
GDP (US$)	
Composition of economy	
Climate	
Other information	

(B) Greenhouse gas emissions inventory

				Gases (tCO2e)									Data Quality		
GPC ref No.	Scope	GHG Emissions Source	Notation keys	CO_2	CH_4	N_2O	HFC	PFC	SF_6	NF_3	CO_2e	$CO_2(b)$	AD	EF	Explanation
I		**STATIONARY ENERGY SOURCES**													
I.1		**Residential buildings**													
I.1.1	1	Emissions from in-boundary fuel combustion													
I.1.2	2	Emissions from consumption of grid-supplied energy													
I.1.3	3	Transmission and distribution losses from grid-supplied energy													
I.2		**Commercial and institutional buildings/facilities**													
I.2.1	1	Emissions from in-boundary fuel combustion													
I.2.2	2	Emissions from consumption of grid-supplied energy													
I.2.3	3	Transmission and distribution losses from grid-supplied energy													
I.3		**Manufacturing industry and construction**													
I.3.1	1	Emissions from in-boundary fuel combustion													
I.3.2	2	Emissions from consumption of grid-supplied energy													
I.3.3	3	Transmission and distribution losses from grid-supplied energy													
I.4		**Energy industries**													
I.4.1	1	Emissions from in-boundary production of energy used in auxiliary operations													
I.4.2	2	Emissions from consumption of grid-supplied energy													
I.4.3	3	Transmission and distribution losses from grid-supplied energy													
I.4.4	1	Emissions from in-boundary production of grid-supplied energy													
I.5		**Agriculture, forestry and fishing activities**													
I.5.1	1	Emissions from in-boundary fuel combustion													
I.5.2	2	Emissions from consumption of grid-supplied energy													
I.5.3	3	Transmission and distribution losses from grid-supplied energy													
I.6		**Non-specified sources**													
I.6.1	1	Emissions from in-boundary fuel combustion													
I.6.2	2	Emissions from consumption of grid-supplied energy													

I.6.3	3	Transmission and distribution losses from grid-supplied energy													
I.7		**Fugitive emissions from mining, processing, storage, and transportation of coal**													
I.7.1	1	In-boundary fugitive emissions													
I.8		**Fugitive emissions from oil and natural gas systems**													
I.8.1	1	In-boundary fugitive emissions													
II		**TRANSPORTATION**													
II.1		**On-road transportation**													
II.1.1	1	Emissions from in-boundary transport													
II.1.2	2	Emissions from consumption of grid-supplied energy													
II.1.3	3	Emissions from transboundary journeys													
II.2		**Railways**													
II.2.1	1	Emissions from in-boundary transport													
II.2.2	2	Emissions from consumption of grid-supplied energy													
II.2.3	3	Emissions from transboundary journeys													
II.3		**Water-borne navigation**													
II.3.1	1	Emissions from in-boundary transport													
II.3.2	2	Emissions from consumption of grid-supplied energy													
II.3.3	3	Emissions from transboundary journeys													
II.4		**Aviation**													
II.4.1	1	Emissions from in-boundary transport													
II.4.2	2	Emissions from consumption of grid-supplied energy													
II.4.3	3	Emissions from transboundary journeys													
II.5		**Off-road**													
II.5.1	1	Emissions from in-boundary transport													
II.5.2	2	Emissions from consumption of grid-supplied energy													
III		**WASTE**													
		Solid waste disposal													
III.1.1	1	Emissions from waste generated and treated within the city													
III.1.2	3	Emissions from waste generated within but treated outside of the city													
III.1.3	1	Emissions from waste generated outside the city boundary but treated within the city													
		Biological treatment of waste													
III.2.1	1	Emissions from waste generated and treated within the city													
III.2.2	3	Emissions from waste generated within but treated outside of the city													
III.2.3	1	Emissions from waste generated outside the city boundary but treated within the city													
		Incineration and open burning													
III.3.1	1	Emissions from waste generated and treated within the city													
III.3.2	3	Emissions from waste generated within but treated outside of the city													
III.3.3	1	Emissions from waste generated outside the city boundary but treated within the city													
		Wastewater treatment and discharge													
III.4.1	1	Emissions from wastewater generated and treated within the city													
III.4.2	3	Emissions from wastewater generated within but treated outside of the city													
III.4.3	1	Emissions from wastewater generated outside the city boundary but treated within the city													
IV		**IPPU**													
IV.1	1	In-boundary emissions from industrial processes													
IV.2	1	In-boundary emissions from product use													
V		**Agriculture, Forestry and Land Use (AFOLU)**													
V.1	1	In-boundary emissions from livestock													
V.1	1	In-boundary emissions from land													
V.1	1	In-boundary emissions from other agriculture													

		Sub-total AFOLU													
VI		**Other indirect emissions**													
VI.1	3	Other indirect emissions													

(C) Summary table by scope

Reporting by scope	Total GHG emissions (tCO_2e)
Scope 1	
Scope 2	
Scope 3	

(D) Summary by reporting level and gas

Reporting level	Total GHG emissions (tCO_2e)	Gases (tCO2e)							
		CO_2	CH_4	N_2O	HFC	PFC	SF_6	NF_3	CO_2(b)
GPC Basic									
GPC Basic +									

Legend

Basic
Basic+
Scope 3
Information item

Part II: Calculation Methodology by Emission Source

5.0 Overview of Calculating GHG Emissions

This chapter provides overarching calculation guidance for sourcing activity data and emission factors and calculating GHG emissions consistent with the requirements set out in Chapters 6.0 – 10.0. The GPC specifies the principles and rules for compiling a city-level GHG emissions inventory; it does not require specific methodologies to be used to produce emissions data.

5.1 Calculation methodology

Emission calculation methodologies define the calculation formulas and necessary activity data and emission factors to determine total emissions from specified activities. Cities should select the most appropriate methodologies based on the purpose of inventory, availability of data, and consistency with their country's national inventory and/or other measurement and reporting programs in which they participate. Where different methodologies are used, cities should ensure they meet the requirements of the GPC and document the methodologies they have used in the inventory report.

IPCC Guidelines set out three hierarchical tiers to categorize the methodological complexity of emissions factors and activity data. Tier 1 uses default data and simple equations, while Tiers 2 and 3 are each more demanding in terms of complexity and data requirements. Tier 2 methodologies typically use country-specific emission factors. These tiers, if properly implemented, successively reduce uncertainty and increase accuracy. The GPC does not use tiers to define methodologies but makes references to them when referring to IPCC Guidelines.

For some activities, cities will be able to use direct measurements of GHG emissions (e.g., through use of continuous emissions monitoring systems at power stations). However, for most emission sources, cities will need to estimate GHG emissions by multiplying activity data by an emission factor associated with the activity being measured (see Equation 5.1).

Equation 5.1 Emission factor approach for calculating GHG emissions

$$GHG\ emissions = Activity\ data \times Emission\ factor$$

Activity data is a quantitative measure of a level of activity that results in GHG emissions taking place during a given period of time (e.g., volume of gas used, kilometers driven, tonnes of waste sent to landfill, etc.). An emission factor is a measure of the mass of GHG emissions relative to a unit of activity. For example, estimating CO_2 emissions from the use of electricity involves multiplying data on kilowatt-hours (kWh) of electricity used by the emission factor ($kgCO_2$/kWh) for electricity, which will depend on the technology and type of fuel used to generate the electricity.

5.2 Activity data

Data collection is an integral part of developing and updating a GHG inventory. This includes gathering existing data, generating new data, and adapting data for inventory use. Table 5.1 sets out the methodological principles of data collection that underpin good practice.

Table 5.1 Good practice data collection principles[12]

Good practice data collection principles
• **Establish collection processes** that lead to continuous improvement of the data sets used in the inventory (resource prioritization, planning, implementation, documentation etc.)
• **Prioritize improvements** on the collection of data needed to improve estimates of key categories which are the largest, have the greatest potential to change, or have the greatest uncertainty
• **Review data collection activities** and methodological needs on a regular basis, to guide progressive, and efficient, inventory improvement
• **Work with data suppliers** to support consistent and continuing information flows

5.2.1 Sourcing activity data

It is good practice to start data collection activities with an initial screening of available data sources. This will be an iterative process to improve the quality of data used and should be driven by two primary considerations:

- Data should be from reliable and robust sources
- Data should be time- and geographically-specific to the assessment boundary, and technology-specific to the activity being measured

Data can be gathered from a variety of sources, including government departments and statistics agencies, a country's national GHG inventory report, universities and research institutes, scientific and technical articles in environmental books, journals and reports, and sector experts/stakeholder organizations. In general, it is preferable to use local and national data over international data, and data from publically-available, peer-reviewed and reputable sources, often available through government publications.

The following information should be requested and recorded when sourcing data:

- Definition and description of the data set: time series, sector breakdown, units, assumptions, uncertainties and known gaps
- Frequency and timescales for data collection and publication
- Contact name and organization(s)

It may be necessary to generate new data if the required activity data does not exist or cannot be estimated from existing sources. This could involve physical measurement[13], sampling

[12] Adapted from *2006 IPCC Guidelines*, Chapter 2.
[13] For example, direct measurement of point source GHG emissions from an industrial or waste treatment facility.

activities, or surveys. Surveys may be the best option, given the tailored data needs of city-scale GHG inventories, although they can be relatively expensive and time-consuming without proper guidance.[14]

5.2.2 Adapting data for inventory use (scaling data)

Where the best available activity data do not align with the geographical boundary of the city or the time period of the assessment, the data can be adapted to meet the assessment boundary by adjusting for changes in activity using a scaling factor. The scaling factor is representative of the ratio between the available data and the required inventory data, and is chosen for its high degree of correlation to variations in the data. Adjusting national data to the city level based on the city's share of the country's population is one example where scaling is useful. This is particularly relevant where data for the inventory year, or city-specific data, are unavailable or incomplete.[15,16] The general formula for scaling data is:

Equation 5.2 Scaling methodology

$$Inventory\ data = \frac{Factor_{Inventory\ data}}{Factor_{Available\ data}} \times Available\ data$$

Available data	Activity (or emissions) data available which needs to be scaled to align with the assessment boundary
Inventory data	Activity (or emissions) data total for the city
$Factor_{Inventory}$	Scaling factor data point for the inventory
$Factor_{Available\ data}$	Scaling factor data point for the original data

Population is one of the most common factors used to scale data because, in the absence of major technological and behavioral changes, the number of people is a key driver of GHG emissions, particularly in the residential sector. For example, the following equation may be used for adjusting household waste data if data for the inventory year are not available:

$$City\ household\ waste\ data\ 2014 = \frac{City\ population_{2014}}{City\ Population_{2013}} \times City\ household\ waste\ data\ 2013$$

[14] Volume 1, Chapter 2: *Approaches to Data Collection*, *Annex 2A.2* of the 2006 IPCC Guidelines provides more general guidance on performing surveys. Specific guidance on conducting surveys in developing countries can be found in *United Nations, Household Sample Surveys in Developing and Transition Countries* (New York, 2005). Available at: unstats.un.org/unsd/HHsurveys/part1_new.htm

[15] For example: gaps in periodic data; recent data are not yet available; only regional or national data are available; data do not align with the geographical boundary of the city; or data are only available for part of the city or part of the year.

[16] The scaling factor methodology is also applicable to data collected using surveys upon a representative sample-set, and can be used to scale-up real data to represent activity of the entire community.

Other scaling factors, such as GDP or industry yield or turnover, may be more suitable to scale data for economic activities.

References are made throughout Chapters 6.0 – 10.0 on how to scale data from a national or regional level to the city for different emission sectors. Recommended scaling factors are also provided. If a different scaling factor from the one recommended is chosen, the relationship between the alternate scaling factor and activity data for the emissions source should be documented in the inventory report. In all cases the original data, scaling factor data points, and data sources should be documented.

It is good practice to use calendar year data whenever available in conformance with national inventory practices (see Section 3.2). However, if calendar year data are unavailable, then other types of annual year data (e.g., non-calendar fiscal year data, April – March) may be used provided the collection periods are used consistently over time (to avoid bias in the trend) and documented. These do not need to be adjusted.

Note, where energy use from a previous year is to be adjusted, variations in weather will also need to be considered. This is due to the high correlation between temperature and energy use to heat or cool buildings. This adjustment is made using a regression analysis of energy use from a previous year against a combination of heating degree-days (HDD) or cooling degree-days (CDD), as appropriate. The inventory-year CDD and HDD are then used to estimate weather-adjusted inventory-year energy use data.

5.3 Emission factors

Emission factors convert activity data into a mass of GHG emissions; for example tonnes of CO_2 released per kilometer travelled, or the ratio of CH_4 emissions produced to amount of waste landfilled. Emission factors should be relevant to the assessment boundary, specific to the activity being measured, and sourced from credible government, industry, or academic sources.

If no local, regional, or country-specific sources are available, one should use IPCC default factors or data from the Emission Factor Database (EFDB)[17], or other standard values from international bodies that reflect national circumstances.[18]

5.4 Conversion of data to standard units

The International System of Units (SI units) should be used for measurement and reporting of activity data, and all GHG emissions data shall be reported as metric tons of CO_2 equivalents (CO_2e). CO_2e is a universal unit of measurement that accounts for the global warming potential (GWP) when measuring and comparing GHG emissions from different gases. Individual GHGs should be converted into CO_2e by multiplying by the 100-year GWP coefficients in the IPCC Guidelines used by the country's national inventory body (see Table 5.2).

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[17] The EFDB is a continuously revised web-based information exchange forum for EFs and other parameters relevant for the estimation of emissions or removals of GHGs at national level. The database can be queried over the internet at www.ipcc-nggip.iges.or.jp/EFDB/main.php.

[18] Volume 1, Chapter 2: "Approaches to Data Collection", Section 2.2.4, Table 2.2 of the *2006 IPCC Guidelines* provides a comprehensive guide to identifying potential sources of emission factors.

Table 5.2 GWP of major GHG gases

Name	Formula	GWP values in IPCC Second Assessment Report[19] (CO_2e)	GWP values in IPCC Third Assessment Report[20] (CO_2e)	GWP values in IPCC Fourth Assessment Report[21] (CO_2e)	GWP values in IPCC Fifth Assessment Report[22] (CO_2e)
Carbon dioxide	CO_2	1	1	1	1
Methane	CH_4	21	23	25	28
Nitrous oxide	N_2O	310	296	298	265
Sulfur hexafluoride	SF_6	23,900	22,200	22,800	23,500
Carbon tetrafluoride	CF_4	6,500	5,700	7,390	6,630
Hexafluoroethane	C_2F_6	9,200	11,900	12,200	11,100
HFC-23	CHF_3	11,700	12,000	14,800	12,400
HFC-32	CH_2F_2	650	550	675	677
HFC-41	CH_3F	150	97	92	116
HFC-125	C_2HF_5	2,800	3,400	3,500	3,170
HFC-134	$C_2H_2F_4$	1,000	1,100	1,100	1,120
HFC-134a	CH_2FCF_3	1,300	1,300	14,300	1,300
HFC-143	$C_2H_3F_3$	300	330	353	328
HFC-143a	$C_2H_3F_3$	3,800	4,300	4,470	4,800
HFC-152a	$C_2H_4F_2$	140	120	124	138
HFC-227ea	C_3HF_7	2,900	3,500	3,220	3,350
HFC-236fa	$C_3H_2F_6$	6,300	9,400	9,810	8,060
HFC-245ca	$C_3H_3F_5$	560	950	1,030	716

All GHG emissions data should be reported as metric tons CO_2e of each individual GHG (see Section 3.3) and by total CO_2e. Where this is not possible (e.g., when the best available emission factors are expressed only in CO_2e and not listed separately by gas), an accompanying explanation should be provided.

5.5 Managing data quality and uncertainty

All data sources used and assumptions made when estimating GHG emissions, whether through scaling, extrapolation, or models, will need to be referenced to ensure full transparency. The

[19] IPCC. 1995, IPCC Second Assessment Report: Climate Change 1995
[20] IPCC. 2001, IPCC Third Assessment Report: Climate Change 2001
[21] IPCC. 2007, IPCC Fourth Assessment Report: Climate Change 2007
[22] IPCC. 2013, IPCC Fifth Assessment Report: Climate Change 2013

IPCC uses "tiers" to rank methodology, and increasing accuracy in methodology often requires more detailed or higher quality data. In this report, where relevant, references are provided within each emission source category chapter (Chapters 6.0 – 10.0) to the corresponding IPCC methodology tiers and methods. In addition to identifying the method used to calculate emissions, cities should also evaluate the quality of both the activity data and the emission factors used. Each of these shall be assessed as high, medium or low, based on the degree to which data reflect the geographical location of the activity, the time or age of the activity and any technologies used, the assessment boundary and emission source, and whether data have been obtained from reliable and verifiable sources.

Table 5.3 Data quality assessment

Data quality	Activity data	Emission factor
High (H)	Detailed activity data	Specific emission factors
Medium (M)	Modeled activity data using robust assumptions	More general emission factors
Low (L)	Highly-modeled or uncertain activity data	Default emission factors

5.6 Verification

Verification involves an assessment of the completeness and accuracy of reported data. Cities may choose to verify their data to demonstrate that their calculations are in accordance with the requirements of the GPC and provide confidence to users that the reported GHG emissions are a fair reflection of a city's activities. Verification can be performed by the same organization that conducted the GPC assessment (self-verification), or by an independent organization (third-party verification). Guidance on verification is provided in Chapter 12.0.

6.0 Stationary Energy

Stationary energy sources are one of the largest contributors to a city's GHG emissions. These emissions come from fuel combusted or released as fugitive emissions in the process of generating, delivering, and consuming useful forms of energy (such as electricity or heat).[23]

Requirements in this chapter:

For BASIC: Cities shall report all GHG emissions from stationary energy sources and fugitive emissions in scope 1, and from use of grid-supplied electricity, steam, heating, and cooling in scope 2.

For BASIC+: Cities shall report all BASIC sources and scope 3 GHG emissions associated with transmission and distribution (T&D) losses from trans-boundary electricity, steam, heating, and cooling.

Unless stated otherwise, calculation methodologies for stationary energy sources are consistent with the *Energy Sector (volume 2)* in the 2006 IPCC Guidelines for National Greenhouse Gas Emissions. IPCC sector category *1A3 Transport* is covered in Chapter 7.0.

6.1 Defining boundaries

Scope 1: Emissions from in-boundary emissions from fuel combustion and fugitive emissions

Scope 1 includes emissions from the combustion of fuels[24] in buildings, industries, and from the conversion of primary energy sources in refineries and power plants located within the city boundary. Fossil resource exploration and refinement, as well as an offshore exploration that occurs within the city boundary, shall also be included in scope 1.

The assessment boundary of certain cities may contain non-urban areas that include agricultural, forestry, and fishing activities. Emissions from stationary energy sources from these activities, such as portable generators, shall be reported as scope 1 emissions.

Scope 2: Emissions from the consumption of grid-supplied electricity, steam, heating and cooling

Electricity consumption is typically the largest source of scope 2 emissions. It occurs when buildings and facilities in the city consume electricity from regional or national electric grids. Grid-distributed steam, heat and cooling rely on smaller-scale distribution infrastructure, but may still cross city boundaries.

Scope 3: Other out-of-boundary emissions

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[23] 2006 *IPCC Guidelines for National Greenhouse Gas Inventories*.

[24] Non-energy uses of fossil fuel shall be assessed and reported under IPPU sector. To differentiate energy and non-energy use of fossil fuel, please see Chapter 9.

Scope 3 emissions include out-of-boundary emissions related to energy use in cities, specifically from transmission and distribution losses of electricity, steam, heating and cooling.

There may also be out-of-boundary energy use associated with activities occurring in the city (e.g., electricity used by a neighboring city to treat wastewater produced by the reporting city), but these are not required for reporting in this GPC BASIC or BASIC+. Methods on calculating out-of-boundary energy use may be explored in future value chain approaches.

Table 6.1 Stationary energy overview

GHG emission source	Scope 1	Scope 2	Scope 3
	Emissions from fuel combustion and fugitive emissions within the city boundary	Emissions from consumption of grid-supplied energy consumed within the city boundary	Transmission and distribution losses from grid-supplied energy
STATIONARY ENERGY			
Residential buildings	I.1.1	I.1.2	I.1.3
Commercial and institutional buildings and facilities	I.2.1	I.2.2	I.2.3
Manufacturing industries and construction	I.3.1	I.3.2	I.3.3
Energy industries	I.4.1	I.4.2	I.4.3
Grid-supplied energy production in-boundary	I.4.4		
Agriculture, forestry and fishing activities	I.5.1	I.5.2	I.5.3
Non-specified sources	I.6.1	I.6.2	I.6.3
Fugitive emissions from mining, processing, storage and transportation of coal	I.7.1		
Fugitive emissions from oil and natural gas systems	I.8.1		

6.2 Defining energy source sub-sectors

When identifying emission sources, it is important to reflect the characteristics of the built environment and to ensure consistency with national GHG inventories. Buildings, industries, and construction are key stationary energy sources in most cities. Table 6.2 below provides detailed descriptions of stationary energy source sub-sectors. Reporting by sub-sector allows for more thorough understanding of where emissions occur and what kinds of mitigation plans might best target those sub-sectors. Cities may adopt additional city- or country-specific categories where data allows, but should clearly describe the differences and assumptions in inventory reports.

Table 6.2 Definitions of stationary energy source sub-sectors

Sub-sectors	Definition
Emissions from stationary energy production and use	Emissions from the intentional oxidation of materials within a stationary apparatus that is designed to raise heat and provide it either as heat or as mechanical work to a process or for use away from the apparatus
I.1 Residential buildings	All emissions from energy production and use in households
I.2 Commercial buildings and facilities	All emissions from energy production and use in commercial buildings and facilities
I.2 Institutional buildings and facilities	All emissions from energy production and use in schools, hospitals, government offices, and other public facilities
I.3 Manufacturing industries and construction	All emissions from energy production and use in industrial facilities and construction activities, except those included in energy industries sub-sector. This also includes combustion for the generation of electricity and heat for own use in these industries.

I.4 Energy industries	All emissions from the generation of energy for grid-distributed electricity, steam, heat and cooling or by fuel extraction industries
I.5 Agriculture, forestry, and fishing activities	Energy use in agriculture, forestry, fishing and fishing activities
I.6 Non-specified sources	All remaining emissions from energy production and use that are not specified elsewhere
Fugitive emissions from fuel	Includes all intentional and unintentional emissions from the extraction, processing, storage and transport of fuel to the point of final use ** Some product uses may also give rise to emissions termed as "fugitive," such as the release of refrigerants and fire suppressants. These shall be reported in IPPU.*
I.7 Mining, processing, storage, and transportation of coal	Includes all intentional and unintentional emissions from the extraction, processing, storage and transport of fuel in-boundary
I.8 Oil and natural gas systems	In-boundary fugitive emissions from all oil and natural gas activities. The primary sources of these emissions may include fugitive equipment leaks, evaporation losses, venting, flaring and accidental releases.

Cities may further subdivide these sub-sectors into sub-categories that are more useful for mitigation action planning.

6.3 Emissions from stationary fuel combustion

Stationary fuel combustion can occur within the sub-sectors outlined in Table 6.2. Emissions of each GHG from stationary energy sources are calculated by multiplying fuel consumption (activity data) by the corresponding emission factors (such as IPCC default emission factors and country-specific emission factors). Cities should aim to obtain:

- *Real consumption data for each fuel type, disaggregated by sub-sector.* This information is typically monitored at the point of fuel use or fuel sale, and should ideally be obtained from utility or fuel providers. Consumption data should be disaggregated by sub-sector or building type.

- *A representative sample set of real consumption data from surveys.* While surveying for fuel consumption for each sub-sector or building type, determine the built space (i.e., square meters of office space and other building characters) of the surveyed buildings for scaling factor.

- *Modeled energy consumption data.* Determine energy intensity, by building and/or facility type, expressed as energy used per square meter (e.g., GJ/m^2/year) or per unit of output. For energy intensity figures from previous years, adjust for inventory-year consumption data by using weather.[25]

[25] Using energy intensity figures may only provide for aggregate energy-related activity (direct fuel combustion + electricity consumption). This aggregate activity can be disaggregated if real electricity consumption data are available (see energy-related indirect emissions below), by subtracting total electricity consumption from total modeled energy usage data derived here, using standard units (e.g., MMBTU or GJ).

- *Incomplete or aggregate real consumption data*:
    - Where fuel consumption data by sub-sector are unavailable, but data are available for total emissions from stationary sources within the community, apportion by total built space for each sub-sector or building type.
    - Where data are only available for a few of the total number of fuel suppliers, determine the population served by real data to scale-up the partial data for total city-wide energy consumption. Alternatively, use built space to scale-up.
    - Where data are only available for one building type, determine a stationary combustion energy intensity figure by using built space of that building type, and use as a scaling factor with built space for the other building types.
- *Regional or national fuel consumption data* (scaled down using population). Adjust data from previous years to the inventory-analysis year, controlling for changes in weather.

6.3.1 Residential, commercial, and institutional buildings and facilities

While the GPC recommends that cities report building emissions in three building sub-sectors, cities may further subdivide these into more detailed sub-categories. For example, residential buildings can be divided into high-rise buildings and landed buildings; commercial buildings may be divided into different sizes and/or types of activities such as retail, office, etc.; and institutional buildings may be divided into different uses, including schools, hospitals, and government offices. Cities may also further divide the emissions into different energy usages such as cooking, heating, and hot water in residential buildings. Detailed, disaggregated data helps cities identify emissions hotspots more precisely and design more specific mitigation actions.

Commercial and institutional facilities provide public services for community needs, including safety, security, communications, recreation, sport, education, health, public administration, religious, cultural and social[26]. These facilities include, but are not limited to, highways, secondary roads and pedestrian areas; parking, mass transit, docks, navigation aids, fire and police protection, water supply, waste collection and treatment (including drainage), and public recreation areas. GHG emissions generated as a result of energy uses within such facilities shall be reported under I.2.2[27]. Typical examples include electricity consumption for street lighting and public fountains, and energy consumption for waste/wastewater treatment.

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[26] *Guidelines for human Settlement Planning and Design.* Chapter 5.5. The Council for Scientific and Industrial Research (CSIR), 2000. Online at www.csir.co.za/Built_environment/RedBook/

[27] Even though electricity generation sites are treated as public facilities in many cities, in this standard all emissions from the electricity generation sites are reported under I.4 Energy industries.

A city may identify multiple functional uses for buildings, which complicates sub-sector classification. In these cases, cities can either subdivide mixed use buildings based on square meters of a building (and 'subdivide' the activity data and resulting emissions), categorize buildings according to their designated usages, or categorize the entire building under one of the sub-categories and provide justification. Possible scenarios include:

- *Mixed use buildings*
  Some buildings may include residential units, ground floor commercial space, and offices. In the absence of floor-by-floor information and activity data, a GHG inventory team may conduct a specific survey to identify such information. In some countries, energy tariffs and billing are different for residential and commercial purposes, so the energy use activity data may be more easily identified.

- *Office buildings in industrial establishments*
  Cities may have one or more office buildings attached to an industrial complex. When industry is the main activity at the site and the property is designated for industrial use, the attached office building should be categorized as part of the industrial complex and emissions reported under the *manufacturing industries and construction* sub-sector or *energy industries* sub-sector as appropriate. Where countries or regions have specific regulations defining these office buildings as commercial buildings, cities should apply the *relevance* principle and allocate emissions to the locally appropriate sub-sector.

- *Workers quarters in industrial establishments*
  In instances where there are permanent workers quarters within the compounds of an industrial site, cities should categorize emissions from buildings based on their designated usages. Whenever possible, cities should report the GHG emissions from these workers quarters in the *residential buildings* sub-sector.

  Similar to the principles outlined in the *mixed use buildings* section above, cities should conduct a survey to identify these workers quarters and count their associated GHG emissions in the *residential buildings* sub-sector. In the absence of such data, cities may report all these emissions as part of the emissions from the industrial site.

  In the case of temporary workers quarters, such as those at construction sites, if cities find it difficult to obtain specific energy consumption information, cities may keep them reported in the associated industrial or construction activities.

  The GPC does not provide specific definitions for *permanent* and *temporary* workers quarters. Cities should adopt the definitions used in their local regulations. In general, workers quarters for construction activities should be considered as *temporary,* considering that the nature of construction activity itself is temporary. If workers quarters in an industrial site are built and demolished within a period shorter than a GHG inventory cycle, it should be considered *temporary* (see Table 6.3 for suggested definitions).

Table 6.3 Definitions of temporary and permanent workers quarters

Type of premises	Temporary	Permanent
Industries	Quarters built and demolished within a period of shorter than 12 months (an inventory cycle)	Quarters that exist for more than 12 months
Construction	All workers quarters for construction activities should be considered temporary	Not applicable unless specified otherwise in local regulations

- *Residential units in agricultural farms*
  When the jurisdictions of cities cover rural areas, there may be individual residential units in the agricultural farms. GHG emissions from household activities such as heating and cooking in these individual units should be included in *residential buildings*. However, emissions from activities related to agricultural activities such as portable generators for lighting of livestock farms and water pumps in aquaculture farms should be categorized as *Agriculture, forestry, and fishing activities*. If only total consumption for the farm area is available, cities can sub-divide this based on average household energy use or average farm equipment usage.

6.3.2 Manufacturing industries and construction

This sub-sector includes fuel consumption in manufacturing industries and construction activities. Fuel combustion occurs in stationary equipment such as boilers, furnaces, burners, turbines, heaters, incinerators, engines, flares, etc. Where data are available, GHG emissions from relevant sub-categories should be reported using the 13 sub-categories identified in the 2006 IPCC Guidelines under the *manufacturing industries and construction* sub-sectors (see Table 6.4). Cities should apply these sub-categories to ensure consistency with national GHG inventories, as appropriate.

Table 6.4 Detailed sub-categories of manufacturing industries and construction sub-sector[28]

Sub-categories[29]	**ISIC Classification**	**Description**
Iron and steel	ISIC Group 271 and Class 2731	Manufacture of primary iron and steel products, including the operation of blast furnaces, steel converters, rolling and finishing mills, and casting
Non-ferrous metals	ISIC Group 272 and Class 2732	Production, smelting, and refinement of precious metals and other non-ferrous metals from ore or scrap
Chemicals	ISIC Division 24	The manufacture of basic chemicals, fertilizer and nitrogen compounds, plastics, synthetic rubber, agro-chemical products, paints and coatings, pharmaceuticals, cleaning agents, synthetic fibers, and other chemical products
Pulp, paper and print	ISIC Divisions 21 and 22	Pulp, paper, paperboard, paper products; publishing and reproduction of recorded media

[28] Further descriptions of each subcategory can be found in the *International Standard Industrial Classification (ISIC) of All Economic Activities*, Revision 3.
[29] 2006 *IPCC Guidelines for National Greenhouse Gas Inventories*

Food processing, beverages, and tobacco	ISIC Divisions 15 and 16	Production, processing, and preservation of food and food products, beverages, and tobacco products
Non-metallic minerals	ISIC Division 26	Manufacture and production of glass and glass products, ceramics, cements, plasters, and stone
Transport equipment	ISIC Divisions 34 and 35	Motor vehicles, trailers, accessories and components, sea vessels, railway vehicles, aircraft and spacecraft, and cycles
Machinery	ISIC Divisions 28, 29, 30, 31, 32	Fabricated metal products, machinery and equipment, electrical machinery and apparatuses, communications equipment, and associated goods
Mining (excluding fuels) and quarrying	ISIC Divisions 13 and 14	Mining of iron, non-ferrous ores, salt, and other minerals; quarrying of stone, sand, and clay
Wood and wood products	ISIC Division 20	Sawmilling and planning of wood; the production of wood products and cork, straw, and other wood-based materials
Construction	ISIC Division 45	Site preparation, construction installation, building completion, and construction equipment
Textile and leather	ISIC Division 17, 18, 19	Spinning, weaving, dyeing, of textiles and manufacture of apparel, tanning and manufacture of leather and footwear
Non-specific industries	Activities not included above	Any manufacturing industry/construction not included above, including water collection, treatment, supply; wastewater treatment and disposal; and waste collection, treatment, and disposal

Industrial facilities may incur emissions that are included in other sectors of the GPC, including:

- *Relationship between manufacture of transport equipment and transportation sector*
  Cities should not double count emissions from transport equipment manufacturing and the *transportation* sector (Chapter 7.0). Transport equipment manufacturing refers to GHG emissions from the manufacture of motor vehicles, ships, boats, railway and tramway locomotives, and aircraft and spacecraft, while the *transportation* sector refers to the GHG emissions from the use of these vehicles.

- *Relationship between on- and off-road transportation*
  GHG emissions from all on-road transportation activities by industries that occur outside the industrial site – e.g., delivery of raw materials, products, and services and employee travels – shall be reported under the *transportation* sector (Chapter 7.0).

  Off-road transportation activities should be categorized according to the area where they occur. For instance, the GHG emissions of off-road transportation activities (vehicle and mobile machinery) occurring within industrial premises should be reported under either the *manufacturing industries and construction* sub-sector, or *energy industries* sub-sector. Table 6.5 provides an overview of reporting guidance for off-road transportation related to the *manufacturing industries and construction* sub-sector, *energy industries* sub-sector, *agriculture, forestry, and fishing activities* sub-sector, *non-specified* sub-sector, and *off-road transportation* sub-sector (under *transportation* sector).

Table 6.5 Overview of reporting guidance for off-road transportation activities

Type of off-road activities	Reporting guidance
Off-road vehicle and mobile machinery within industrial premises and construction sites	Report as a stationary energy source under *manufacturing industries and construction* sub-sector or *energy industries* sub-sector as appropriate
Off-road vehicle and mobile machinery within agriculture farms, forests, and aquaculture farms	Report as a stationary energy source under *agriculture, forestry, and fishing activities* sub-sector
Off-road vehicle and mobile machinery within the transportation facility premises such as airports, harbors, bus terminals, and train stations	Report as a mobile (transportation) source under *off-road transportation* sub-sector
Off-road vehicle and mobile machinery within military premises	Report as a stationary energy source under *unidentified activities* sub-sector.

- *Water supply system, solid waste, and wastewater treatment and disposal facilities*
  Most cities operate solid waste and wastewater treatment and disposal facilities. These facilities produce methane (CH_4) from decay of solid wastes and anaerobic degradation of wastewater, which shall be reported under *waste* sector. But water collection, treatment, and supply systems consume either primary or secondary energy to power water pumps, water treatment facilities, and other equipment. GHG emissions from the fuel combustion for these operations should be reported under *institutional* (if owned by the city) or *industrial* (if owned by a private company) sub-sectors (see section 6.2 on scope 2 emissions from grid-distributed energy).

  This also applies to direct fuel combustion for operating off-road vehicles, machinery, and buildings within the waste facility. Among the typical off-road machinery are the compactors and bulldozers spreading and compacting the solid waste on the working surface of landfills. However, off-road vehicles and machinery do not include on-road transportation of wastes, which shall be reported under *transportation* sector (Chapter 7.0).

6.3.3 Energy industries

Energy industries include three basic types of activities[30]:

- Primary fuel production (e.g., coal mining and oil and gas extraction)
- Conversion to secondary and tertiary fossil fuels (e.g., crude oil to petroleum products in refineries, coal to coke and coke oven gas in coke ovens)
- Energy production, typically distributed to a grid (e.g., electricity generation and district heating) or used on-site for auxiliary energy use.

Where possible, cities should follow 2006 IPCC Guidelines and disaggregate accounting and reporting of *energy industries* sub-sector into different sub-categories as detailed in Table 6.6.

[30] 2006 IPCC Guidelines for National Greenhouse Gas Inventories

Table 6.6 Detailed sub-categories of energy industries sub-sector[31]

Sub-categories	Descriptions	Detailed breakdown
Electricity and heat production	Emissions from main activity producers of electricity generation, combined heat and power generation, and heat plants. Main activity producers (formerly known as public utilities) are defined as those whose primary activity is to supply energy to the public, but the organization may be under public or private ownership. Emissions from on-site use of fuel should be included. Emissions from auto-producers (which generate electricity/heat wholly or partly for their own use, as an activity that supports their primary activity) should be assigned to the sector where they were generated. Auto-producers may be under public or private ownership.	*Electricity generation sold and distributed* comprises emissions from all fuel use for electricity generation from main activity producers except those from combined heat and power plants (see *CHP* below). This includes emissions from the incineration of waste or waste byproducts for the purpose of generating electricity.
		Auxiliary energy use on the site of energy production facilities (e.g., a small administrative office). Energy produced at power plants is used "on-site" for auxiliary operations before being sold and distributed to a grid. Therefore, auxiliary energy use and sold/distributed energy should together add up to total emissions from fuel combusted for energy generation.
		Combined heat and power generation (CHP) Emissions from production of both heat and electrical power from main activity producers for sale to the public, at a single CHP facility
		Heat plants Production of heat for city-wide district heating or industrial usage. Distributed by pipe network
Petroleum refining	All combustion activities supporting the refining of petroleum products including on-site combustion for the generation of electricity and heat for own use	
Manufacture of solid fuels and other energy industries	Combustion emissions from fuel use during the manufacture of secondary and tertiary products from solid fuels including production of charcoal. Emissions from own on-site fuel use should be included. Also includes combustion for the generation of electricity and heat for own use in these industries.	*Manufacture of solid fuels* Emissions arising from fuel combustion for the production of coke, brown coal briquettes and patent fuel
		Other energy industries Combustion emissions arising from the energy-producing industries own (on-site) energy use not mentioned above or for which separate data are not available. This includes the emissions from on-site energy use for the production of charcoal, bagasse, saw dust, cotton stalks and carbonizing of biofuels as well as fuel used for coal mining, oil and gas

[31] 2006 IPCC Guidelines for National Greenhouse Gas Inventories

		extraction and the processing and upgrading of natural gas. This category also includes emissions from pre-combustion processing for CO2 capture and storage.

- *Cogeneration and tri-generation*
  Cogeneration, or combined heat and power (CHP), is the use of power plant or heat engine systems to simultaneously generate electricity and useful heat. Tri-generation, or combined cooling, heat and power (CCHP), refers to the simultaneous generation of electricity, heat, and cooling. GHG emissions from these facilities should be calculated based on the quantity of fuel combusted. With the exception of added transparency, emissions from this combustion should be allocated across the heating/steam and electricity outputs when reporting by detailed sub-category.[32] This allocation can be performed using the percentage of each energy output (% of total MMBUT or GJ from electricity and from heat).

- *Waste-to-energy and bioenergy*
  Where waste is used to generate energy, emissions are counted as *stationary energy sources.* This includes energy recovered from landfill gas or waste combustion. When a power plant is generating electricity from biomass fuels, the resulting CH_4 and N_2O emissions shall be reported under scope 1 in *energy industries* sub-sector while biogenic CO_2 shall be reported separately from the scopes (CO_2 emissions are effectively "reported" in AFOLU, as the biofuel usage was linked by corresponding land use change). If waste decomposition or treatment is not used for energy generation, emissions are reported under scope in the *waste* sector (see Chapter 8.0).

Table 6.7 provides an overview of principles to help avoid double counting between waste, energy, and AFOLU sectors.

Table 6.7 An overview of reporting categorization for waste-to-energy and bioenergy emissions

Activity	Purpose	Gas	
		CO_2	CH4 and N_2O
Landfill gas combustion	As part of waste disposal process	Report as information item under *waste* sector	Report as *waste* sector emissions
	Energy generation	Report as information item under *stationary energy sources* sector	Report as *stationary energy sources* sector emissions
Waste incineration	Waste disposal (no energy recovery)	Report emissions from fossil origin waste as *waste* sector emissions Report emissions from biomass waste as	Report as *waste* sector emissions

[32] Different methods may be used to perform this allocation, see GHG Protocol methodology www.ghgprotocol.org/files/ghgp/tools/CHP_guidance_v1.0.pdf

		information item under *waste* sector	
	Energy generation	Report emissions from fossil origin waste as *stationary energy sources* sector emissions Report emissions from biomass waste as information item under *stationary energy sources* sector	Report *stationary energy sources* sector emissions
Biomass incineration	Waste disposal	Report as information item under *waste* sector	Report as *waste* sector emissions
	Energy generation	Report as information item under *stationary energy sources* sector	Report as *stationary energy sources* sector emissions

6.3.4 Agriculture, forestry, and fishing activities

This sub-sector covers GHG emissions from direct fuel combustion in agricultural activities, including plant and animal cultivation, afforestation and reforestation activities, and fishery activities (e.g., fishing and aquaculture). The emissions are typically from the operation of farm vehicles and machinery, generators to power lights, pumps, heaters, coolers, and others. In order to avoid double counting with other sectors and sub-sectors, Table 6.8 provides reporting guidance for typical emissions sources in agriculture, forestry, and fishing activities.

Table 6.8 Reporting guidance for energy sources in agriculture, forestry, and fishing activities

Sources of emission	Reporting guidance
Off-road vehicles and machinery (stationary and mobile) used for agriculture, forestry, and fishing activities	Report as a stationary energy source under *agriculture, forestry, and fishing activities* sub-sector
On-road transportation to and from the locations of agriculture, forestry, and fishing activities	Report under *transportation* sector
Burning of agricultural residues	Report under *AFOLU* sector
Enteric fermentation and manure management	Report under *AFOLU* sector

6.3.5 Non-specified sources

This subcategory includes all remaining emissions from stationary energy sources that are not specified elsewhere, including emissions from direct fuel combustion for stationary units in military establishments.

6.4 Guidance for calculating fugitive emissions from fuels

A small portion of emissions from the energy sector frequently arises as fugitive emissions, which typically occur during extraction, transformation, and transportation of primary fossil fuels. Where applicable, cities should account for fugitive emissions from the following sub-sectors: 1) *mining, processing, storage, and transportation of coal*; and 2) *oil and natural gas systems*.

6.4.1 Mining, processing, storage, and transportation of coal

The geological processes of coal formation produce CH_4 and CO_4, collectively known as seam gas. It is trapped in the coal seam until the coal is exposed and broken during mining or post-mining operations, which can include handling, processing, and transportation of coal, low temperature oxidation of coal, and uncontrolled combustion of coal. At these points, the emitted gases are termed fugitive emissions. When accounting for and reporting fugitive emissions from coal mines, cities should categorize the emissions as mining and post-mining (handling) emissions for both *underground mines* and *surface mines*.

- *Methane recovery and utilization*
  Fugitive methane emissions may be recovered for direct utilization as a natural gas resource or by flaring to produce CO_2 that has a lower global warming potential.
    - When recovered methane is utilized as an energy source, the associated emissions should be accounted for under Stationary Energy.
    - When it is fed into a gas distribution system and used as a natural gas, the associated fugitive emissions should be reported under *oil and natural gas systems* sub-sector.
    - When it is flared, the associated emissions should be reported under *mining, processing, storage, and transportation of coal* sub-sector.

- *Time period of inventory*
  All fugitive emissions should be accounted for based on the emissions and recovery operations that occur during the assessment period of the inventory, regardless of when the coal seam is mined through.

Cities can determine coal production at surface and underground mines within the city boundary by inquiring with mining companies, mine owners, or coal mining regulators. Cities should separate data by average overburden depth for surface mines and average mining depth for underground mines, then apply emission factors per unit of production for mining and post-mining fugitive emissions.[33]

6.4.2 Oil and natural gas systems

Fugitive emissions from oil and natural gas systems include GHG emissions from all operations to produce, collect, process or refine, and deliver natural gas and petroleum products to market. Specific sources include, but are not limited to, equipment leaks, evaporation and flashing losses, venting, flaring, incineration, and accidental releases. Cities should also include emissions from all offshore operations that fall within the assessment boundaries.

The following emissions are *<u>not</u>* included in this category:

- Fugitive emissions from carbon capture and storage projects.
- Fugitive emissions that occur at industrial facilities other than oil and gas facilities, or that are associated with the end use of oil and gas products at anything other than oil and gas facilities, which are reported under *IPPU* sector.
- Fugitive emissions from waste disposal activities that occur outside of the oil and gas industry, which are reported under *waste* sector.

[33] IPCC default values can be found in the *2006 IPCC Guidelines*, Volume 2, Chapter 4 Fugitive Emissions. Available at: www.ipcc-nggip.iges.or.jp/public/2006gl/vol2

6.5 Calculation guidance for scope 2 emissions

Scope 2 emissions shall be reported for all grid-supplied electricity, steam, heating and cooling consumed within the city boundary. Depending on the sources of energy generation, emissions associated with the use of grid-supplied energy can represent a significant source of city-level GHG emissions. Grid-supplied energy in the form of direct steam (heating) and/or chilled water (cooling) are typically provided by district energy systems.

Unlike stationary fuel combustion, which generates GHG emissions directly at the point of energy consumption, emissions associated with the use of grid-supplied energy are produced at generation units off-site from the consuming facilities. For this reason, emissions from a city's consumption of grid-supplied energy are reported as an energy-related indirect source of emissions (scope 2), regardless of where the generation occurs.

If cities have energy generation facilities (such as coal-fired power plants) located inside the city boundary, this energy production contributes to the grid supply and emission factor that is reported in scope 2 (for energy consumed by the city). While some cities may try to determine their "net" consumption based on the assumption that all energy produced within the city boundary is also used within the city boundary *(total consumption – total production = net consumption),* this may not be an accurate reflection of regional grid distribution and demand response. Therefore, to avoid double counting when reporting emissions for BASIC or BASIC+ levels, scope 1 emissions from energy production and sales shall not be included, while scope 2 emissions are included. This reflects a greater focus on city consumption rather than production patterns. However, all emissions shall be included when reporting total emissions by scope.

6.5.1 Grid-supplied electricity

Electricity is the most common form of grid-supplied energy, used in almost all homes, offices, other buildings, and outdoor lighting.

Preferred activity data for electricity calculation includes:

- *Real consumption data from utility providers, disaggregated by building type or non-building facility:*
    - Where consumption data by building type is unavailable, but total community energy consumption data for buildings are available by energy type, apportion by total built space for each building type.
    - Where data are only available for a few of the total number of energy utilities, determine the population served by real data to scale-up for total city-wide energy consumption. Alternately use built space as the scaling factor.
    - Where data are only available for one building type, determine an energy end-use intensity figure by using built space of that building type, and use as a scaling factor with total built space for the other building types.
- *Representative sample sets of real consumption data from surveys* scaled up for total city-wide fuel consumption and based on the total built space for each building type.

- *Modeled energy consumption data* by building and/or facility type, adjusted for inventory-year consumption data by weather.

- *Regional or national consumption data* scaled down using population, adjusted for inventory-year consumption data by weather.

Because this approach examines grid-supplied energy from a consumption perspective, communities are encouraged to develop local energy emissions coefficients (emission factors for each unit of electricity). This requires an understanding of where the community receives its grid-supplied energy. However, any energy purchases or utility procurement programs (such as green power programs) in which individual city residents or commercial consumers participate shall not be reported at the level of a city inventory. Instead, the city inventory uses a *location-based approach* to scope 2, based on grid-average emission factors.[34]

Emissions data should be disaggregated by the same sub-sectors listed in Table 6.1.

6.5.2 Grid-supplied steam, heating and cooling

Many cities consume energy through district steam, heating and/or cooling systems. If the system crosses the city boundary and the district heating plant is located *outside* the assessment boundary, GHG emissions from the production of the portion of electricity/heat/cooling consumed in the reporting city should be counted as scope 2 emissions (see Section 6.3.3 on allocating and reporting emissions).

6.6 Calculation guidance for transmission and distribution losses

During the transmission and distribution of electricity, steam, heating and cooling on a grid, some of the energy produced at the power station is lost during delivery to end consumers (due to inefficiencies or technology). Emissions associated with these transmission and distribution losses are reported in scope 3 as part of out-of-boundary emissions associated with city activities. Calculating scope 3 requires a grid loss factor[35] provided by local utility or government publications. Multiplying total consumption (activity data for scope 2) by the loss factor yields the activity data for transmission and distribution (T&D) losses. This figure is then multiplied by the grid average emissions factors.

[34] See GHG Protocol *Scope 2 Guidance* for more on this method compared with a market-based method.
[35] Transmission and distribution losses vary by location, see the World Bank World Development Indicators (WDI) for an indication of national transmission and distribution losses as a percent of output, see: http://data.worldbank.org/indicator/EG.ELC.LOSS.ZS

7.0 Transportation

City transportation systems are designed to move people and goods within and beyond city borders. Transport vehicles and mobile equipment or machinery produce GHG emissions directly by combusting fuel or indirectly by consuming grid-delivered electricity.

Requirements in this chapter:

For BASIC: Cities shall report all GHG emissions from transportation occurring within the city boundary in scope 1 and scope 2.

For BASIC+: Cities shall also report all GHG emissions from transboundary transportation in scope 3.

7.1 Defining boundaries

City transit via road, rail, water or air can either be wholly contained within the city boundary (e.g., a city-only bus route) or, more often, will cross city boundaries into neighboring communities. There are typically four types of transboundary trips:

1. Trips that originate in the city and terminate outside the city
2. Trips that originate outside the city and terminate in the city
3. Regional transit (typically busses) with an intermediate stop (or multiple stops) within the city
4. Trips that pass through the city, with both origin and destination outside the city

Unlike stationary emission sectors, transit by definition is mobile and can pose challenges in both accurately calculating emissions and allocating them to the cities linked to the transit activity. Depending on the objectives of the inventory and available data, different methods can be used to quantify and allocate transit emissions. For instance, a transportation sector GHG inventory can be a vital metric that shows the impact of transportation policies and mitigation projects over time. While cities have varying levels of control or influence over more regional transportation policies and infrastructure decisions that affect the transit routes of their city, a transportation inventory should inform and support actions that can influence emission reductions.

The methods most commonly used for transportation modeling and planning vary in terms of their "system boundaries," or how the resulting data can be attributable to a city's geographic boundary and thus the GPC scopes framework. The GPC does not require a specific calculation method for each transport mode, and therefore the emissions reported in each scope will likely vary by method.

Overall, the city transportation sector inventory should reflect the following scopes reporting:

Scope 1: Emissions from in-boundary transport
Scope 1 includes all GHG emissions from travel the transport of people and freight occurring within the city boundary.

Scope 2: Emissions from grid-supplied electricity for transport

Scope 2 includes all GHG emissions from the generation of grid-supplied electricity used for electric-powered mobile units. The amount of electricity used should be assessed at the point of consumption within the city boundary.

Scope 3: Emissions from transboundary journeys occurring outside the city boundary, and transmission and distribution losses from grid-supplied energy

This includes a portion of all out-of-boundary GHG emissions from trips that either originate or terminate within the city boundaries. The portion of these transboundary emissions that occur within the city boundary should be recorded in scope 1, while the portion that occurs outside the city boundary should be included in scope 3. This may include on-road transit that burns fuel, or out-of-boundary stops for an electric railway.

The mobile source emissions from large regional transit hubs (e.g., airports or seaports) serving the city, but outside of the geographic boundary, should be counted in scope 3. These emissions are driven by activities within the city and should be included to provide a more holistic view of the city's transportation sector.

Table 7.1 Transportation overview

GHG emission source	Scope 1	Scope 2	Scope 3
	Emissions from fuel combustion for in-boundary transportation	Emissions from consumption of grid-supplied energy for in-boundary transportation	Emissions from transboundary journeys occurring outside the city boundary, and transmission and distribution losses from grid-supplied energy
TRANSPORTATION			
On-road transportation	II.1.1	II.1.2	II.1.3
Railways	II.2.1	II.2.2	II.2.3
Water transport	II.31	II.3.2	II.3.3
Aviation	II.4.1	II.4.2	II.4.3
Off-road transportation	II.5.1	II.5.2	

7.2 Defining transit modes

The GPC categorizes emission sources in the transportation sector by transit mode, including:

- On-road transportation
- Railway
- Water transport
- Aviation
- Off-road transportation

Table 7.2 identifies sub-categories within each transit mode, and demonstrates emissions sources for each. Cities should report emissions by these sub-categories within each mode if data is available.

Table 7.2 Scope 1, 2 and 3 emission sources in transport sector

Road			

Taxi	√	√	√
Bus	√	√	√
Private car (fuel powered)	√		√
Hybrid car	√	√	
Electric car		√	
Truck	√		√
Motorcycle	√	√	√
Railway			
Tram		√	√
Urban train/subway systems	√	√	
Regional (inter-city) commuter rail transport	√	√	√
National rail systems	√	√	√
International rail systems	√	√	√
Water transport			
Sightseeing ferries	√		
Domestic inter-city		√	√
International water transport		√	√
Civil aviation			
Helicopter	√		
Domestic inter-city flights		√	√
International flights		√	√
Off-road			
Airport ground support equipment	√	√	
Agricultural tractors	√	√	
Chain saws	√	√	
Forklifts	√	√	
Snowmobiles	√	√	

7.3 Calculation guidance for on-road transportation

On-road vehicles are designed for transporting people, property or material on common or public roads, thoroughfares, or highways. This category includes vehicles such as buses, cars, trucks, and motorcycles identified in Table 7.2. Most vehicles burn liquid or gaseous fuel in internal combustion engines. The combustion of these fuels produces CO_2, CH_4, and N_2O, often referred to collectively as tailpipe emissions. Increasingly, electric or hybrid vehicles can also be charged at stations within or outside the city. The methodology chosen for calculating on-road transportation emissions from fuel combustion will impact how scope 1 and 3 emissions are allocated for transboundary journeys. Scope 2 emissions should be calculated based on consumption at charging stations in the city boundary, regardless of the trip destination.

Methodology

The GPC does not prescribe a specific method for calculating on-road emissions due to variations in data availability, existing transportation models, and inventory purposes. However, cities should calculate and report emissions based on one of four common methods[36] identified in Figure 7.3 and described in Table 7.3. The GPC recommends cities use the *induced activity* approach, as it provides results more suited to local policy making.

The methodologies for estimating transport emissions can be broadly categorized as top-down and bottom-up approaches.

- *Top-down* approaches start with fuel consumption as a proxy for travel behavior. Here, emissions are the result of total fuel sold multiplied by a GHG emission factor for each fuel.
- *Bottom-up* approaches begin with detailed activity data. Bottom-up approaches generally rely on an ASIF Framework for determining total emissions (see Figure 7.1).

The ASIF framework relates travel activity, the mode share, energy intensity of each mode, fuel, and vehicle type, and carbon content of each fuel to total emissions. The amount of **Activity (A)** is often measured as VKT (vehicle kilometers traveled), which reflects the number and length of trips. **Mode share (S)** describes the portion of trips taken by different modes (e.g., walking, biking, public transport, private car) and vehicle types (e.g., motorcycle, car, bus, truck). Energy **Intensity (I)** by mode, often simplified as energy consumed per vehicle kilometer, is a function of vehicle types, characteristics (e.g., the occupancy or load factor, represented as passengers per km or tonnes cargo per km) and driving conditions (e.g., often shown in drive cycles, a series of data points showing the vehicle speed over time). Carbon content of the fuel, or **Fuel** factor **(F)**, is primarily based on the composition of the local fuel stock.[37, 38]

Most cities start with top-down approaches and progress towards more detailed bottom-up methodologies that enable more effective emissions mitigation assessments and transportation planning. A robust inventory can use data under each approach to validate results and improve reliability. Figure 7.3 illustrates what type of transport activity is reflected in each method. Table 7.4 further shows how to allocate these activity emissions in scope 1, 2 and 3.

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[36] GIZ (2012) *Balancing Transport Greenhouse Gas Emissions in Cities – A Review of Practices in Germany*
[37] Cooper, E., Jiang X., Fong W. K., Schmied M., and GIZ. *Scoping Study on Developing a Preferred Methodology and Tool to Estimate Citywide Transport Greenhouse Gas Emissions,* unpublished, 2013
[38] Schipper, L., Fabian, H., & Leather, J. *Transport and Carbon Dioxide Emissions: Forecasts, Options Analysis, and Evaluation*. 2009.

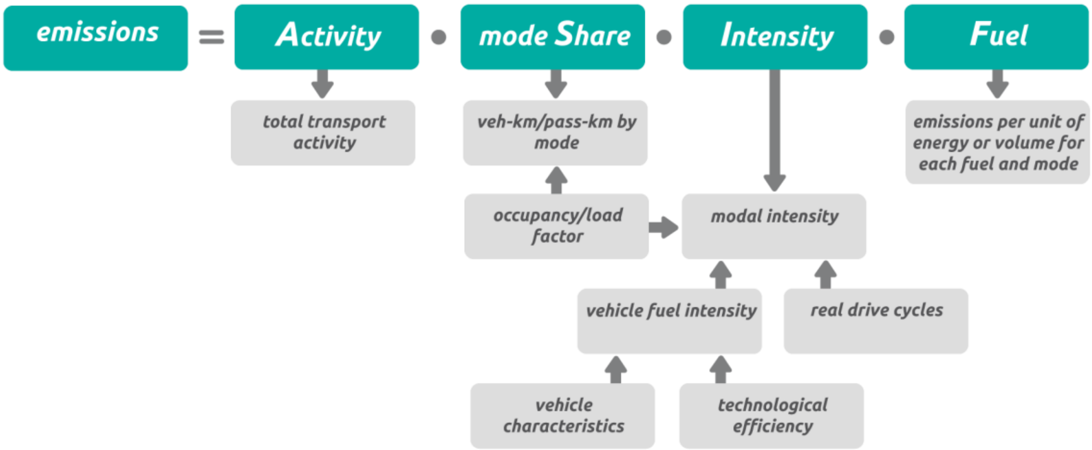


Figure 7.1 ASIF Framework[39]

Fuel sales method

This method calculates on-road transport emissions based on the total fuel sold within the city boundary. In theory, this approach treats sold fuel as a proxy for transport activity. The activity data on the volume of fuel sold within the city boundary can be obtained from fuel dispensing facilities and/or distributors, or fuel sales tax receipts. If a strictly in-boundary fuel sales figure is unavailable, data may still be available at the regional scale (through distributors). This data should be scaled-down using population as the scaling factor. Calculating fuel sales emissions requires multiplying activity data (quantity of fuel sold) by the GHG-content of the fuel by gas (CO_2, CH_4, N_2O).

To allocate total fuel sales by on-road vehicle sub-category, apportioning factors can be determined based on vehicle registration by vehicle class (starting with vehicle registrations within the community, then state or region, and finally national). Without further information, all fuel sales from in-boundary fuel dispensaries should be accounted for in scope 1, even though fuel purchases may be for trans-boundary trips.

Induced activity method

This bottom-up method seeks to quantify the emissions from transportation *induced* by the city, including trips that begin, end, or are fully contained within the city (usually excluding pass-through trips). The method relies on models or surveys to assess the number and length of all on-road trips occurring – both transboundary and in-boundary only. This yields a vehicle kilometers traveled (VKT) figure for each identified vehicle class. It also requires information on vehicle fuel intensity (or efficiency) and fuel emission factors.

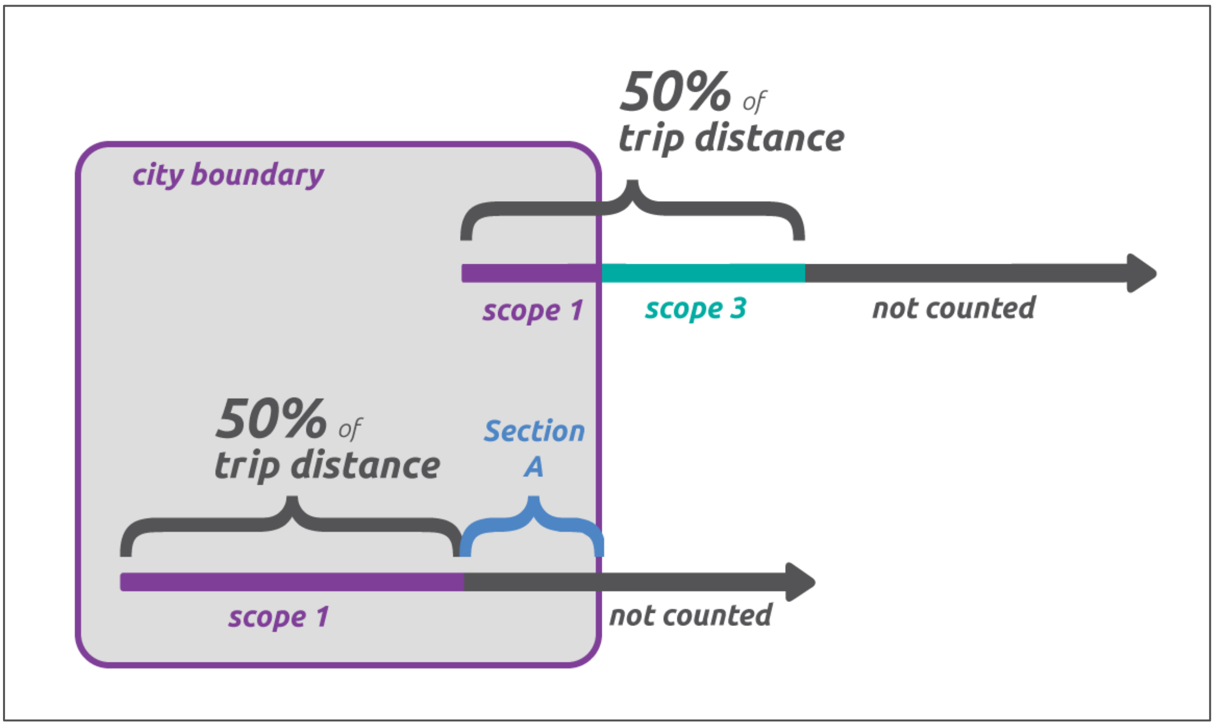
These models are more common in U.S. cities[40], and identify the *origin* and *destination* of each trip assessed. To reflect the responsibility shared by both cities inducing these trips, cities can use an *origin-destination* allocation that reports 50% of transboundary trips (and excludes pass

[39] Ibid
[40] Ibid

through trips). Of that 50%, the portion that occurs within the city boundary is reported in scope 1, while the remaining percent that occurs outside the boundary is reported in scope 3. If 50% of the trip is entirely within the city boundary (e.g., a trip that just passes the city boundary), then the entire 50% should be in scope 1. 100% of all in-boundary trips that begin and end in the same city are included, but pass through trips are excluded from scope 1 even though they represent "in-boundary" traffic (since they are not "induced" by the city).

See Figure 7.2 for an illustration of these allocation boundaries. Due to differences in traffic models, the "Section A" may include in-boundary emissions that are not tracked in scope 1. Cities can disclose these omissions if they are identified by the model.

Figure 7.2 Induced activity allocation



Advantage: sophisticated travel demand models that provide data that are richly detailed, disaggregated, and generally useful for mitigation action planning. Such data are typically provided by a regional government or planning authority.
Disadvantage: the cost and expertise required to collect this data can be high.

Geographic or territorial method

This method quantifies emissions from transportation activity occurring solely within city boundaries, regardless of the trip's origin or destination. Some European traffic demand models[41] quantify these emissions primarily for local air pollution estimates or traffic pricing, but GHG emissions can be quantified based on the same ASIF model, limiting VKT to in-city travel.

[41] Ibid

This model aligns with scope 1 emissions, as all in-boundary transportation is included. Although, no out-of-boundary trips are assessed or quantified, additional surveys could be combined in order to report scope 3 emissions as the portion of out-of-boundary transit.

Resident activity method

This method quantifies emissions from transportation activity undertaken by city residents only. It requires information on resident VKT, from vehicle registration records and surveys on resident travels. While these kinds of surveys may be more manageable and cost-effective than traffic models, its limitation to resident activity overlooks the impact of non-city resident traffic by commuters, tourists, logistics providers, and other travelers. Here, an inventory could apply the origin-destination allocation approach and report 50% of all resident trips.

Figure 7.3 Methodology system boundaries

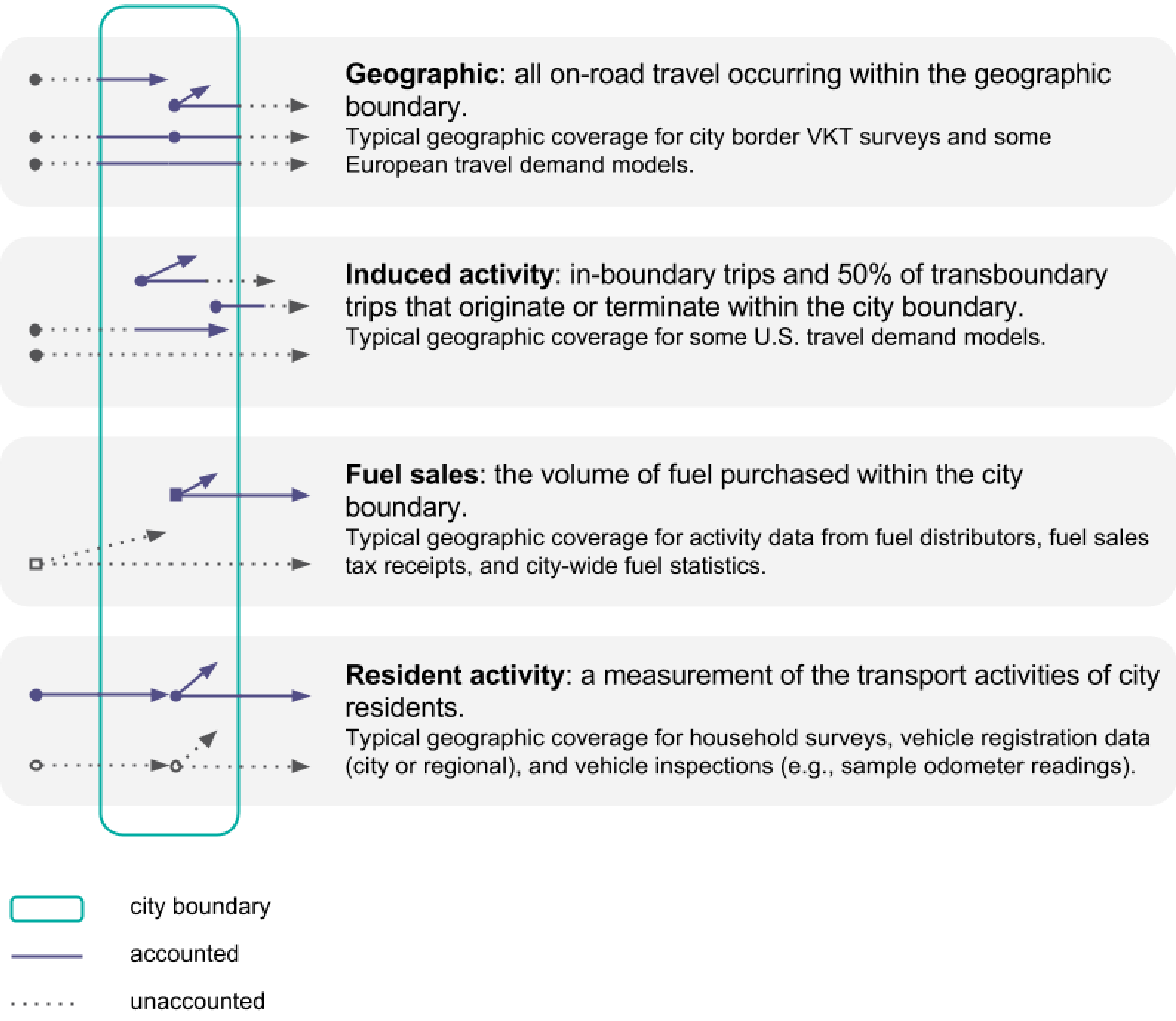


Table 7.3 Boundary types and scopes allocation					
Approach Type	**Method**	**Allocation principle**	**Scope 1**	**Scope 2**	**Scope 3**

Top Down	**Fuel Sales Approach**	N/A unless additional steps taken	All emission from fuel sold within boundary	*Any electric charging station in the city boundary*	N/A unless fuel sales allocated between scope 1 and 3 by specified method
Bottom Up	**City-induced Activity** (e.g. US demand models)	Origin-Destination	Report in-boundary 50% of trip (pass-through trips excluded)		Report out-of-boundary portion of 50% of trip
	Geographic/ Territorial (e.g., European demand models)	N/A	All traffic occurring within city boundaries, regardless of origin or destination		N/A
	Resident Activity	Options	Either resident activity is all scope 1 or use origin-destination		

How to select on-road calculation methodologies

Cities should decide which methodology and boundaries to use based on the quality and availability of data, regional practices, and the objectives of the inventory. Cities should seek consistent methods over time or document when methods have changed (see base year recalculation in Chapter 11.0).

In general, top-down approaches – such as fuel sales – are:

- More consistent with national inventory practices
- Well suited to aggregation with other city's transport inventories[42]
- Less costly
- Less time-consuming to conduct
- Do not require high level of technical capacity

However, the fuel sales method does not:

- Capture all on-road travel, as vehicles may be fueled at locations outside the city boundary but driven within the city
- Disaggregate the reasons for travel emissions, e.g., origin, destination, vehicle efficiency changes, modal shift, etc.
- Demonstrate mitigation potential
- Allow for allocating emissions by scope

In turn, bottom-up approaches – such as induced activity – can:

- Produce detailed and more actionable data for transportation planning

[42] A fuel sales approach where all fuel sold in boundary is classified as scope 1 will avoid double counting of emissions in aggregation.

- Better integrate with existing city transport models and planning processes

However, bottom-up transport modeling or surveys are often more expensive and time-consuming to produce.

7.4 Calculation guidance for railway transportation

Railways can be used to transport people and goods, and are powered by a locomotive, which typically uses energy through combustion of diesel fuels or electricity (known as electric traction). Rail transit can be further divided into four sub-categories, as shown with examples in Table 7.4. Each can be further classified as passenger or freight.

Table 7.4 Railway types

Railway type	Examples
Urban train/subway systems	Tokyo transit system
Regional (inter-city) commuter rail transport	Tokyo subway/train systems that connect to the adjacent cities like Yokohama, Tsukuba, and Chiba
National rail	Japan national railway system operate by the Japanese Rail
International rail systems	Trans-Europe rail systems such as Euro Star

The allocation principle for railway broadly reflects an assessment of "induced activity," but reports all in-city stops as scope 1 while out-of-city stops can be apportioned on the basis of city passengers or goods. This differs slightly from the origin-destination model used for on-road transportation, where each "trip end" city reports 50% of emissions from the trip. By contrast, railway lines potentially include multiple stops that can be clearly identified as falling within or outside city boundaries; it is assumed that in-city stops are "induced" by the city.

7.4.1 Calculating scope 1 emissions

Scope 1 emissions include emissions from direct combustion of fossil fuels incurred during the length of railway transit within the city boundary for railway lines that have stops in the city boundary. Based on available data and local circumstances, cities may either include or omit emissions from pass-through rail trips that do not stop in the city boundary. Whichever the case, cities shall transparently report the adopted approach for estimating railway emissions and indicate whether it covers pass-through rail transit.

Rail fuel combustion is typically diesel, but may also use natural gas or coal, or include compressed natural gas (CNG) or biofuels.[43] Cities should obtain fuel consumption data from the railway operator(s) by fuel types and by application (e.g., transit system, freight, etc.) for the distance covered within the city boundary (scope 1) and the lines' extension outside the city (see scope 3).

Where detailed activity data are unavailable, cities can also:

[43] Diesel locomotives also consume lubricant oils, emissions from which shall be reported in IPPU.

- Use rail company queries or surveys
  - Survey rail companies for real fuel consumption and amount of goods or people moved (movement driver).
  - Calculate real fuel consumption per tonne of freight and/or per person (e.g., gallons of diesel per person).

- Scale-up incomplete transportation activity data (e.g., tonnes freight and/or people movement). Total community activity may be determined through local, state, or national statistics or transportation agencies for the community.

- Scale down regional transit system fuel consumption based on:
  - Population served by the region's model and the population of the community, to derive an in-boundary number.
  - Share of transit revenue service miles served by the region (utilize data on scheduled stops and length of the railway) and the number of miles that are within the community's geopolitical boundary.

- Scale down national railway fuel consumption based on city population.

7.4.2 Calculating scope 2 emissions

Grid-supplied electricity used to power rail-based transportation systems is accounted for at points of supply (where the electricity is being supplied to the railway system), regardless of trip origin or destination. Therefore, all electricity charged for railway vehicle travel within the city boundary shall be accounted for under scope 2 emissions. Cities can seek this data from the railway operator, utility provider, or scale down regional or national statistics.

7.4.3 Calculating scope 3 emissions

Transboundary railway emissions (from either direct fuel combustion or grid-supplied electricity charged outside the city) can be allocated based on type of railway service and geographic range. For instance:

- For urban transit systems, lines may extend outside city boundaries into suburbs within a metro area geographic range. Here, all out-of-boundary emissions could be recorded in scope 3.
- For inter-city, national or international railway travel, a city can allocate based on:
  - Resident travel, where the number of city residents disembarking at each out-of-boundary stop (relative to the total riders on the out-of-boundary stops) can be used to scale down total emissions from the out-of-boundary stops. Cities can determine this based on surveys.
  - Freight quantity (weight or volume), where the freight quantity coming from the city (relative to the total freight on the out-of-boundary stops) can be used to scale down total emissions from out-of-boundary stops.

7.5 Calculation guidance for waterborne navigation

Water transportation includes ships, ferries, and other boats operating within the city boundary, as well as marine-vessels whose journeys originate or end at ports within the city's boundary but travel to destinations outside of the community. While water transportation can be a significant source of emissions globally, most emissions occur during oceanic journeys outside of the boundaries of a port city. Air transportation faces a similar challenge in applying a city-level geographic boundary.

IPCC international guidelines allow for exclusion of international waterborne navigation and air travel, but these journeys and their associated emissions can be useful for a city to understand the full impact of the transit connecting through the city. As a result, the GPC requires water transportation wholly occurring within a city to be reported in scope 1 for BASIC, while emissions from all departing ships for inter-city/national/international trips shall be reported in scope 3 under BASIC+.

7.5.1 Calculating scope 1 emissions

Scope 1 emissions include emissions from direct combustion of fossil fuels for all trips that originate and terminate within the city boundary. This includes all riverine trips within the city boundary as well as marine ferries and boats that travel between seaports within the city boundary (including sightseeing ferries that depart from and return to the same seaport within the city boundary). To calculate scope 1 emissions, cities can:

- Obtain total real fuel sales estimates of fuel loaded onto marine vessels by inquiring with shipping companies, fuel suppliers (e.g., quantity of fuels delivered to port facilities), or individual port and marine authorities, separated by geographic scale of activity.
  - Where a representative sampling survey is used, identify the driver of activity at the sample site (e.g., tonnes of freight or number of people), and use driver information to scale-up the activity data to the city-scale.
  - Total community activity may be determined through local, state, or national statistics or transportation agencies for the community.

- Estimate distances traveled and resulting fuel usage.
  - Use ferry movement schedules to calculate distances traveled.
  - Utilize fuel economy figures for boats.

- Scale national level data down using population or GDP per capita.
  - National marine navigation data may be found through national maritime (marine) administration agencies.

7.5.2 Calculating scope 2 emissions

Scope 2 emissions include any grid-supplied energy that marine-vessels purchase and consume, typically at docks, ports or harbors. (This should be distinguished from electricity consumption at other stationary port structures, such as a marina). Cities should seek data from port operators on water vessel consumption.

7.5.3 Calculating scope 3 emissions

Scope 3 emissions are GHG emissions from all departing trans-boundary trips powered by direct fuel combustion. As with air transportation, emissions from trans-boundary trips can be calculated based on:

- VKT, or the distance travelled from the seaport within the city to the next destination
- Fuel combustion, quantifying the combustion of fuel loaded at the stations within the city boundary

7.6 Calculation guidance for aviation

Civil aviation, or air travel, includes emissions from airborne trips occurring within the geographic boundary (e.g., helicopters operating within the city) and emissions from flights departing airports that serve the city. A significant amount of emissions associated with air travel occur outside the city boundary. Airports located within a city, or under local jurisdiction, typically service the greater region in which the community exists. These complexities make it challenging to properly account for and attribute aviation emissions. For simplicity, scope 3 includes all emissions from departing flights. Cities may elect to report just the portion of scope 3 aviation emissions produced by travelers departing the city.

Cities should also disaggregate data between domestic and international flights to improve integration with national GHG inventories.[44] Oftentimes, the separation of data between in-boundary (scope 1), domestic, and international aviation may be difficult to obtain. Classification of airports should indicate whether the airports service local, national, or international needs.

7.6.1 Calculating scope 1 emissions

Scope 1 includes emissions from the direct combustion of fuel for all aviation trips that depart and land within the city boundary (e.g., local helicopter, light aircraft, sightseeing and training flights). The methodology for quantifying aviation emissions is similar to the methodology provided for waterborne navigation in Section 7.5:

- Obtain activity data in the form of total real fuel sales estimates of fuel loaded onto airplanes by inquiring with airports, airlines, or port authorities.
  - Where real data for all airports are unavailable, utilize a survey of a sample of airports. Identify the driver of activity at the sample site (e.g., goods and freight or passenger movement), and use driver information to scale-up the activity data to the city-scale.
  - Total city activity may be determined through local, state, or national statistics or transportation agencies for the city.
- Where in-city aviation data are unavailable:
  - Survey local helicopter companies and airlines for fuel use data.
  - Estimate other local aviation use through schedule information and fuel economy estimates.
- Alternatively, scale national level data down using population or GDP per capita.
  - National aviation data may be found through national aviation administration agencies (e.g. U.S. FAA).
- Apply emission factors, which can be disaggregated by fuel type and technology (typically provided by national environmental agencies or research institutions), or use default IPCC emissions factors.[45]

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[44] Fuel use data is disaggregated from national and international trips as a UNFCCC/IPCC reporting requirement. Under the *2006 IPCC Guidelines*, national governments are required to calculate domestic (trips occurring within the geopolitical boundary of the country) waterborne navigation and aviation trips, while international trips are designated as optional.

[45] IPCC default emission factors can be found in Volume 2 Energy; Chapter 3 Mobile Combustion; Section 3.6 Civil Aviation; CO_2 Table 3.6.4 and CH_4 and N2O Table 3.6.5. Available at: www.ipcc-nggip.iges.or.jp/public/2006gl/vol2

7.6.2 Calculating scope 2 emissions

Scope 2 includes any grid-supplied energy consumed by in-boundary aviation activities.[46] Grid-supplied energy consumed by airport facilities is included in *stationary energy*.

7.6.3 Calculating scope 3 emissions

Scope 3 includes emissions from departing flights at airports that serve the city. Information on the types of fuels consumed in departing aviation trips, the quantity (volume or energy) of each type of fuel consumed by the aircraft associated with these flights, and whether the trips are domestic or international should be determined.

Quantification follows the same process described in 7.6.1. Additional resources for obtaining activity data include statistical offices or transportation agencies, airport records, air traffic control records or official records, or published air traffic schedules.

Optionally, the city may report just the emissions from departing flights that are attributable to the city by estimating the proportion of passengers traveling from the city, using carrier flight data or surveys to determine the allocation.

7.7 Calculation guidance for off-road transportation

Off-road vehicles are vehicles designed or adapted for travel on unpaved terrain. This category typically includes all-terrain vehicles, landscaping and construction equipment, tractors, amphibious vehicles, snowmobiles and other off-road recreational vehicles. For the purposes of the GPC, only in-boundary (scope 1) emissions are included.

Only emissions from off-road transportation activities within transportation facility premises such as airports, harbors, bus terminals, and train stations, are required to be reported under the *off-road transportation* sub-sector. Other off-road transportation activities, e.g., within industrial premises and construction sites, agriculture farms, forests, aquaculture farms, and military premises, are required to be reported under corresponding sub-sectors in the stationary units. (See Table 6.5)

All GHG emissions from combustion of fuels in off-road vehicles within the city boundary shall be reported under scope 1. Emissions from generation of grid-supplied electricity used to power off-road vehicles shall be reported under scope 2 emissions.

Comprehensive top-down activity data on off-road vehicles are often unavailable, and alternative methods are typically necessary to estimate emissions within this category. Some options include:

- Conducting a survey:
    - Be sure to include construction households (for garden and recreational equipment), and other relevant businesses.
    - Use population served by the survey to scale for the community, generally. More specifically, aggregate scale of sub-sectors for increased accuracy:

[46] Grid-supplied fixed ground power provided by the airport.

        - Construction permits served by the survey to scale for total permits issued for the community
        - Number of households (or population) served by the survey to scale for total community households (or population)

- Using national – or regional, where available – off-road modeling software:
    - Requires inputs on number of engines and technology types:
        - Engine populations
        - Annual hours of use (can be estimated, based upon community characteristics)
        - Power rating (derived from off-road vehicle types)
    - U.S. EPA has a tool that can be used for this purpose, NONROAD 2005:
        - Available on the U.S. EPA website: www.epa.gov/otaq/nonrdmdl
- Scale national off-road mobile fuel consumption down according to population share.

8.0 Waste

This chapter provides accounting guidance for governments to estimate GHG emissions from waste/wastewater disposal and treatment activities.

Requirements in this chapter:

For BASIC: Cities shall report all GHG emissions from disposal or treatment of waste or wastewater generated within the city boundary, whether treated inside or outside the city boundary.

Emissions from imported waste and wastewater treatment shall be EXCLUDED from BASIC reporting, but included in total scope 1 emissions.

8.1 Defining boundaries

Waste and wastewater might be generated and treated within the same city boundary, or in different cities. Therefore, for accounting purposes the following rules apply:

Scope 1: Emissions from in-boundary waste treatment
This includes all GHG emissions from waste/wastewater treatment facilities within the city boundary regardless whether the waste is generated within or outside the city boundary. Only GHG emissions from waste/wastewater generated within the city boundary will be reported under BASIC. GHG emissions from imported waste/wastewater shall only be reported as scope 1 but not as BASIC or BASIC+.

Scope 2: **Included elsewhere**
All emissions from the use of grid-supplied electricity from waste/wastewater treatment facilities within the city boundary shall be reported under Stationary Energy (I.2.2).

Scope 3: Emissions from waste treated out of boundary
This includes all GHG emissions from treatment of waste/wastewater generated by the city but treated at a facility outside the city boundary.

If methane is recovered from waste or waste/wastewater treatment facilities as energy sources, those GHG shall be reported under stationary energy. In case of waste incineration, emissions from waste incineration without energy recovery are reported here, while emissions from incineration with energy recovery are reported in Stationary Energy, both with a distinction between fossil and biogenic carbon dioxide (CO_2) emissions (see Section 3.3 for reporting requirements)

Figure 8.1 Waste sector reporting

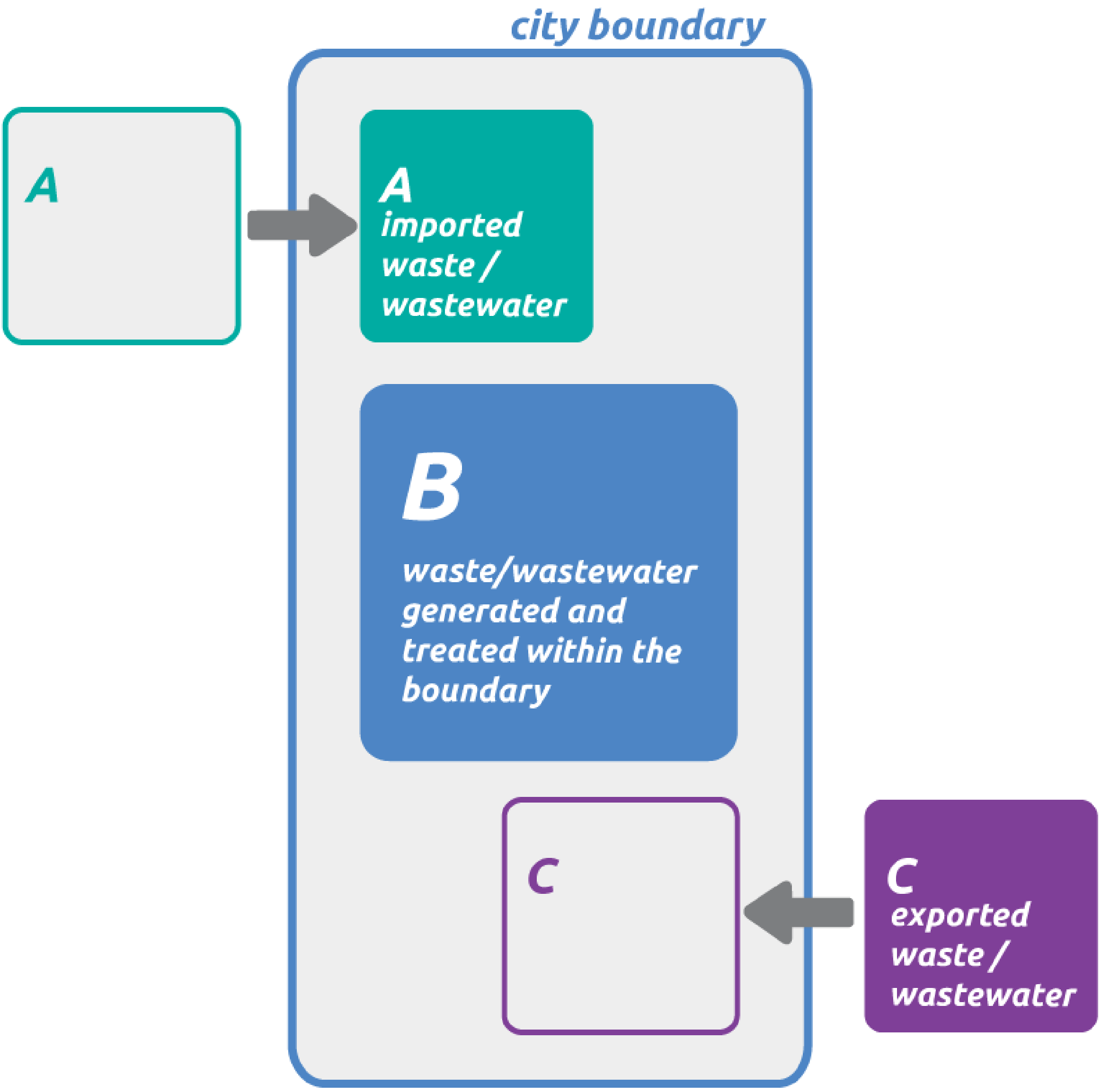

Figure 8.1 demonstrates some of the boundary issues associated with accounting for waste/wastewater emissions. The blue frame represents the city's geographic boundary and:

- **A** stands for waste/wastewater generated outside of the city boundary and treated within the boundary
- **B** stands for waste/wastewater generated and treated within the city's boundary
- **C** stands for waste/wastewater generated inside the boundary and treated outside of the boundary

Based on the above, the reporting requirement for the waste sector is as follows:

- Scope 1 emissions = emissions from **A+B** (all emission generated within the city boundary)
- Scope 3 emissions = emissions from **C**
- Emissions reported for BASIC = emissions from **B+C** (all emissions resulting from waste generated by the city)

Table 8.1 Waste overview

GHG emission source	Scope 1	Scope 2	Scope 3
	Emissions from in-boundary waste treatment		Emissions from waste generated in the city but treated out-of-boundary
WASTE			
Solid waste generated in the city	III.1.1	Included elsewhere (IE) – Stationary energy	III.1.2
Solid waste generated outside the city	III.1.3		
Biological waste generated in the city	III.2.1		III.2.2
Biological waste generated outside the city	III.2.3		
Incinerated and burned waste generated in the city	III.3.1		III.3.2
Incinerated and burned waste generated outside the city	III.3.3		
Wastewater generated in the city	III.4.1		III.4.2
Wastewater generated outside the city	III.4.3		

8.2 Defining the emissions source

Measuring GHG emissions from waste and wastewater management is mainly determined by two factors:

- Composition of waste or wastewater, or the waste type, particularly the amount of degradable organic matter present
- Treatment method of the waste or wastewater

8.2.1 Defining waste types

Waste type categorization, waste collection methods, and resulting waste data vary by country. This chapter focuses on GHG emissions from different types of solid waste generated from offices, households, shops, markets, restaurants, public institutions, industrial installations, water works and sewage facilities, construction and demolition sites and agricultural activities.

When estimating waste-related GHG emissions, accuracy increases when a city authority can provide city-specific waste composition and generation data. For cities without data on solid waste generation or waste treatment techniques – or for those cities lacking access to historical waste data – the GPC provides a set of default solid waste types and definitions (outlined below). These default types will help a city estimate waste composition and emissions based on defaults in the *2006 IPCC Guidelines*. At the same time, they are also open for city-specific

Box 8.1 Reporting scope 1 emissions from waste sector: the case of Lahti, Finland

In Lahti, Finland, municipally-owned Päijät-Häme Waste Disposal Ltd serves not only the city of Lahti, but also 21 other municipalities and 200,000 residents around the Päijät-Häme region. All relevant GHG emissions from waste treatment facilities in Lahti, which manage both the waste generated by the city itself and by entities outside the city boundary, are around two times larger than the GHG emissions from Lahti residents only. Therefore, the GPC recommends that the city of Lahti report all emissions from the entire waste sector under scope 1 with an accompanying explanation about the proportion of emissions from imported MSW.

modification. Default types of solid waste include:

1. Municipal solid waste (MSW)

MSW is generally defined as waste collected by municipalities or other local authorities. MSW typically includes: food waste, garden and park waste, paper and cardboard, wood, textiles, disposable diapers, rubber and leather, plastics, metal, glass, and other materials (e.g., ash, dirt, dust, soil, electronic waste).

2. Sludge

In some cities, domestic wastewater sludge is reported as MSW, and industrial wastewater treatment sludge in industrial waste. Other cities may consider all sludge as industrial waste. Whichever category they prefer, cities should make note when reporting sludge emissions.

3. Industrial Waste

Industrial waste generation and composition vary depending on the type of industry and processes/technologies used and how the waste is classified by country. For example, construction and demolition waste can be included in industrial waste, MSW, or defined as a separate category. In many countries industrial solid waste is managed as a specific stream and the waste amounts are not covered by general waste statistics.

In most developing countries industrial wastes are included in the municipal solid waste stream. Therefore, it is difficult to obtain data on industrial waste separately, and cities should carefully notate the category when reporting waste sector emissions.

4. Other waste

Clinical waste: These wastes include materials from plastic syringes and animal tissues, to bandages and cloths. Some countries choose to include these items under MSW. Clinical waste is usually incinerated, but on occasion may be disposed of at solid waste disposal sites (SWDS). No regional or country-specific default data are given for clinical waste generation and management.

Hazardous waste: Waste oil, waste solvents, ash, cinder, and other wastes with hazardous properties – such as flammability, explosiveness, causticity, and toxicity – are included in hazardous waste. Hazardous wastes are generally collected, treated and disposed of separately from non-hazardous MSW and industrial waste streams.

In most countries, GHG emissions from clinical and hazardous wastes are less than those coming from other waste streams, so the GPC does not provide methodological guidance specifically for "Other Waste." When a city has specific needs, city government can apply the waste composition and waste treatment data to MSW methodology.

8.2.2 Defining waste treatment methods

This chapter provides accounting guidance for city governments to estimate carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) from the following waste/wastewater management activities:

1. Solid waste disposal in landfill

2. Biological treatment of solid waste
3. Incineration and open burning of waste
4. Wastewater treatment and discharge

Treatment and disposal of municipal, industrial and other solid waste produces significant amounts of methane (CH_4). CH_4 produced at solid waste disposal sites (SWDS) contributes approximately 3 to 4 percent to annual global anthropogenic GHG emissions.[47] In addition to CH_4, SWDS also produce biogenic carbon dioxide (CO_2) and non-methane volatile organic compounds (NMVOCs) as well as smaller amounts of nitrous oxide (N_2O), nitrogen oxides (NO_x), and carbon monoxide (CO). This section focuses only on guidance on methane emission calculation.

The quantification of GHG emissions from solid waste disposal and treatment is determined by two main factors: the mass of waste disposed and the amount of degradable organic carbon (DOC) within the waste, which determines the methane generation potential. Detailed guidance for quantifying waste mass and degradable organic content includes the following steps:

- *Determine the quantity (mass) of waste generated by the community and how and where it is treated.* Waste that is incinerated or treated biologically can be estimated using the mass of waste generated by the community in the inventory analysis year. In cases where a city does not incinerate or biologically treat the waste, these emissions categories can be labeled as "Not Occurring."

  Where it is not possible to determine the total waste generated by a city in the analysis year, the *2006 IPCC Guidelines* provide national default values for waste generation rates based upon a tonnes/capita/year basis and default breakdowns of fraction of waste disposed in landfills (SWDS), incinerated, composted (biological treatment), and unspecified (landfill methodology applies here).[48]

- *Determine the emission factor*. For solid waste disposal and treatment, the emission factor is illustrated as methane generation potential (L_0). This factor is further explained in Section 8.3.1.

- *Multiply quantity of waste disposed by relevant emission factors to determine total emissions.*

The preferred method to determine the composition of the waste stream is to undertake a waste composition study, using survey data and a systematic approach to analyze the waste stream and determine the waste source (paper, wood, textiles, garden waste, etc.). In addition, the analysis should indicate the fraction of DOC and fossilized carbon present in each matter type and the dry weight percentages of each matter type. In the absence of a comprehensive waste composition study, the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* provide

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[47] IPCC (2001). Summary for Policymakers and Technical Summary of *Climate Change 2001: Mitigation. Contribution of Working Group III to the Third Assessment Report of the Intergovernmental Panel on Climate Change,* Bert Metz *et al.* eds. Cambridge University Press, Cambridge, United Kingdom

[48] *2006 IPCC Guidelines*, Volume 5: Waste, Chapter 2: Waste Generation, Composition, and Management, Annex2A.1. Available at: www.ipcc-nggip.iges.or.jp/public/2006gl/vol5

ample regional and country-specific data to determine waste composition and carbon factors in the weight of wet waste.[49]

DOC represents a ratio or percentage that can be calculated from a weighted average of the carbon content of various components of the waste stream. The following equation estimates DOC using default carbon content values:

Equation 8.1 Degradable organic carbon (DOC)

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

Where:

A	=	Fraction of solid waste that is food
B	=	Fraction of solid waste that is garden waste and other plant debris
C	=	Fraction of solid waste that is paper
D	=	Fraction of solid waste that is wood
E	=	Fraction of solid waste that is textiles
F	=	Fraction of solid waste that is industrial waste

Source: Equation adapted from *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (2000). Default carbon content values sourced from IPCC Waste Model spreadsheet, available at: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_2_Ch2_Waste_Data.pdf

8.3 Calculating emissions from solid waste disposal in landfill

In cases where solid waste is disposed in a landfill site, a city should quantify the tonnes of CH_4 from landfill gas based on one of two methods: Methane Commitment (MC) method or the First Order of Decay (FOD) model.

The Methane Commitment method takes a mass-balance approach. It calculates landfill emissions based on the amount of waste disposed in a given year, regardless of when the emissions actually occur (a portion of emissions are released every year after the waste is disposed).

The First Order of Decay model assumes that the degradable organic component (degradable organic carbon, DOC) in waste decays slowly over a few decades, during which CH_4 and CO_2 are released. If conditions are constant, the rate of CH_4 production depends solely on the amount of carbon remaining in the waste. As a result, CH_4 emissions are highest in the first few years after waste is initially deposited in a disposal site, then gradually decline as the degradable carbon in the waste is consumed by the bacteria responsible for the decay.

The FOD method provides a more accurate estimate of annual emission and is recommended in the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, but it requires historical waste disposal information.

[49] Default values are available in Volume 5: Waste, Chapter 2: Waste Generation, Composition, and Management (Table 2.3 and Table 2.4).

8.3.1 First Order of Decay model

Due to the complexity of this method, the GPC recommends that cities use the IPCC Waste Model, which provides two options for the estimation of emissions from solid waste that can be chosen depending on the available activity data. The first option is a multi-phase model based on waste composition data. The second option is single-phase model based on bulk waste (solid waste). Emissions from industrial waste and sludge are estimated in a similar way to bulk solid waste. When waste composition is relatively stable, both options give similar results. However when rapid changes in waste composition occur, the different calculation options might yield different results.

8.3.2 Methane Commitment method

Downstream emissions associated with solid waste sent to landfill during the inventory year can be calculated using the following equation for each landfill:

Equation 8.2 Methane commitment estimate for solid waste sent to landfill

$$CH_4 \text{ emissions} = M_{waste} \times L_0 \times (1-f_{rec}) \times (1-OX)$$

Description			*Value*
CH_4 emissions	=	Total CH_4 emissions in metric tonnes	Computed
M_{waste}	=	Mass of solid waste sent to landfill in inventory year, measured in metric tonnes	User input
L_0	=	Methane generation potential in metric tons CH_4	Equation 8.3
f_{rec}	=	Fraction of methane recovered at the landfill (flared or energy recovery)	User input
OX	=	Oxidation factor	0.1 for well-managed landfills; 0 for unmanaged landfills

Source: Adapted from *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*.

Methane generation potential, L_0

Methane generation potential (L_0) is an emission factor that specifies the amount of CH_4 generated per tonne of solid waste. L_0 is based on the portion of degradable organic carbon (DOC) that is present in solid waste, which is in turn based on the composition of the waste stream. L_0 can also vary depending on the characteristics of the landfill. Unmanaged landfills produce less CH_4 from a given amount of waste than managed landfills because a larger fraction of waste decomposes aerobically in the top layers of a landfill. L_0 can be determined using the IPCC equation below:

Equation 8.3 Methane generation potential, L_0

$$L_0 = W \times MCF \times DOC \times DOC_F \times F \times 16/12$$

Description			*Value*
L_0	=	Methane generation potential, in metric tons of CH_4	Computed
W	=	Mass of waste deposited, in metric tons	User input

MCF	=	Methane correction factor based on type of landfill site (managed, unmanaged, etc.)	Managed = 1.0 Unmanaged (≥5 m deep) = 0.8 Unmanaged (<5 m deep) = 0.4 Uncategorized = 0.6
DOC	=	Degradable organic carbon (metric tons C/metric tons waste)	Equation 8.1
DOC_F	=	Fraction of DOC that is ultimately degraded (reflects the fact that some organic carbon does not degrade)	Assumed equal to 0.6
F	=	Fraction of methane in landfill gas	Default range 0.4-0.6 (usually taken to be 0.5)
16/12	=	Stoichiometric ratio between methane and carbon	
Source: *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (2000).			

8.4 Calculating emissions from biological treatment of solid waste

The biological treatment of waste refers to composting and anaerobic digestion of organic waste, such as food waste, garden and park waste, sludge, and other organic waste sources. Biological treatment of solid waste reduces overall waste volume for final disposal (in landfill or incineration) and reduces the toxicity of the waste.

In cases where waste is biologically treated (e.g., composting), cities shall report the CH_4, N_2O and non-biogenic CO_2 emissions associated with the biological treatment of waste based upon the amount of city-generated waste treated in the analysis year.

1. Data on composting and anaerobic treatment should be collected separately, in order to use different sets of emission factors.
2. Where there is gas recovery from anaerobic digestion, subtract recovered gas amount from total estimated CH_4 to determine net CH_4 from anaerobic digestion.

Equation 8.4 Direct emissions from biologically treated solid waste

$$CH_4\ Emissions = \left(\sum_i (m_i \times EF\_CH4_i) \times 10^{-3} - R\right)$$

$$N_2O\ Emissions = \left(\sum_i (m_i \times EF\_N2O_i) \times 10^{-3}\right)$$

Description			*Value*
CH_4 emissions	=	Total CH_4 emissions in metric tons	Computed
N_2O emissions	=	Total N_2O emissions in metric tons	Computed
m	=	Mass of organic waste treated by biological treatment type *i, kg*	User input
*EF_* CH_4	=	CH_4 emissions factor based upon treatment type, *i*	User input or default value (Table 8.2)
*EF_* N_2O	=	N_2O emissions factor based upon treatment type, *i*	User input or default value (Table 8.2)

i	=	Treatment type: composting or anaerobic digestion	User input
R	=	Total metric tons of CH_4 recovered in the inventory year, if gas recovery system is in place	User input, measured at recovery point
Source: *2006 IPCC Guidelines*			

Table 8.2 Biological treatment emission factors				
Treatment type	**CH_4 Emissions Factors (g CH_4/kg waste)**		**N_2O Emissions Factors (g N_2O /kg waste)**	
	Dry waste	Wet waste	Dry waste	Wet waste
Composting	10	4	0.6	0.3
Anaerobic digestion at biogas facilities	2	1	N/A	N/A
Source: *2006 IPCC Guidelines*				

8.5 Calculating emissions from waste incineration

Cities shall report the CH_4, N_2O and non-biogenic CO_2 emissions associated with waste combustion based upon the amount of city-generated waste incinerated in the analysis year.

CO_2 emissions associated with incineration facilities can be estimated based on the mass of waste incinerated at the facility, the total carbon content in the waste, and the fraction of carbon in the solid waste of fossil origin. Non-CO_2 emissions, such as CH_4 and N_2O, are more dependent on technology and conditions during the incineration process. For further information, local governments should follow the quantification guidelines outlined in the *2006 IPCC Guidelines* (Volume 5, Chapter 5).

To calculate emissions from waste incineration, cities must identify:

- Quantity (mass) of total solid waste generated by other communities and incinerated in the inventory analysis year (if calculating for in-boundary incineration facilities)
- Type of technology and conditions used in the incineration process
- "Energy transformation efficiency" (applies to incineration with energy recovery)

Equation 8.5 CO_2 Emissions from the incineration of waste

$$CO_2\ Emissions = m \times \sum_i (WF_i \times dm_i \times CF_i \times FCF_i \times OF_i) \times (44/12)$$

Description			*Value*
CO_2 emissions	=	Total CO_2 emissions from incineration of solid waste	Computed

		in metric tons	
m	=	Mass of waste incinerated, metric tons	User input
WF_i	=	Fraction of waste of consisting of type *i* matter	User input[50]
dm_i	=	Dry matter content in the type *i* matter	User input (default values provided in Table 8.3 below)
CF_i	=	Fraction of carbon in the dry matter of type *i* matter	
FCF_i	=	Fraction of fossil carbon in the total carbon component of type *i* matter	
OF_i	=	Oxidation fraction or factor	
i	=	Matter type of the Solid Waste incinerated such as paper/cardboard, textile, food waste, etc.	User input (default values provided in Table 8.3 below)
NOTE:		$\sum_i WF_i = 1$	
Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories			

Table 8.3 Default data for CO2 emission factors for incineration and open burning

Parameters	Management practice	MSW	Industrial Waste (%)	Clinical Waste (%)	Sewage Sludge (%) Note 4	Fossil liquid waste (%) Note 5
Dry matter content in % of wet weight		see Note 1	NA	NA	NA	NA
Total carbon content in % of dry weight		see Note 1	50	60	40 – 50	80
Fossil carbon fraction in % of total carbon content		see Note 2	90	40	0	100
Oxidation factor in % of carbon input	incineration	100	100	100	100	100
	Open- burning (see Note 3)	58	NO	NO	NO	NO

NA: Not Available, NO: Not Occurring

Note 1: Use default data from Table 2.4 in Section 2.3 Waste composition and equation 5.8 (for dry matter), Equation 5.9 (for carbon content) and Equation 5.10 (for fossil carbon fraction).

Note 2: Default data by industry type is given in Table 2.5 in Section 2.3 Waste composition. For estimation of emissions, use equations mentioned in Note 1.

Note 3: When waste is open-burned, refuse weight is reduced by approximately 49 to 67 percent (US-EPA, 1997, p.79). A default value of 58 percent is suggested.

Note 4: See Section 2.3.2 Sludge in Chapter 2.

Note 5: The total carbon content of fossil liquid waste is provided in percent of wet weight and not in percent of dry weight (GIO, 2005).

References: *GPG2000* (IPCC, 2000), Lead Authors of the *2006 Guidelines*, Expert judgment.

[50] Default data available in 2006 IPCC Guidelines, Vol. 5, Ch. 2, Table 2.4

8.6 Calculating emissions from wastewater treatment and handling

Municipal wastewater can be treated aerobically (in presence of oxygen) or anaerobically (in absence of oxygen). When wastewater is treated anaerobically, methane (CH_4) is produced. Both types of treatment also generate nitrous oxide (N_2O) through the nitrification and denitrification of sewage nitrogen. N_2O and CH_4 are potent greenhouse gases that are accounted for during wastewater treatment, while CO_2 from wastewater treatment is considered to be of biogenic origin and reported outside the scopes.

There are a variety of ways wastewater is handled, collected, and treated. Distinctions between capacities and methods of wastewater handling vary greatly country-to-country and city-to-city. Depending on the wastewater source, it can generally be categorized as Domestic Wastewater or Industrial Wastewater. Domestic wastewater is defined as wastewater from household water use, while industrial wastewater is from industrial practices only. But in practice, industrial wastewater may be treated on-site or released into domestic sewer systems. If it is released into the domestic sewer system, those emissions must be included with the domestic wastewater emissions.

8.6.1 Calculation methane emissions from wastewater treatment and handling

In order to quantify the methane emissions from wastewater treatment, local governments will need to know:

- ✓ How wastewater and sewage are treated
- ✓ The wastewater's source and its organic content (this can be estimated based upon the communities' population served and the community's composition in the case of domestic wastewater, or the community's industrial sector in the case of industrial waste water)
- ✓ Proportion of wastewater treated for other communities, at facilities located within the city's boundaries (this can be estimated based upon other communities' population served)

The general equation to estimate methane emissions from wastewater is demonstrated in Equation 8.6. The organic content of the wastewater differs depending on whether the treatment is industrial or residential wastewater, as shown in Equation 8.7. The income group suggested in variable *I* influences the usage of treatment/pathway, therefore influences the emission factor.

Equation 8.6 CH_4 generation from wastewater treatment

$$CH_4\ emissions = \sum_i [(TOW_i - S_i)\ EF_i - R_i] \div 1000$$

Description			*Value*
CH_4 emissions	=	Total CH_4 emissions in metric tonnes	Computed
TOW_i	=	Organic content in the wastewater **For domestic wastewater**: total organics in wastewater in inventory year, kg BOD/yr **For industrial wastewater**: total organically degradable material in wastewater from industry *i* in inventory year, kg COD/yr	Equation 8.7

EF_i	=	Emission factor kg CH_4 per kg BOD or kg CH_4 per kg COD	Equation 8.7
S_i	=	Organic component removed as sludge in inventory year, kg COD/yr or kg BOD/yr	User input
R_i	=	Amount of CH_4 recovered in inventory year, kg CH_4/yr	User input
i	=	Type of wastewater **For domestic wastewater**: income group for each wastewater treatment and handing system **For industrial wastewater**: total organically degradable material in wastewater from industry *i* in inventory year, kg COD/yr	Equation 8.7
Source: Chapter 6: Wastewater Treatment and Discharge, *2006 IPCC Guidelines for National Greenhouse Gas Inventories.* Biochemical Oxygen Demand (BOD): The BOD concentration indicates only the amount of carbon that is aerobically biodegradable. The standard measurement for BOD is a 5-day test, denoted as BOD_5. The term 'BOD' in this chapter refers to BOD_5. Chemical Oxygen Demand (COD): COD measures the total material available for chemical oxidation (both biodegradable and non-biodegradable).			

Equation 8.7 Organic content and emission factors in domestic wastewater			
$TOW = P \bullet BOD \bullet I \bullet 365$ $EF_j = B_o \bullet MCF_j \bullet U_i \bullet T_{i,j}$			
Definition			*Value*
TOW_i	=	For domestic wastewater: total organics in wastewater in inventory year, kg BOD/yr	Computed
P		City's population in inventory year (person)	User input
BOD	=	City-specific per capita BOD in inventory year, g/person/day	User input[51]
I	=	Correction factor for additional industrial BOD discharged into sewers	In the absence of expert judgment, a city may apply default value 1.25 for collected wastewater, and 1.00 for uncollected.[52]
EF_i	=	Emission factor for each treatment and handling system	Computed

[51] if city-specific data are not available, city can consult national specific data or reference the default national value provided by 2006 *IPCC Guidelines for National Greenhouse Gas Inventories* (table 6.4 of Volume 5, Chapter 6: Wastewater Treatment and Discharge)

[52] Based on expert judgment by the authors, it expresses the BOD from industries and establishments (e.g., restaurants, butchers or grocery stores) that is co-discharged with domestic wastewater. In some countries, information from industrial discharge permits may be available to improve *I*. Otherwise, expert judgment is recommended.

B_o	=	Maximum CH_4 producing capacity	User input or default value: • 0.6 kg CH4/kg BOD • 0.25 kg CH4/kg COD
MCF_j	=	Methane correction factor (fraction)	User input[53]
U_i	=	Fraction of population in income group *i* in inventory year	User input[54]
$T_{i,j}$	=	Degree of utilization (ratio) of treatment/discharge pathway or system, *j*, for each income group fraction *i* in inventory year	
Source: Chapter 6: Wastewater Treatment and Discharge, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*			

8.6.2 Calculating nitrous oxide (N_2O) emissions from wastewater treatment and handling

Nitrous oxide (N_2O) emissions can occur as direct emissions from treatment plants or as indirect emissions from wastewater after disposal of effluent into waterways, lakes or the sea. Direct emissions from nitrification and denitrification at wastewater treatment plants may be considered as a minor source not quantified here. Therefore, this section addresses indirect N_2O emissions from wastewater treatment effluent that is discharged into aquatic environments.

Equation 8.8 Indirect N_2O emissions from wastewater effluent			
$N_2O_{Emissions} = [(P \cdot Protein \cdot F_{NPR} \cdot F_{NON-CON} \cdot F_{IND-COM}) - N_{SLUDGE}] \cdot EF_{EFFLUENT} \cdot 44/28 \div 1000$			
Description			*Value*
$N_2O_{emissions}$	=	Total N_2O emissions in metric tons	Computed
P	=	Total population served by the water treatment plant	User input
Protein	=	Annual per capita protein consumption, kg/person/yr	User input
$F_{NON-CON}$		Factor to adjust for non-consumed protein	1.1 for countries with no garbage disposals, 1.4 for countries with garbage disposals
F_{NPR}	=	Fraction of nitrogen in protein	0.16, kg N/kg protein
$F_{IND-COM}$	=	Factor for industrial and commercial co-discharged protein into the sewer system	1.25
N_{SLUDGE}	=	Nitrogen removed with sludge, kg N/yr	User input or default value: 0
$EF_{EFFLUENT}$	=	Emission factor for N_2O emissions from discharged to wastewater in kg N_2O-N per kg	0.005

[53] or consult with default value provided by *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (table 6.3 (domestic) and table 6.8 (industrial) of Volume 5, Chapter 6: Wastewater Treatment and Discharge)
[54] or consult with default value provided by *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (table 6.5 of Volume 5, Chapter 6: Wastewater Treatment and Discharge)

		N_2O	
44/ 28	=	The conversion of kg N_2O-N into kg N_2O	
Source: Chapter 6: Wastewater Treatment and Discharge, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*			

9.0 Industrial Processes and Product Use Emissions

GHG emissions can result from non-energy related industrial activities and product uses. All GHG emissions occurring from industrial processes, product use, and non-energy uses of fossil fuel, shall be assessed and reported under *Industrial Processes and Product Use*, or IPPU.

Requirements in this chapter:

For BASIC+: cities shall report all IPPU emissions under BASIC+.

9.1 Defining boundaries

Scope 1: In-boundary emissions resulting from industrial processes occurring within the city boundary

Local governments shall identify the major product use sources in the categories below and apply relevant quantification methodologies as referenced.

Scope 2: Not applicable.

Emissions from use of grid-supplied energy in buildings and vehicles shall be reported under Stationary Energy.

Scope 3: Not applicable.

Emissions from IPPU outside the city are not included in the assessment boundary but may be reported under "Other" scope 3 emissions.

Table 9.1 IPPU overview

GHG emission source	Scope 1	Scope 2	Scope 3
	Emissions from industrial processes and product use occurring within the city boundary		
INDUSTRIAL PROCESSES AND PRODUCT USE			
Industrial processes	IV.1	IE – Stationary energy	
Product use	IV.2		

9.2 Defining the emissions source

Table 9.2 IPPU chapter summary

GHG emission sources	Industrial processes or Products use
GHG emissions from industrial processes	• Production and use of mineral products (9.3) • Production and use of chemicals (9.4) • Production of metals (9.5)

GHG emissions from product use	• Lubricants and paraffin waxes used in non-energy products (9.6) • FC gases used in electronics production (9.7) • Fluorinated gases used as substitutes for Ozone depleting substances (9.8)

9.2.1 Separating IPPU GHG emissions and energy-related GHG emissions

Allocation of emissions from the use of fossil fuel between the stationary energy and IPPU sectors can be complex. The GPC follows IPCC Guidelines[55], which define "fuel combustion" in an industrial process context as: "*the intentional oxidation of material within an apparatus that is designed to provide heat or mechanical work to a process, or for use away from the apparatus.*"

Therefore:

- If the fuels are combusted for energy use, the emission from fuel uses shall be counted under Stationary Energy.
- If the derived fuels are transferred for combustion in another source category, the emissions shall be reported under Stationary Energy.
- If combustion emissions from fuels are obtained directly or indirectly from the feedstock, those emissions shall be allocated to IPPU.
- If heat is released from a chemical reaction, the emissions from that chemical reaction shall be reported as an industrial process in IPPU.

CO_2 capture and storage

In certain IPPU categories, particularly large point sources of emissions, there may be emissions capture for recovery and use, or destruction. Cities should identify detailed city-specific or plant-level data on capture and abatement activities, and any abatement totals should be deducted from the emission total for that sub-sector or process.

9.3 Calculation guidance for industrial processes

GHG emissions are produced from a wide variety of industrial activities. The main emission sources are releases from industrial processes that chemically or physically transform materials (e.g., the blast furnace in the iron and steel industry, and ammonia and other chemical products manufactured from fossil fuels used as chemical feedstock). During these processes, many different greenhouse gases, including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs), can be produced. The following sections will illustrate a methodological guide for emissions from industrial processes by industrial type.

9.3.1 Mineral industry emissions

Three industrial processes are highlighted under the mineral industry: cement production, lime production, and glass production. For these processes, the release of CO_2 is the calcination of carbonate compounds, during which – through heating – a metallic oxide is formed. A typical calcination reaction, shown below for the mineral calcite (or calcium carbonate), would be:

[55] Box 1.1 from *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, Volume 3 IPPU, Chapter 1 introduction.

Equation 9.1 Calcination example
$CaCO_3$+ heat --→CaO + CO_2

To calculate mineral industry emissions, cities will need to know:

- Major mineral production industry within its community boundary
- Annual mineral product output and raw material consumption in the industrial process
- Emission factor of raw material or product

With the above information, GHG emissions can be quantified with the following simplified formulae. These formulae are also illustrated in Table 9.3, and in the following sectors of this chapter, the emission quantification guidance will only be provided in table form.

Equation 9.2 Emissions from cement production			
CO_2 emissions = M_{cl} • EF_{cl}			
Description			*Value*
CO_2 emissions	=	CO_2 emissions in metric tons	Computed
M_{cl}	=	Weight (mass) of clinker produced in metric tonnes	User input
EF_{cl}	=	CO_2 per mass unit of clinker produced (e.g., CO_2/tonne clinker)	User input or default value

Equation 9.3 Emissions from lime production			
CO_2 emissions =$\sum(EF_{lime,i} \bullet M_{lime,\ i})$			
Description			*Value*
CO_2 emissions	=	CO_2 emissions in metric tons	Computed
M_{lime}	=	Weight (mass) of lime produced of lime type i in metric tonnes	User input
EF_{lime}	=	CO_2 per mass unit of lime produced of lime type i (e.g. CO2/tonne lime of type i)	User input or default value
i	=	Type of lime	

Equation 9.4 Emissions from glass production			
CO_2 emissions = M_g •EF •(1−CR)			
Description			*Value*
CO_2 emissions	=	CO_2 emissions in metric tons	Computed
M_{cl}	=	Mass of melted glass of type i (e.g., float, container, fiber glass, etc.), tonnes	User input
EF_{cl}	=	Emission factor for manufacturing of glass of type i, tonnes CO2/tonne glass melted	User input or default value

CR_i		Cullet ratio[56] for manufacturing of glass of type i	User input or default value

Cities should use factory-specific production data and regionally-specific emission factors. If a city does not have access to factory-specific data, IPCC methodologies and data sources are listed in Table 9.3.

[56] In practice, glass makers recycle a certain amount of scrap glass (cullet) when making new glass. Cullet ratio is the fraction of the furnace charge represented by cullet.

Table 9.3 Calculating mineral industry emissions

Emission sources	**GHG emissions**	**Simplest approach for quantifying emissions**[57]	**Source of active data**	**Link to default emission factor calculation**
Cement production	CO_2	Emission factor multiplied with Weight (mass) of Clinker produced	• Contact the operators or owners of the industrial facilities at which the processes occur and obtain relevant activity data. • Contact national inventory compiler to ask for specific production data within the city boundary.	2.2.1.2 of Page 2.11 from Chapter 2 of Volume 3 of 2006 IPCC Guidelines for National Greenhouse Gas Inventories
Lime production		Emission factor multiplied with Weight (mass) of each type of lime produced		Table 2.4 of Page 2.22 from Chapter 2 of Volume 3 of 2006 IPCC Guidelines for National Greenhouse Gas Inventories
Glass production		Emission factor multiplied with Weight (mass) melted for each type of glass produced		Table 2.6 of Page 2.30 from Chapter 2 of Volume 3 of 2006 IPCC Guidelines for National Greenhouse Gas Inventories

[57] The GPC utilizes the IPCC's more simplified Tier 1 method – which involves using default IPCC data – when accounting for emissions from the mineral industry, and other industries outlined in this chapter. If users have facility-specific production data and emission factors they should consult the tier 2 and tier 3 methods found in *2006 IPCC Guidelines for National Greenhouse Gas Inventories*.

9.3.2 Chemical industry emissions

GHG emissions arise from the production of various inorganic and organic chemicals, including:

- Ammonia
- Nitric acid
- Adipic acid
- Caprolactam, glyoxal, and glyoxylic acid
- Carbide
- Titanium dioxide
- Soda ash

Emissions from the chemical industry depend on the technology used. Cities need to know:

- Major chemical production industry within its community boundary
- Annual mineral product output and raw material consumption in the industrial process
- Technology used in the industrial process
- Emission factors of different product/raw material in different production technology

Cities should obtain industrial facility data and emission factors from:

- Continuous emissions monitoring (CEM), where emissions are directly measured at all times
- Periodic emissions monitoring undertaken over a period(s) that is reflective of the usual pattern of the plant's operation to derive an emission factor that is multiplied by output to derive emissions
- Irregular sampling to derive an emission factor that is multiplied by output to derive emissions

If a city does not have access to factory-specific data for the chemical industry, IPCC methods are outlined in Table 9.4.

Table 9.4 Calculating chemical industry emissions

Emission sources	GHG emissions	Simplest approach for quantifying emissions	Source of active data	Link to default emission factor calculation
Ammonia production	CO_2	Ammonia production multiplied by fuel emission factor	• Contact the operators or owners of the industrial facilities at which the processes occur and obtain relevant activity data • Contact national inventory compiler to ask for specific production data within the city boundary	Table 3.1 of Page 3.15 from Chapter 3 of Volume 3 of 2006 IPCC Guidelines for National Greenhouse Gas Inventories
Nitric acid production	N_2O	Nitric acid production multiplied by default emission factor		Table 3.3 of Page 3.23 from Chapter 3 of Volume 3 of 2006 IPCC Guidelines for National Greenhouse Gas Inventories
Adipic acid production	N_2O	Adipic acid production multiplied by default emission factor		Table 3.4 of Page 3.15 from Chapter 3 of Volume 3 of 2006 IPCC Guidelines for National Greenhouse Gas Inventories
Caprolactam production	N_2O	Caprolactam production multiplied by default emission factor		Table 3.5 of Page 3.36 from Chapter 3 of Volume 3 of 2006 IPCC Guidelines for National Greenhouse Gas Inventories
Carbride production	CO_2 *and* CH_4	Carbride production multiplied by default emission factor		Table 3.7 of Page 3.44 from Chapter 3 of Volume 3 of 2006 IPCC Guidelines for National Greenhouse Gas Inventories
Titanium dioxide production	CO_2	Titanium slag production multiplied by default emission factor		Table 3.9 of Page 3.49 from Chapter 3 of Volume 3 of 2006 IPCC Guidelines for National Greenhouse Gas Inventories
Soda ash production	CO_2	Soda ash production, or Trona used, multiplied by default emission factor		Table 3.1 of Page 3.15 from Chapter 3 of Volume 3 of 2006 IPCC Guidelines for National Greenhouse Gas Inventories

9.3.3 Emissions from metal industry

GHG emissions can result from the production of iron steel and metallurgical coke, ferroalloy, aluminum, magnesium, lead and zinc.

Emissions from metal industry depend on the technology and raw material type used in production processes. In order to estimate metal industry emissions, cities need to know:

- Major metal production industry within its community boundary
- Annual metal production output and different types of raw material consumption
- Technology used in the metal production process
- Emission factors of different product/raw material in different production technology

Cities should seek data and emission factors from:

- Continuous emissions monitoring (CEM) where emissions are directly measured at all times
- Periodic emissions monitoring that is undertaken over a period(s) that is reflective of the usual pattern of the plant's operation to derive an emission factor that is multiplied by output to derive emissions
- Irregular sampling to derive an emission factor that is multiplied by output to derive emissions

If a city does not have access to factory-specific data for the metal industry, IPCC methods are outlined in Table 9.5.

Table 9.5 Metal industry

Metal production	**GHG emissions**	**Simplest approach for quantifying emissions**	**Source of active data**	**Link to default emission factor calculation**
Metallurgical coke production	CO_2, CH_4	Assume that all coke made onsite at iron and steel production facilities is used onsite. Multiply default emission factors by coke production to calculate CO_2 and CH_4 emissions	Governmental agencies responsible for manufacturing statistics, business or industry trade associations, or individual iron and steel companies	Table 4.1 and Table 4.2 from Chapter 4 of Volume 3 of 2006 IPCC Guidelines for National Greenhouse Gas Inventories
Iron and steel production		Multiply default emission factors by iron and steel production data		
Ferroalloy production	CO_2, CH_4	Multiply default emission factors by ferroalloy product type		Table 4.5 and Table 4.7 from Chapter 4 of Volume 3 of 2006 IPCC Guidelines for National Greenhouse Gas Inventories
Aluminum production	CO_2	Multiply default emission factors by aluminum product by different process	Aluminum production facilities	Table 4.10 from Chapter 4 of Volume 3 of 2006 IPCC Guidelines for National Greenhouse Gas Inventories
Magnesium production	CO_2	Multiply default emission factors by Magnesium product by raw material type	The magnesium production, casted/handled data and raw material type might be difficult to obtain. Inventory compiler may consult industry associations such as the International Magnesium Association.	Table 4.19 from Chapter 4 of Volume 3 of 2006 IPCC Guidelines for National Greenhouse Gas Inventories
	SF_6	Assume all SF6 consumption in the magnesium industry segment is emitted as SF Estimate SF6 by multiplying default emission factors by total amount of magnesium casted or handled.		Table 4.20 from Chapter 4 of Volume 3 of 2006 IPCC Guidelines for National Greenhouse Gas Inventories
	HFC and other GHG emissions[58]	For HFC and other GHG gases, collect direct measurements or meaningful indirect data		Not applicable
Lead production	CO_2	Multiply default emission factors by lead products by sources and furnace type	Governmental agencies responsible for manufacturing statistics, business or industry trade associations, or individual iron and steel companies	Table 4.21 from Chapter 4 of Volume 3 of 2006 IPCC Guidelines for National Greenhouse Gas Inventories
Zinc production	CO_2	Multiply default emission factors by zinc production		Table 4.24 from Chapter 4 of Volume 3 of 2006 IPCC Guidelines for National Greenhouse Gas Inventories

[58] Others include fluorinated ketone and various fluorinated decomposition products e.g., PFCs

9.4 Guidance on calculating emissions from product use

Products such as refrigerants, foams or aerosol cans can release potent GHG emissions. Hydrofluorocarbons (HFCs), for example, are used as alternatives to ozone depleting substances (ODS) in various types of product applications. Similarly, sulfur hexafluoride (SF_6) and N_2O are present in a number of products used in industry (e.g., electrical equipment and propellants in aerosol products), and used by end-consumers (e.g., running shoes and anesthesia). The following methodological guide is listed according to the type of common product uses.

9.4.1 Non-energy products from fuels and solvent use

This section provides methods for estimating emissions from the use of fossil fuels as a product for primary purposes (but not for combustion or energy production). The main type of fuel usage and their emissions can been seen in Table 9.6.

Table 9.6 Non-energy product uses of fuels and other chemical products

Types of fuels used	Examples of non-energy uses	Gases covered in this chapter	
		CO_2	NMVOC, CO
Lubricants	Lubricants used in transportation and industry	X	
Paraffin waxes	Candles, corrugated boxes, paper coating, board sizing, adhesives, food production, packaging	X	
Bitumen; road oil and other petroleum diluents	Used in asphalt production for road paving		X
White spirit[59], kerosene[60], some aromatics	As solvent, e.g., for surface coating (paint), dry cleaning		X

Fuel and solvents are consumed in industrial processes. To estimate emissions on a mass-balance approach, cities need to know:

- Major fuel and solvent used within its community boundary
- Annual consumption of fuels and solvent
- Emission factors for different types of fuel and solvent consumption

Cities should obtain facility-specific fuel/solvent consumption data and their respective uses with city-specific emission factors. If unavailable, IPCC methods are detailed in Table 9.7.

CO_2 emissions from all product uses can be estimated by following Equation 9.5, where:

Equation 9.5 CO2 emissions from non-energy product uses

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[59] Also known as mineral turpentine, petroleum spirits, or industrial spirit ('SBP').
[60] Also known as paraffin or paraffin oils (UK, South Africa).

$$CO_2\ Emissions = \sum_i (NEU_i \bullet CC_i \bullet ODU_i) \bullet 44/12$$

NEU_i	=	non-energy use of fuel *i*, TJ
CC_i	=	specific carbon content of fuel *i*, tonne C/TJ (=kg C/GJ)
ODU_i	=	ODU factor for fuel *i*, fraction
44/12	=	mass ratio of CO_2/C

Source: Equation adapted from *2006 IPCC Guidelines for National Greenhouse Gas Inventories* Volume 3 Industrial Processes and Product Use available at: www.ipcc-nggip.iges.or.jp/public/2006gl/vol3.html

In this equation, ODU represents the fraction of fossil fuel carbon that is *oxidized during use* (ODU), e.g., actual co-combustion of the fraction of lubricants that slips into the combustion chamber of an engine. The sources of data and default value links can be found in Table 9.7.

Table 9.7 Non-energy product emissions

Types of fuels used	Examples of non-energy uses	GHG emissions	Source of active data	Link to default emission factor calculation
Lubricants	Lubricants used in transportation and industry	CO_2	Basic data on non-energy products used in a country may be available from production, import and export data and on the energy/non-energy use split in national energy statistics.	Method 1, Chapter 5 of Volume 3 of 2006 IPCC Guidelines for National Greenhouse Gas Inventories (p. 5.9)
Paraffin waxes	Candles, corrugated boxes, paper coating, board sizing, adhesives, food production, packaging			Chapter 5 of Volume 3 of 2006 IPCC Guidelines for National Greenhouse Gas Inventories (section 5.3.2.2, page 5.12)

9.4.2 Calculating emissions from the electronics industry

This section includes methods to quantify GHG emissions from semiconductors, thin-film-transistor flat panel displays, and photovoltaic manufacturing (collectively termed 'electronics industry'). Several advanced electronics manufacturing processes utilize fluorinated compounds (FC) for plasma etching intricate patterns, cleaning reactor chambers, and temperature control, all of which emit GHGs.

To estimate the fluorinated gas emissions from the electronics industry, cities need to know:

- Major electronic production industries within its community boundary
- Annual production capacity of the industrial facility
- FC emission control technology used
- Gas fed-in and destroyed by the FC emission control system

Cities should contact electronic production facilities to obtain facility-specific emissions data. If facility-specific data are not available, cities can use IPCC methods outlined in Table 9.8.

Table 9.8 Calculating emissions from the electronics industry

Electronics production processes	GHG emissions	Simplest approach for quantifying emissions	Source of active data	Link to default emission factor calculation
Etching and CVD cleaning for semiconductors, liquid crystal displays and photovoltaic	CF_4, C_2F_6, C_3F_8, c-C_4F_8, c-C_4F_8O, C_4F_6, C_5F_8, CHF_3, CH_2F_2, NF_3, SF_6	Generic emissions factors are multiplied by the annual capacity utilization and the annual manufacturing design capacity of substrate processes	Inventory compilers will need to determine the total surface area of electronic substrates processed for a given year. Silicon consumption may be estimated using an appropriate edition of the World Fab Watch (WFW) database, published quarterly by Semiconductor Equipment & Materials International (SEMI).[17] The database contains a list of plants (production as well as R&D, pilot plants, etc.) worldwide, with information about location, design capacity, wafer size and much more. Similarly, SEMI's 'Flat Panel Display Fabs on Disk' database provides an estimate of glass consumption for global TFT-FPD manufacturing	Table 6.2,Page 6.16 from Chapter 6 of Volume 3 of 2006 IPCC Guidelines for National Greenhouse Gas Inventories
Heat transfer fluids		Generic emissions factors are multiplied by the average capacity utilization and design capacity		

9.4.3 Emissions from fluorinated substitutes for ozone depleting substances

Hydrofluorocarbons (HFCs) and, to a very limited extent, perfluorocarbons (PFCs), are serving as alternatives to ozone depleting substances (ODS) being phased out under the Montreal Protocol. Current and expected application areas of HFCs and PFCs include[61]:

- Refrigeration and air conditioning
- Fire suppression and explosion protection
- Aerosols
- Solvent cleaning
- Foam blowing
- Other applications[62]

To estimate GHG emissions from these products, cities need to know:

- Major industry that use fluorinated substitutes within its community boundary
- Fluorinate gas purchase record by the major industry and their application

For accuracy, a city should contact a related facility to get plant-specific purchase and application data. Cities can use IPCC methods in Table 9.9 for default activity data and emission factors.

[61] (IPCC/TEAP, 2005)

[62] HFCs and PFCs may also be used as ODS substitutes in sterilization equipment, for tobacco expansion applications, and as solvents in the manufacture of adhesives, coating and inks.

Table 9.9 Substitutes for ozone depleting substances

Substitutes for ozone depleting substances	GHG emissions	Simplest approach for quantifying emissions	Source of active data	Link to default emission factor calculation
Substitutes for ozone depleting substances	HFC-23, HFC-32, HFC-125, HFC-134a, HFC-143a, HFC-152a, HFC-227ea, HFC-236fa, HFC-245fa, HFC-365mfc, HFC-43-10mee, PFC-14 (CF4), PFC-116 (C2F6), PFC-218 (C3F8), PFC-31-10 (C4F10), PFC-51-144 (C6F14)	Emission-factor approach: • Data on chemical sales by application • Emission factors by application Mass-balance approach: • Data on chemical sales by application • Data on historic and current equipment sales adjusted for import/export by application	Quantity of each chemical sold as substitutes for ozone-depleting substances. Data on both domestic and imported substitutes quantities should be collected from suppliers.	Users can search the IPCC Emissions Factor Database (EFDB) for datasets

Box 9.1 Consumption-based assumption on emissions from fluorinated substitutes for ozone depleting substances

A notable feature of these product uses is that, in almost all cases, significant time can elapse between the manufacture of the product and the release of the greenhouse gas. In other words, GHG emissions will not be released during product production but rather during the usage period and away from the production factory. If possible, local governments should take a bottom-up approach by collecting product purchase and consumption information according to product type, technology applied, and information for assuming "actual" emissions generated within their geographic boundary.

To this end, city governments may conduct a survey to obtain the following information:

1. The prevailing product types containing fluorinated substitutes used within the city boundary
2. Average duration of those products served within the city boundary
3. Average emitting rate of the fluorinated substitute in prevailing products

But to avoid complexity and huge uncertainty, this bottom-up approach will not be introduced here. In this report, assumption is based on the total GHG emissions consumed during the product production period and all data collected are from the product producer.

10.0 Agriculture, Forestry and Other Land Use

The Agriculture, Forestry and Other Land Use (AFOLU) sector produces GHG emissions through a variety of pathways. Land use changes that alter the composition of the soil, methane produced in the digestive processes of livestock, and nutrient management for agricultural purposes each contribute to a city's GHG emissions.

Requirements in this chapter:

For BASIC+: Cities shall report all GHG emissions resulting from the AFOLU sector within the city boundary in scope 1.

10.1 Defining boundaries

Scope 1: **In-boundary emissions from agricultural activity, land use and land use change within the city boundary**

Note GHG emissions associated with the manufacture of nitrogen fertilizers, which account for a large portion of agricultural emissions, are not counted under AFOLU. IPCC guidelines allocate these emissions to IPPU.

Scope 2: **Not occurring**

Emissions from use of grid-supplied energy in buildings and vehicles shall be reported in stationary energy and transportation.

Scope 3: **Not occurring**

Emissions from land-use activities outside the city are not included in the assessment boundary but may be reported under "Other" scope 3 emissions.

10.2 Defining the emission source

Given the highly variable nature of land-use and agricultural emissions across geographies, GHG emissions from AFOLU are amongst the most complex categories for GHG accounting. Some cities, where there are no measurable agricultural activities or managed lands within the city boundary, may have no significant source of AFOLU emissions. IPCC divides AFOLU activities into three categories:

- Livestock
- Land
- Aggregate sources and non-CO_2 emissions sources on land

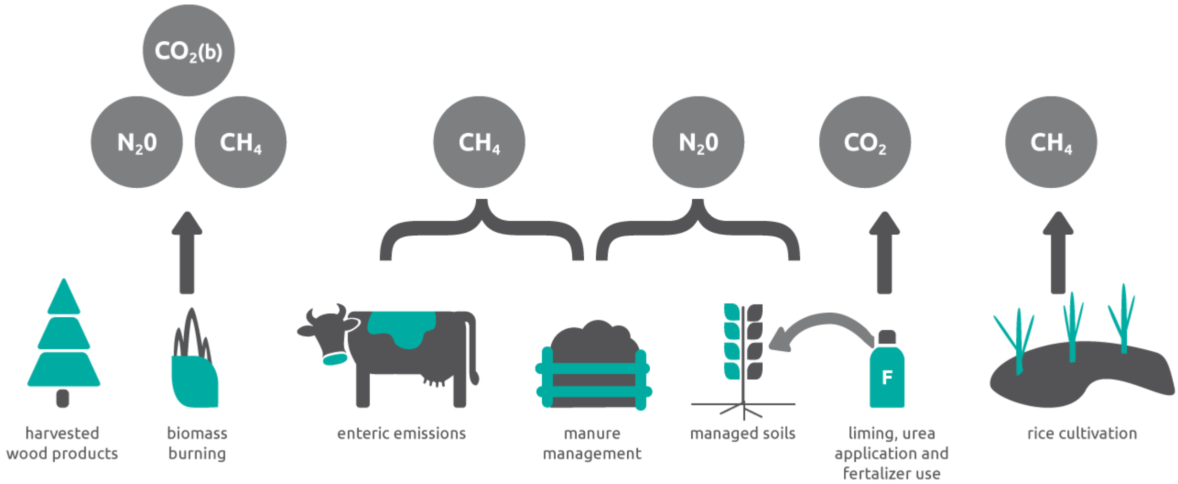
Table 10.1 AFOLU summary table

GHG emission source	Scope 1	Scope 2	Scope 3
	Emissions from agricultural, other land-use and land-use-change		
AGRICULTURE, FORESTRY AND OTHER LAND USE			
Livestock	V.1		

Land	V.2		
Aggregate sources and non-CO2 emission sources on land	V.3		

Multiple methodologies can be used to quantify AFOLU emissions. Guidance provided in this chapter is consistent with IPCC Tier 1 methodologies, unless otherwise specified. The Tier 1 methodologies involve using default IPCC data, while the Tier 2 methodologies involve using country-specific data. Where country-specific data is readily available, these should be used. Alternatively, default IPCC data should be used. More complete guidance can be found in the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* and the *IPCC Good Practice Guidance for Land Use, Land Use Change and Forestry (2013)*.

Figure 10.1 Overview of AFOLU emission sources



10.3 Emissions from livestock

Livestock production emits CH_4 (methane) through enteric fermentation, and both CH_4 and N_2O through management of their manure. CO_2 emissions from livestock are not estimated because annual net CO_2 emissions are assumed to be zero – the CO_2 photosynthesized by plants is returned to the atmosphere as respired CO_2. A portion of the C is returned as CH_4 and for this reason CH_4 requires separate consideration.

Table 10.2 Livestock emission sources and corresponding IPCC references

Category	Emission sources	2006 IPCC Reference
Livestock	Enteric fermentation	Volume 4; Chapter 10; Section 10.3
	Manure management	Volume 4; Chapter 10; Section 10.4-5

10.3.1 Enteric fermentation

The amount of CH_4 emitted by enteric fermentation is driven primarily by the number of animals, the type of digestive system, and the type and amount of feed consumed. Methane emissions can be estimated by multiplying the number of livestock for each animal type by an emission factor (see Equation 10.1).

Equation 10.1 CH_4 emissions from enteric fermentation

$$CH_4 = N_{(T)} * EF_{(Enteric,T)} * 10^{-3}$$

Where:

CH_4		CH_4 emissions in metric tons	Computed
T	=	Species / Livestock category	User input
N	=	Number of animals (head)	User input
EF	=	Emission factor for enteric fermentation (kg of CH_4 per head per year)	User input or default values

Source: Adapted from *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, Volume 4, Agriculture, Forestry and Other Land Use. Available at: www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

Activity data on livestock can be obtained from various sources such as government and agricultural industry. If such data are not available, estimates may be made based on survey and land use data. Livestock should be disaggregated by animal type, consistent with IPCC categorization: Cattle (dairy and other); Buffalo; Sheep; Goats; Camels; Horses; Mules and Asses; Deer; Alpacas; Swine; Poultry; and Other. Country-specific emission factors should be used, where available. Alternatively default IPCC emission factors may be used.[63]

10.3.2 Manure management

CH_4 is produced by the decomposition of manure under anaerobic conditions, during storage and treatment, whilst direct N_2O emissions occur via combined nitrification and denitrification of nitrogen contained in the manure. The main factors affecting CH_4 emissions are the amount of manure produced and the portion of the manure that decomposes anaerobically. The former depends on the rate of waste production per animal and the number of animals, and the latter on how the manure is managed. The emission of N_2O from manure during storage and treatment depends on the nitrogen and carbon content of manure, and on the duration of the storage and type of treatment. The term 'manure' is used here collectively to include both dung and urine (i.e., the solids and the liquids) produced by livestock. Emissions associated with the burning of dung for fuel shall be reported under Stationary Energy, or under Waste if burned without energy recovery.

CH_4 emissions from manure management

[63] See IPCC 2006 Guidelines, Volume 4, Chapter 10 Emissions from Livestock and Manure Management. Available at: www.ipcc-nggip.iges.or.jp/public/2006gl/vol4

CH_4 emissions from manure management systems are temperature dependent. Calculating CH_4 emissions from manure management, therefore, requires data on livestock by animal type and average annual temperature, in combination with relevant emission factors (see Equation 10.2).

Equation 10.2 CH_4 emissions from manure management

$$CH_4 = (N_{(T)} * EF_{(T)} * 10^{-3})$$

Where:

CH4	=	CH4 emissions in metric tons
T	=	Livestock category
$N_{(T)}$	=	Number of animals for each livestock category
$EF_{(T)}$	=	Emission factor for manure management (kg per head per year)

Source: Equation adapted from *2006 IPCC Guidelines for National Greenhouse Gas Inventories* Volume 4 Agriculture, Forestry and Other Land Use available at: www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

Livestock numbers and categorization should be consistent with 10.3.1 above. Average annual temperature data can be obtained from international and national weather centers, as well as academic sources. Country-specific temperature-dependent emission factors should be used, where available. Alternatively default IPCC emission factors may be used.[64]

N_2O emissions from manure management

To estimate N_2O emissions from manure management systems – during the storage and treatment of manure before it is applied to land or otherwise used for feed, fuel, or construction purposes – involves multiplying the total amount of N excretion (from all livestock categories) in each type of manure management system by an emission factor for that type of manure management system (see Equation 10.3). This includes the following steps:

1. Collect livestock data by animal type (T)
2. Determine the annual average nitrogen excretion rate per head ($Nex_{(T)}$) for each defined livestock category T
3. Determine the fraction of total annual nitrogen excretion for each livestock category T that is managed in each manure management system S ($MS_{(T,S)}$)
4. Obtain N_2O emission factors for each manure management system S ($EF_{(S)}$)
5. For each manure management system type S, multiply its emission factor ($EF_{(S)}$) by the total amount of nitrogen managed (from all livestock categories) in that system, to estimate N_2O emissions from that manure management system

Emissions are then summed over all manure management systems. Country-specific data may be obtained from the national inventory, agricultural industry and scientific literature.

[64] See *2006 IPCC Guidelines*, Volume 4, Chapter 10, Tables 10A.1 to 10A-9

Alternatively, data from other countries that have livestock with similar characteristics, or IPCC default nitrogen excretion data and default manure management system data may be used.[65]

N_2O emissions generated by manure in the system 'pasture, range, and paddock' (grazing) occur directly and indirectly from the soil, and are reported under the category 'N_2O emissions from managed soils' (see 10.5.4). N_2O emissions associated with the burning of dung for fuel are reported under Stationary Energy (Chapter 6.0), or under Waste and Wastewater (Chapter 8.0) if burned without energy recovery.

Equation 10.3 N_2O emissions from manure management

$$N_2O = [\Sigma_S [\Sigma_T (N_{(T)} * Nex_{(T)} * MS_{(T),(S)})] * EF_{(S)}] * 44/28 * 10^{-3}$$

Where:

N_2O	=	CH_4 emissions in metric tons
S	=	Manure management system (MMS)
T	=	Livestock category
$N_{(T)}$	=	Number of animals for each livestock category
$Nex_{(t)}$	=	Annual N excretion for livestock category T, kg N per animal per year (see Equation 10.4)
MS	=	Fraction of total annual nitrogen excretion managed in MMS for each livestock category
$EF_{(s)}$	=	Emission factor for direct N_2O-N emissions from MMS, kg N_2O-N per kg N in MSS
44/28	=	Conversion of N_2O-N emissions to N_2O emissions

Source: Equation adapted from *2006 IPCC Guidelines for National Greenhouse Gas Inventories* Volume 4 Agriculture, Forestry and Other Land Use available at: www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

Equation 10.4 Annual N excretion rates

$$Nex_{(T)} = N_{rate(T)} * TAM_{(T)} * 10^{-3} * 365$$

Where:

$Nex_{(T)}$	=	Annual N excretion for livestock category T, kg N per animal per year
$N_{rate(T)}$	=	Default N excretion rate, kg N per 1000kg animal per day
$TAM_{(T)}$	=	Typical animal mass for livestock category T, kg per animal

Source: Equation adapted from *2006 IPCC Guidelines for National Greenhouse Gas Inventories* Volume 4 Agriculture, Forestry and Other Land Use available at: www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

[65] See *2006 IPCC Guidelines* Volume 4, Chapter 10 Emissions from Livestock and Manure Management, Tables 10.19, and 10.21. Available at: www.ipcc-nggip.iges.or.jp/public/2006gl/vol4

Note that emissions from liquid/slurry systems without a natural crust cover, anaerobic lagoons, and anaerobic digesters are considered negligible based on the absence of oxidized forms of nitrogen entering these systems combined with the low potential for nitrification and denitrification to occur in the system.

10.4 Emissions from land use and land-use change

IPCC divides land-use into six categories: forest land; cropland; grassland; wetlands; settlements; and other (see Table 10.3). Emissions and removals of CO_2 are based on changes in ecosystem C stocks and are estimated for each land-use category (see Equation 10.5). This includes both land remaining in a land-use category as well as land converted to another use. C stocks consist of above-ground and below-ground biomass, dead organic matter (dead wood and litter), and soil organic matter.

Table 10.3 Land use categories and corresponding IPCC references

Category	Definition	2006 IPCC Reference
Forest land	All land with woody vegetation consistent with thresholds used to define forest land in national inventory	Volume 4; Chapter 4
Cropland	Cropped land, including rice fields, and agro-forestry systems where the vegetation structure falls below the thresholds for forest land	Volume 4; Chapter 5
Grassland	Rangelands and pasture land that are not considered cropland, and systems with woody vegetation and other non-grass vegetation that fall below the threshold for forest land	Volume 4; Chapter 6
Wetlands	Areas of peat extraction and land that is covered or saturated by water for all or part of the year	Volume 4; Chapter 7
Settlements	All developed land, including transportation infrastructure and human settlements of any size	Volume 4; Chapter 8
Other	Bare soil, rock, ice, and all land areas that do not fall into any of the other five categories	Volume 4; Chapter 9

Equation 10.5 Carbon emissions from land use and land-use change

$$\Delta C_{AFOLU} = \Delta C_{FL} + \Delta C_{CL} + \Delta C_{GL} + \Delta C_{WL} + \Delta C_{SL} + \Delta C_{OL}$$

Where:

ΔC	=	Change in carbon stock
AFOLU	=	Agriculture, Forestry and Other Land Use
FL	=	Forest land

CL	=	Cropland
GL	=	Grassland
WL	=	Wetlands
SL	=	Settlements
OL	=	Other land

Source: Equation adapted from *2006 IPCC Guidelines for National Greenhouse Gas Inventories* , Volume 4 Agriculture, Forestry and Other Land Use, Section 2.2.1, eq 2.1. Available at: www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

Estimating changes in carbon depends on data and model availability, and resources to collect and analyze information. The GPC recommends cities adopt a simplified approach that consists of multiplying net annual C stock change for different land-use (and land-use-change) categories by surface area.

Equation 10.6 CO_2 emissions from land use and land-use change

$$CO_2 = \Sigma_{LU}[Flux_{LU} * Area_{LU}]$$

Where:

GHG	=	GHG emissions in metric tons CO_2
Area	=	Surface area of city by land-use category, km2
Flux	=	Net annual CO_2 flux per land use category, metric tons CO_2 per km2
LU	=	Land-use category

Land-use categorization by surface area can be obtained from national agencies or local government using land zoning or remote sensing data. These categorizations will need to be aligned to the definitions provided in Table 10.3. Some lands can be classified into one or more categories due to multiple uses that meet the criteria of more than one definition. However, a ranking has been developed for assigning these cases into a single land-use category. The ranking process is initiated by distinguishing between managed and unmanaged lands. The managed lands are then assigned, from highest to lowest priority, in the following manner: Settlements > Cropland > Forest Land > Grassland > Wetlands > Other Land.

In addition to the current land use, any land-use changes within the last 20 years will need to be determined. If the land-use change took place less than 20 years prior to undertaking the assessment, land is considered to have been converted. In this case, assessment of GHG emissions takes place on the basis of equal allocation to each year of the 20-year period. Large quantities of GHG emissions can result as a consequence of a change in land use. Examples include change of use from agriculture (e.g., urban farms) or parks, to another use (e.g., industrial development). When the land use is changed, soil carbon and carbon stock in vegetation can be lost as emission of CO_2.

Next, all land should be assigned to one of the categories listed in Table 10.4. Lands stay in the same category if a land-use change has not occurred in the last 20 years. Otherwise, the land is classified as 'converted' (e.g., Cropland converted to Forest land) based on the current use and most recent use before conversion to the current use.

Table 10.4 Land use categories

	Forest land	Cropland	Grassland	Wetlands	Settlements	Other
Forest Land	Forest land remaining Forest land	Forest land converted to Cropland	Forest land converted to Grassland	Forest land converted to Wetlands	Forest land converted to Settlements	Forest land converted to Other land
Cropland	Cropland converted to Forest land	Cropland remaining Cropland	Cropland converted to Grassland	Cropland converted to Wetlands	Cropland converted to Settlements	Cropland converted to Other land
Grassland	Grassland converted to Forest land	Grassland converted to Cropland	Grassland remaining Grassland	Grassland converted to Wetlands	Grassland converted to Settlements	Grassland to Other land
Wetlands	Wetlands converted to Forest land	Wetlands converted to Cropland	Wetlands converted to Grassland	Wetlands remaining Wetlands	Wetlands converted to Settlements	Wetlands converted to Other land
Settlements	Settlements converted to Forest land	Settlements converted to Cropland	Settlements converted to Grassland	Settlements converted to Wetlands	Settlements remaining Settlements	Settlements converted to Other land
Other	Other land converted to Forest land	Other converted to Cropland	Other land converted to Grassland	Other land converted to Wetlands	Other land converted to Settlements	Other land remaining Forest land

Finally, average annual C stock change data (CO_2 flux per km^2) for all relevant land-use (and land-use change) categories need to be determined and multiplied by the corresponding surface area of that land use. Net emissions are then summed across all categories. Default data on annual C stock change can be obtained from the country's national inventory reporting body, United Nations Framework Convention on Climate Change (UNFCCC) reported GHG emissions for countries, IPCC, and other peer-reviewed sources.

IPCC guidance provides the option of calculating all AFOLU GHG emissions consolidated by land-use category, because certain AFOLU data are not easily disaggregated by land-use category (e.g., CH_4 from rice cultivation could be counted in cropland or counted separately). Cities should make clear if any of the emission sources listed under Table 10.4 are included in Table 10.5.

10.5 Aggregate sources and non-CO_2 emissions sources on land

Other sources of GHG emissions from land required for IPCC reporting are detailed below. This includes rice cultivations, fertilizer use, liming, and urea application, which can make up a significant portion of a city's AFOLU emissions.

Table 10.5 Aggregate sources and non-CO_2 emissions sources on land

Category	Emission sources	2006 IPCC Reference
Aggregate sources and non-CO_2 emissions sources on land	GHG emissions from biomass burning	Volume 4; Chapters 4-9
	Liming	Volume 4; Chapter 11; Section 11.3
	Urea application	Volume 4; Chapter 11; Section 11.4
	Direct N_2O from managed soils	Volume 4; Chapter 11; Section 11.2.1
	Indirect N_2O from managed soils	Volume 4; Chapter 11;

		Section 11.2.2
	Indirect N_2O from manure management	Volume 4; Chapter 10; Section 10.5.1
	Rice cultivations	Volume 4; Chapter 5; Section 5.5
	Harvested wood products	Volume 4; Chapter 12

10.5.1 GHG emissions from biomass burning

Where biomass is burned for energy, the non-CO_2 emissions shall be reported under scope 1 for Stationary Energy (see Chapter 6.0), while the CO_2 emissions are reported separately in CO_2 (biogenic). However, where biomass is burned without energy recovery, such as periodic burning of land or accidental wildfires, and these activities aren't included in 10.4, GHG emissions should be reported here.

Equation 10.7 GHG emissions from biomass burning

$$GHG = A * M_B * CF * EF \div 1000$$

Where:

GHG	=	GHG emissions in metric tons of CO_2 equivalent
A	=	Area of burnt land in hectares
M_B	=	Mass of fuel available for combustion, tonnes per hectare. This includes biomass, ground litter and dead wood. NB The latter two may be assumed to be zero except where this a land-use change.
CF	=	Combustion factor (a measure of the proportion of the fuel that is actually combusted)
EF	=	Emission factor, g GHG per kg of dry matter burnt

Source: Equation adapted from *2006 IPCC Guidelines for National Greenhouse Gas Inventories* Volume 4 Agriculture, Forestry and Other Land Use available at: www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

Country-specific factors should be used where available. Alternatively, default IPCC values may be used for M_B, CF and EF.[66]

10.5.2 Liming

Liming is used to reduce soil acidity and improve plant growth in managed systems, particularly agricultural lands and managed forests. Adding carbonates to soils in the form of lime (e.g., calcic limestone ($CaCO_3$), or dolomite ($CaMg(CO_3)_2$) leads to CO_2 emissions as the carbonate limes dissolve and release bicarbonate ($2HCO_3$-), which evolves into CO_2 and water (H_2O). Equation 10.8 sets out the formula for estimating CO_2 emissions from liming. The total amount

[66] These are listed the *2006 IPCC Guidelines*, Volume 4 Agriculture, Forestry and Other Land Use, Chapter 2 General Methodologies Applicable to Multiple Land-Use Categories; Tables 2.4, 2.5 and 2.6. Available at: www.ipcc-nggip.iges.or.jp/public/2006gl/vol4

of carbonate containing lime applied annually to soils in the city will need to be estimated, differentiating between limestone and dolomite.

Equation 10.8 CO_2 emissions from liming		
$CO_2 = ((M_{Limestone} * EF_{Limestone}) + (M_{Dolomite} * EF_{Dolomite})) * 44/12$ Where:		
CO_2	=	CO_2 emissions in metric tons
M	=	Amount of calcic limestone ($CaCO_3$) or dolomite ($CaMg(CO_3)_2$), tonnes per year
EF	=	Emission factor, tonne of C per tonne of limestone or dolomite
44/12	=	Conversion of C stock changes to CO_2 emissions
Source: Equation adapted from *2006 IPCC Guidelines for National Greenhouse Gas Inventories* Volume 4 Agriculture, Forestry and Other Land Use available at: www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html		

Activity data may be obtained from regional or national usage statistics, or may be inferred from annual sales under the assumption that all lime sold within the city is applied to land within the city that year. Note, if lime is applied in a mixture with fertilizers, the proportion used should be estimated. Default emission factors of 0.12 for limestone and 0.13 for dolomite should be used if emission factors derived from country-specific data are unavailable.

10.5.3 Urea application

The use of urea ($CO(NH_2)_2$) as fertilizer leads to emissions of CO_2 that were fixed during the industrial production process. Urea in the presence of water and urease enzymes is converted into ammonium (NH_{4+}), hydroxyl ion (OH), and bicarbonate (HCO_{3-}). The bicarbonate then evolves into CO_2 and water.

Equation 10.9 CO_2 emissions from urea fertilization		
$CO_2 = M * EF * 44/12$ Where:		
CO_2	=	CO_2 emissions in metric tons
M	=	Amount of urea fertilization, tonnes urea per year
EF	=	Emission factor, tonne of C per tonne of urea
44/12	=	Conversion of C stock changes to CO_2 emissions
Source: Equation adapted from *2006 IPCC Guidelines for National Greenhouse Gas Inventories* Volume 4 Agriculture, Forestry and Other Land Use available at: www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html		

A default emission factor of 0.20 for urea should be used if emission factors derived from country-specific data are unavailable.

10.5.4 Direct N_2O from managed soils

Agricultural emissions of N_2O result directly from the soils to which N is added/released and indirectly through the volatilization, biomass burning, leaching and runoff of N from managed soils. Direct emissions of N_2O from managed soils are estimated separately from indirect emissions, though using a common set of activity data. Tier 1 methodologies do not take into account different land cover, soil type, climatic conditions or management practices. Cities that have data to show that default factors are inappropriate for their country should utilize Tier 2 or Tier 3 approaches.

Equation 10.10 Direct N_2O from managed soils

$$N_2O_{Direct} = (N_2O\text{-}N_{N\ inputs} + N_2O\text{-}N_{OS} + N_2O\text{-}N_{PRP}) * 44/28 * 10^{-3}$$

Where:

N_2O_{Direct}	=	Direct N_2O emissions produced from managed soils, in metric tons
$N_2O\text{-}N_{N\ inputs}$	=	Direct N_2O-N emissions from N inputs to managed soils, kg N_2O-N per year
$N_2O\text{-}N_{OS}$	=	Direct N_2O-N emissions from managed inorganic soils, kg N_2O-N per year
$N_2O\text{-}N_{PRP}$	=	Direct N_2O-N emissions from urine and dung inputs to grazed soils, kg N_2O-N per year
44/28	=	Molar conversion of N (N_2O-N) to N_2O

Source: Equation adapted from *2006 IPCC Guidelines for National Greenhouse Gas Inventories* Volume 4 Agriculture, Forestry and Other Land Use available at: www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

Equation 10.11 Direct N_2O-N from managed soils

$$N_2O\text{-}N_{N\ inputs} = [[(F_{SN} + F_{ON} + F_{CR} + F_{SOM}) * EF_1] + [(F_{SN} + F_{ON} + F_{CR} + F_{SOM})_{FR} * EF_{1FR}]]$$

Where

$N_2O\text{-}N_{N\ inputs}$	=	Direct N_2O-N emissions from N inputs to managed soils, kg N_2O-N per year
F_{SN}	=	Amount of synthetic fertilizer N applied to soils, kg N per year
F_{ON}	=	Amount of animal manure, compost, sewage sludge and other organic N additions applied to soils (Note: If including sewage sludge, cross-check with Waste sector to ensure there is no double counting of N_2O emissions from the N in sewage sludge), kg N per year. See Equation 10.14
F_{CR}	=	Amount of N in crop residues (above-ground and below-ground), including N-fixing crops, and from forage/pasture renewal, returned to soils, kg N per year. See Equation 10.17
F_{SOM}	=	Annual amount of N in mineral soils that is mineralized, in association with loss of soil C from soil organic matter as a result of changes to land use or management, kg N per year. See Equation 10.18
EF_1	=	Emission factor for N_2O emissions from N inputs, kg N_2O–N (kg N input)-1
EF_{1FR}	=	Emission factor for N_2O emissions from N inputs to flooded rice, kg N_2O–N

		(kg N input)-1
Source: Equation adapted from *2006 IPCC Guidelines for National Greenhouse Gas Inventories* Volume 4 Agriculture, Forestry and Other Land Use available at: www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html		

Equation 10.12 Direct N_2O-N from managed inorganic soils

$$N_2O\text{-}N_{OS} = [(F_{OS,CG,Temp} * EF_{2CG,Temp}) + (F_{OS,CG,Trop} * EF_{2CG,Trop}) + (F_{OS,F,Temp,NR} * EF_{2F,Temp,NR}) + (F_{OS,F,Temp,NP} * EF_{2F,Temp,NP}) + (F_{OS,F,Trop} * EF_{2F,Trop})$$

Where:

$N_2O\text{-}N_{OS}$	=	Direct N_2O-N emissions from managed inorganic soils, kg N_2O-N per year
F_{OS}	=	Area of managed / drained organic soils, ha (Note: the subscripts CG, F, Temp, Trop, NR and NP refer to Cropland and Grassland, Forest Land, Temperate, Tropical, Nutrient Rich, and Nutrient Poor, respectively)
EF_2	=	Emission factor for N_2O emissions from drained/managed organic soils, kg N_2O–N per hectare per year

Source: Equation adapted from *2006 IPCC Guidelines for National Greenhouse Gas Inventories* Volume 4 Agriculture, Forestry and Other Land Use available at: www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

Equation 10.13 Direct N_2O-N from urine and dung

$$N_2O\text{-}N_{PRP} = [(F_{PRP,CPP} * EF_{3PRP,CPP}) + (F_{PRP,SO} * EF_{3PRP,SO})]$$

Where:

$N_2O\text{-}N_{PRP}$	=	Direct N_2O-N emissions from urine and dung inputs to grazed soils, kg N_2O-N per year
F_{PRP}	=	Annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock, kg N per year (Note: the subscripts CPP and SO refer to Cattle, Poultry and Pigs, and Sheep and Other animals, respectively) See Equation 10.16
EF_{3PRP}	=	Emission factor for N_2O emissions from urine and dung N deposited on pasture, range and paddock by grazing animals, kg N_2O–N (kg N input)-1; (Note: the subscripts CPP and SO refer to Cattle, Poultry and Pigs, and Sheep and Other animals, respectively)

Source: Equation adapted from *2006 IPCC Guidelines for National Greenhouse Gas Inventories* Volume 4 Agriculture, Forestry and Other Land Use available at: www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

Three emission factors (EF) are needed to estimate direct N_2O emissions from managed soils. The first EF (EF_1) refers to the amount of N_2O emitted from the various synthetic and organic N applications to soils, including crop residue and mineralization of soil organic carbon in mineral soils due to land-use change or management. The second EF (EF_2) refers to the amount of N_2O emitted from an area of drained/managed organic soils, and the third EF (EF_{3PRP}) estimates the amount of N_2O emitted from urine and dung N deposited by grazing animals on pasture, range and paddock. Country-specific emission factors should be used, where available. Alternatively default IPCC emission factors may be used.[67]

(a) Applied synthetic fertilizer (F_{SN})

The amount of synthetic fertilizer applied to soils may be collected from national statistics. If country-specific data are not available, data on total fertilizer use by type and by crop from the International Fertilizer Industry Association (IFIA) or the Food and Agriculture Organization of the United Nations (FAO) can be used.

(b) Applied organic N fertilizer (F_{ON})

Equation 10.14 N from organic N additions applied to soils

$$F_{ON} = F_{AM} + F_{SEW} + F_{COMP} + F_{OOA}$$

Where:

F_{ON}	=	Amount of organic N fertilizer applied to soil other than by grazing animals, kg N per year
F_{AM}	=	Amount of animal manure N applied to soils, kg N per year. See Equation 10.15
F_{SEW}	=	Amount of total sewage N applied to soils, kg N per year
F_{COMP}	=	Amount of total compost N applied to soils, kg N per year
F_{OOA}	=	Amount of other organic amendments used as fertilizer, kg N per year

Source: Equation adapted from *2006 IPCC Guidelines for National Greenhouse Gas Inventories* Volume 4 Agriculture, Forestry and Other Land Use available at: www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

Equation 10.15 N from animal manure applied to soils

$$F_{AM} = N_{MMS\_Avb} * [1 - (Frac_{FEED} + Frac_{FUEL} + Frac_{CNST})]$$

Where:

F_{AN}	=	Amount of animal manure N applied to soils, kg N per year
N_{MMS_Avb}	=	Amount of managed manure N available for soil application, feed, fuel of construction, kg N per year
$Frac_{FEED}$	=	Fraction of managed manure used for feed

[67] Table 11.1 in the *2006 IPCC Guidelines*, Volume 4, Chapter 11 N_20 Emissions from Managed Soils, and CO_2 Emissions from Lime and Urea Application. Further equations will need to be applied to estimate the activity data, default values for which can also be found in the *2006 IPCC Guidelines*. Available at: www.ipcc-nggip.iges.or.jp/public/2006gl/vol4

$Frac_{FUEL}$	=	Fraction of managed manure used for fuel
$Frac_{CNST}$	=	Fraction of managed manure used for construction

Source: Equation adapted from *2006 IPCC Guidelines for National Greenhouse Gas Inventories* Volume 4 Agriculture, Forestry and Other Land Use available at: www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

(c) Urine and dung from grazing animals (F_{PRP})

Equation 10.16 N in urine and dung deposited by grazing animals on pasture, range and paddock

$$F_{PRP} = \Sigma_T [(N_{(T)} * Nex_{(T)}) * MS_{(T,PRP)}]$$

Where:

F_{PRP}	=	Amount of urine and dung N deposited on pasture, range, paddock and by grazing animals, kg N per year
$N_{(T)}$	=	Number of head of livestock per livestock category
$Nex_{(T)}$	=	Average N excretion per head of livestock category T, kg N per animal per year
$MS_{(T,PRP)}$	=	Fraction of total annual N excretion for each livestock category T that is deposited on pasture, range and paddock

Source: Equation adapted from *2006 IPCC Guidelines for National Greenhouse Gas Inventories* Volume 4 Agriculture, Forestry and Other Land Use available at: www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

(d) Crop residue N, including N-fixing crops and forage/pasture renewal, returned to soils (F_{CR})

Equation 10.17 N from crop residues and forage/pasture renewal

$$F_{CR} = \Sigma_T [Crop_{(T)} * (Area_{(T)} - Area\ burnt_{(T)} * CF) * Frac_{Renew(T)} * [R_{AG(T)} * N_{AG(T)} * (1 - Frac_{Remove(T)}) + R_{BG(T)} * N_{BG(T)}]]$$

Where:

F_{CR}	=	Amount of N in crop residue returned to soils, kg N per year
$Crop_{(T)}$	=	Harvested dry matter yeield for crop T, kg d.m. per ha
$Area_{(T)}$	=	Total harvested area of crop T, ha per year
Area $burnt_{(T)}$	=	Area of crop burnt, ha per year
CF	=	Combustion factor
$Frac_{Renew(T)}$	=	Fraction of total area under crop T that is renewed. For annual crops $Frac_{Renew} = 1$
$R_{AG(T)}$	=	Ratio of above-ground residues dry matter ($AG_{DM(T)}$) to harvested yield for crop T. $R_{AG(T)} = AG_{DM(T)}) * 1000 / Crop_{(T)}$
$N_{AG(T)}$	=	N content of above-ground residues for crop T, kg N per kg dm
$Frac_{Remove(T)}$	=	Fraction of above-ground residues of crop T removed for purposes such as

		feed, bedding and construction, kg N per kg crop-N. If data for $Frac_{Remove(T)}$ is not available, assume no removal
$R_{BG(T)}$	=	Ratio of below-ground residues to harvested yield for crop T
$N_{BG(T)}$	=	N content of below-ground residues for crop T, kg N per kg dm
T	=	Crop or forage type

Source: Equation adapted from *2006 IPCC Guidelines for National Greenhouse Gas Inventories* Volume 4 Agriculture, Forestry and Other Land Use available at: www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

Default IPCC values for CF, $AG_{DM(T)}$, $N_{AG(T)}$, $R_{BG(T)}$ and $N_{BG(T)}$ can be found in the *2006 IPCC Guidelines*, Volume 4, Chapter 2 Table 2.6 and Chapter 11 Table 11.2.

(e) Mineralized N resulting from loss of soil organic C stocks in mineral soils through land-use change or management practices (F_{SOM})

Equation 10.18 N mineralized in mineral soils as a result of loss of soil C through change in land use or management

$$F_{SOM} = \Sigma_{LU} [(\Delta C_{Mineral,LU} * (1/R)) * 1000]$$

Where:

F_{SOM}	=	Amount of N mineralized in mineral soils as a result of loss of soil carbon through change in land use or management, kg N per year
$\Delta C_{Mineral,LU}$	=	Loss of soil carbon for each land use type (LU), tonnes C (for Tier 1, this will be a single value for all land-uses and management systems)
R	=	C:N ratio of the soil organic matter
LU	=	Land-use and/or management system type

Source: Equation adapted from *2006 IPCC Guidelines for National Greenhouse Gas Inventories* Volume 4 Agriculture, Forestry and Other Land Use available at: www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

A default value of 15 for R, the C:N ratio, may be used for land-use change from Forest Land or Grassland to Cropland, and a default value of 10 may be used for situations involving management changes on Cropland remaining Cropland.

(f) Area of drained/managed organic soils (F_{OS})

Data for the area of managed/drained organic soils may be collected from official national statistics and soil survey organizations, or expert advice may be used

10.5.5 Indirect N_2O from managed soils

Emissions of N_2O also take place through volatilization of N as NH_3 and oxides of N (NO_x), and leaching and runoff from agricultural N additions to managed lands.

Equation 10.19 N_2O from atmospheric deposition of N volatilized from managed

soils

$$N_2O_{(ATD)} = [(F_{SN} * Frac_{GASF}) + ((F_{ON} + F_{PRP}) * Frac_{GASM})] * EF_4 * 44/28 * 10^{-3}$$

Where:

$N_2O_{(ATD)}$	=	Amount of N_2O produced from atmospheric deposition of N volatilized from managed soils in metric tons
F_{SN}	=	Amount of synthetic fertilizer N applied to soils, kg N per year
F_{ON}	=	Amount of animal manure, compost, sewage sludge and other organic N additions applied to soils (Note: If including sewage sludge, cross-check with Waste sector to ensure there is no double counting of N_2O emissions from the N in sewage sludge), kg N per year. See Equation 10.14
F_{PRP}	=	Annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock, kg N per year (Note: the subscripts CPP and SO refer to Cattle, Poultry and Pigs, and Sheep and Other animals, respectively) See Equation 10.16
44/28	=	Molar conversion of N (N_2O-N) to N_2O
$Frac_{GASF}$	=	Fraction of synthetic fertilizer N that volatilizes as NH3 and NOx, kg N volatilized per kg N applied
$Frac_{GASM}$	=	Fraction of applied organic N fertilizer materials (F_{ON}) and of urine and dung N deposited by grazing animals (F_{PRP}) that volatilizes as NH3 and NOx, kg N volatilized per kg N applied or deposited
EF_4	=	Emission factor for N_2O emissions from atmospheric deposition of N on soils and water surfaces, kg N_2O-N per kg NH3-N and NOx-N volatilized

Source: Equation adapted from *2006 IPCC Guidelines for National Greenhouse Gas Inventories* Volume 4 Agriculture, Forestry and Other Land Use available at: www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

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Equation 10.20 N_2O from leaching/runoff from managed soils in regions where leaching/runoff occurs

$$N_2O_{(L)} = [(F_{SN} + F_{ON} + F_{PRP} + F_{CR} + F_{SOM}) * Frac_{LEACH-(H)} * EF_5] * 44/28 * 10^{-3}$$

Where:

$N_2O_{(L)}$	=	Amount of N_2O produced from leaching and runoff of N additions to managed soils in regions where leaching / runoff occurs, in metric tons
$Frac_{LEACH-(H)}$	=	Fraction of all N added to/mineralized in managed soils in regions where leaching/runoff occurs that is lost through leaching and runoff, kg N per kg if N additions
EF_5	=	Emission factor for N_2O emissions from N leaching and runoff, kg N_2O-N per kg N leached and runoff

Source: Equation adapted from *2006 IPCC Guidelines for National Greenhouse Gas Inventories* Volume 4 Agriculture, Forestry and Other Land Use available at: www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

Activity data used in the above two equations is the same as that used to estimate direct N_2O from managed soils. For Equation 10.20, only those amounts in regions where leaching/runoff occurs need to be considered. Default emission, volatilization and leaching factors should be used in the absence of country-specific data.[68]

10.5.6 Indirect N_2O from manure management

Indirect emissions result from volatile nitrogen losses that occur primarily in the forms of NH_3 and NOx. Calculation is based on multiplying the amount of nitrogen excreted (from all livestock categories) and managed in each manure management system by a fraction of volatilized nitrogen (see Equations 10.21 and 10.22). N losses are then summed over all manure management systems.

Equation 10.21 Indirect N_2O emissions due to volatilization of N from manure management

$$N_2O = (N_{volatilization\text{-}MMS} * EF_4) * 44/28 * 10^{-3}$$

Where:

N_2O	=	Indirect N_2O emissions due to volatilization of N from manure management in metric tons
$N_{volatilization\text{-}MMS}$	=	Amount of manure nitrogen that is lost due to volatilization of NH_3 and NOx, kg N per year. See Equation 10.22
EF_4	=	Emission factor for N_2O emissions from atmospheric deposition of N on soils and water surfaces, kg N_2O-N per kg NH_3-N and NOx-N volatilized

Source: Equation adapted from *2006 IPCC Guidelines for National Greenhouse Gas Inventories* Volume 4 Agriculture, Forestry and Other Land Use available at: www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

Equation 10.22 N losses due to volatilization from manure management

$$N_{volatilization\text{-}MMS} = \Sigma_S [\Sigma_T [(N_{(T)} * N_{ex(T)} * MS_{(T,S)}) * (Frac_{GasMS} / 100)_{(T,S)}]]$$

Where:

$N_{volatilization\text{-}MMS}$	=	Amount of manure nitrogen that is lost due to volatilization of NH_3 and NOx, kg N per year
S	=	Manure management system (MMS)
T	=	Livestock category
$N_{(T)}$	=	Number of head of livestock per livestock category

[68] Default factors can be found in the *2006 IPCC Guidelines*, Volume 4, Chapter 11, N_20 Emissions from Managed Soils, and CO_2 Emissions from Lime and Urea Application, Table 11.3. Available at: www.ipcc-nggip.iges.or.jp/public/2006gl/vol4

$Nex_{(T)}$	=	Average N excretion per head of livestock category T, kg N per animal per year
$MS_{(T,S)}$	=	Fraction of total annual N excretion for each livestock category T that is managed in manure management system S
$Frac_{GasMS}$	=	Percent of managed manure nitrogen for livestock category T that volatilizes as NH3 and NOx in the manure management system S, %

Source: Equation adapted from *2006 IPCC Guidelines for National Greenhouse Gas Inventories* Volume 4 Agriculture, Forestry and Other Land Use available at: www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

IPCC default nitrogen excretion data, default manure management system data and default fractions of N losses from manure management systems due to volatilization are listed in the *2006 IPCC Guidelines*, Volume 4, Chapter 10, Annex 10A.2, Tables 10A-4 to 10A-8 and Table 10.22. A default value of 0.01 kg N_2O-N (kg NH3-N + NOx-N volatilized)$^{-1}$ may be used for EF_4.

10.5.7 Rice cultivations

Anaerobic decomposition of organic material in flooded rice fields produces methane (CH_4), which escapes to the atmosphere primarily by transport through rice plants. The amount of CH_4 emitted is a function of the number and duration of the crop grown, water regimes before and during cultivation period, and organic and inorganic soil amendments. CH_4 emissions are estimated by multiplying daily emission factors by cultivation period of rice and harvested areas (see Equation 10.23).

Equation 10.23 CH_4 emissions from rice cultivation

$$CH_{4Rice} = \Sigma_{i,j,k}(EF_{i,j,k} * t_{i,j,k} * A_{i,j,k} * 10^{-6})$$

Where:

CH_{4Rice}	=	Methane emissions from rice cultivation, Gg (i.e., 1000 metric tonnes) CH_4 per year
$EF_{i,j,k}$	=	Daily emission factor for i, j and k conditions, kg CH4 per hectare per year
$t_{i,j,k}$	=	Cultivation period of rice for i, j and k conditions, number of days
$A_{i,j,k}$	=	Harvested area of rice for i, j and k conditions, hectares per year
i,j,k	=	Represent different ecosystems, water regimes, type and amount of organic amendments, and other conditions under which CH4 emissions from rice may vary (e.g. irrigated, rain-fed and upland)

Source: Equation adapted from *2006 IPCC Guidelines for National Greenhouse Gas Inventories* Volume 4 Agriculture, Forestry and Other Land Use available at: www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

The disaggregation of harvested area should cover the following three water regimes, where these occur within the city boundary: irrigated, rain-fed, and upland. However, it is good practice to account for as many different factors influencing CH_4 emissions from rice cultivation (i, j, k etc.), where such data is available. The daily emission factor for each water regime is calculated by multiplying a baseline default emission factor by various scaling factors to account for variability in growing conditions (see Equation 10.24)

Equation 10.24 Adjusted daily emission factors

$$EF_i = EF_c * SF_w * SF_p * SF_o$$

Where:

EF_i	=	Adjusted daily emission factor for a particular harvested area (kg CH_4 per hectare per day)
EF_c	=	Baseline emission factor for continuously flooded fields without organic amendments (kg CH_4 per hectare per day)
SF_w	=	Scaling factor to account for the differences in water regime during the cultivation period
SF_p	=	Scaling factor to account for the differences in water regime in the pre-season before cultivation period
SF_o	=	Scaling factor should vary for both type and amount of organic amendment applied

Source: Equation adapted from *2006 IPCC Guidelines for National Greenhouse Gas Inventories* Volume 4 Agriculture, Forestry and Other Land Use available at: www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

Equation 10.25 Adjusted CH_4 emission scaling factors for organic amendments

$$SF_o = (1 + \Sigma_i ROA_i * CFOA_i)^{0.59}$$

Where:

SF_o	=	Scaling factor should vary for both type and amount of organic amendment applied
ROA_i	=	Application rate or organic amendment *i*, in dry weight for straw and fresh weight for others, tonne per hectare
$CFOA_i$	=	Conversion factor for organic amendment *i*

Source: Equation adapted from *2006 IPCC Guidelines for National Greenhouse Gas Inventories* Volume 4 Agriculture, Forestry and Other Land Use, Chapter 5 (Cropland), equation 5.3. Available at: www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

Activity data are based on harvested area, which should be available from a national statistics agency or local government, as well as complementary information on cultivation period and agricultural practices, which may be estimated from industry or academic sources. Country-specific emission factors should be used where available and may be obtained from the national inventory, agricultural industry and scientific literature. Alternatively, IPCC default values should be used. The IPCC default value for EF_c is 1.30 kg CH_4 per hectare per day.[69]

10.5.8 **Harvested wood products (HWP)**

Harvested wood products (HWP) include all wood material that leaves harvest sites and constitutes a carbon reservoir (the time carbon is held in products will vary depending on the product and its uses). Fuel wood, for example, may be burned in the year of harvest, and many types of paper are likely to have a use life less than five years, including recycling. Wood used for panels in buildings, however, may be held for decades to over 100 years. Discarded HWP can be deposited in solid waste disposal sites where they may subsist for long periods of time. Due to this storage in products in use and in SWDS, the oxidation of HWP in a given year could be less, or potentially more, than the total amount of wood harvested in that year.

2006 IPCC guidelines allow for net emissions from HWP to be reported as zero, if it is judged that the annual change in carbon in HWP stocks is insignificant. The term ‘insignificant’ is defined as being less than the size of any key category. If, however, it is determined that the annual change in carbon in HWP stocks is significant, the Tier 1 methodology outlined in the 2006 IPCC Guidelines should be followed.

[69] Defaults values for SFw and SFp and CFOAi are listed in the *2006 IPCC Guidelines*, Volume 4, Chapter 5, Tables 5.12, 5.13, and 5.14. Available at: www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

Part III: Tracking Changes and Setting Goals

11.0 Setting Goals and Tracking Emissions Over Time

This chapter shows how inventories can be used as the basis for goal setting and performance tracking. Further guidance on setting a mitigation goal and tracking progress over time can be found in the GHG Protocol Mitigation Goals Standard[70], which applies to national, sub-national, and city entities.

11.1 Setting goals and evaluating performance

Developing GHG inventories, setting goals, and tracking progress are part of an interconnected process. Setting reduction or "mitigation" goals can help cities focus efforts on key emission sources, identify innovative mitigation solutions, demonstrate leadership and reduce long-term costs. The type of goal provides the basis against which emissions and emissions reductions are tracked and reported. In general, there are four goal types:

1. Base year goals
2. Fixed level goals
3. Intensity goals
4. Baseline scenario goals

Base year goals represent a reduction in emissions relative to an emissions level in a historical base year. They are typically framed in terms of a percent reduction of emissions, rather than an absolute reduction in emissions.

Fixed levels goals represent a reduction in emissions to an absolute emissions level in a target year. For example, a fixed level goal could be to achieve 200 Mt (million metric tons) CO_2e by 2020. The most common type of fixed level goals are carbon neutrality goals, which are designed to reach zero net emissions by a certain date (though such goals often include the purchase and use of offset credits to compensate for remaining emissions after annual reductions). Fixed levels goals do not include a reference to an emissions level in a baseline scenario or historical base year.

Intensity goals represent a reduction in emissions intensity relative to an emissions intensity level in a historical base year. Emissions intensity is emissions per unit of output. Examples of units of output include gross domestic product (GDP), population, and energy use. Intensity goals are typically framed in terms of a percent reduction of emissions intensity, rather than an absolute reduction in emissions intensity.

Baseline scenario goals represent a reduction in emissions relative to a baseline scenario emissions level. They are typically framed in terms of a percent reduction of emissions from the

[70] www.ghgprotocol.org/mitigation-accounting

baseline scenario, rather than an absolute reduction in emissions. A baseline scenario is a set of reasonable assumptions and data that best describe events or conditions that are most likely to occur in the absence of activities taken to meet a mitigation goal ("business-as-usual").

All goal types, except for fixed level goals, require inventories information at the base year and target year for the goal setting and evaluation. Table 11.1 gives examples of different goal types and minimum inventory need.

Table 11.1 Examples of city goal types and inventory need

Goal type	Example	Minimum inventory need
Base year goals		
Single-year goal	London (UK): By 2025 60% GHG emissions reduction on 1990 levels	Inventory for 1990 and 2025
Multi-year goal	Wellington (New Zealand): Stabilize from 2000 by 2010, 3% GHG emissions reduction by 2012, 30% by 2020, 80% by 2050	Inventory for 2000, 2010, 2012, 2020 and 2050
Fixed level goals	Carbon-neutral is another type of fixed level goal type. Melbourne (Australia) set a target to achieve zero net carbon emissions by 2020, and plans to achieve the goal through internal reductions and purchasing offsets.	In the case of Melbourne, inventory required to determine quantity of offsets necessary to cover remainder of emissions
Intensity goals		
Per capita goal	Belo Horizonte (Brazil): 20% GHG emissions reduction per capita until 2030 from 2007 levels	Inventory for 2007 and 2030
Per GDP goal	China is the major country adopting GHG emissions reduction per unit of GDP goal for cities. For example, Beijing: 17% reduction per unit of GDP in 2015 from 2010 levels	Inventory for 2010 and 2015
Baseline scenario goals	Singapore pledged to reduce GHG emissions to 16% below business-as-usual (BAU) levels by 2020 if a legally binding global agreement on GHG reductions is made. In the meantime, Singapore started implementing measures to reduce emissions by 7% to 11% of 2020 BAU levels.	Inventory for 2020 and a projected BAU inventory for 2020

11.2 Aligning goals with the inventory assessment boundary

Inventory and goal boundaries are mutually influenced. In determining the goal boundary, cities should first take into account the assessment boundary of their GHG inventory to ensure that adequate data exist for tracking and assessing goal progress.

Mitigation goals can apply to a city's overall emissions or to a subset of the gases, scopes, or emission sectors identified in the inventory assessment boundary (Chapter 3.0). Goals incorporating inventory data to establish base year emissions or measure goal progress should use the same geographic boundary as the GHG inventory. Cities may choose to set a sectoral goal as a way to target a specific sector, sub-sector, or group of sectors. For example, a city may establish a goal to reduce emissions from the IPPU sector by 20%. The results of a compiled

GHG inventory, along with a mitigation assessment and any of the city's specific mitigation interests, should determine which parts of the assessment boundary are included or excluded in the goal.

Use of transferable emissions units

Cities may designate a portion of their mitigation goals to be met using transferable emissions units such as offset credits generated from emissions reduction projects. To ensure transparency and prevent "double counting" of emissions reductions, cities must document any sold GHG offsets from projects located within the inventory boundary as well as any credits for the purpose of goal attainment.

11.1 Tracking emissions over time and recalculating emissions

Tracking emissions over time is an important component of a GHG inventory because it provides information on historical emissions trends, and tracks the effects of policies and actions to reduce emissions at the city level. All emissions over time should be estimated consistently, which means that as far as possible, the time series should be calculated using the same methods, data sources and boundary definitions in all years. Using different methods, data or applying different boundaries in a time series could introduce bias because the estimated emissions trend will reflect both real changes in emissions or removals *and* the pattern of methodological refinements.

Cities may undergo significant changes, which will alter a city's historical emissions profile, making meaningful comparisons over time difficult. In order to maintain consistency over time, historic emissions data from a base year inventory will have to be recalculated. Cities shall recalculate base year emissions and emissions for all previous years in the goal period if they encounter significant changes such as the ones listed in Table 11.2.

- **Structural changes in the assessment boundary**. This may be triggered by adjustment in a city's administrative boundary, or changes in inclusion or exclusion of activities within the city boundary. For example, a category previously regarded as insignificant has grown to the point where it should be included in the inventory. But no emissions recalculations are needed for activities that either did not exist in the base year, or reflect a natural increase or decrease in city activities.("organic growth").

- **Changes in calculation methodology or improvements in data accuracy**. A city might report the same sources of GHG emissions as in previous years, but measure or calculate them differently. Changes resulting in significant emission differences should be considered as recalculation triggers, but any changes that reflect real changes in emissions do not trigger a recalculation.

  Sometimes the more accurate data input may not reasonably be applied to all past years, or new data points may not be available for past years. The city may then have to backcast these data points, or the change in data source may simply be acknowledged without recalculation. This acknowledgement should be made in the report each year in order to enhance transparency; otherwise, new users of the report in the two or three years after the change may make incorrect assumptions about the city's performance.

- **Discovery of significant errors.** A significant error, or a number of cumulative errors that are collectively significant, should also be considered as a reason to recalculate emissions.

Table 11.2 Example of recalculation triggers

		Recalculation needed	**No recalculation needed**
Changes in assessment boundary	A community is included in or set aside from a city's administrative boundary	X	
	Change in goal boundary from Basic to Basic+, or from 6 GHGs to 7 GHGs	X	
	Shut down of a power plant		X
	Build of a new cement factory		X
Changes in calculation methodology or improvements in data accuracy	Change in calculation methodology for landfilled MSW from *Mass Balance Method* to the *First Order Decay Method*	X	
	Adoption of more accurate local emission factors instead of a national average for scope 2 emissions	X	
	Change in electricity emission factor due to energy efficiency improvement and growth of renewable energy utilization		X
Discovery of significant errors	Discovery of mistake in units conversion in formula used	X	

Whether recalculation is needed depends on the significance of the changes. The determination of a significant change may require taking into account the cumulative effect on base year emissions of a number of small changes. The GPC makes no specific recommendations as to what constitutes "significant." However, some GHG programs do specify numerical significance thresholds, e.g., the California Climate Action Registry, where the change threshold is 10 percent of the base year emissions, determined on a cumulative basis from the time the base year is established.

In summary, base year emissions – and emissions for other previous years when necessary – should be retroactively recalculated to reflect changes in the city that would otherwise compromise the consistency and relevance of the reported GHG emissions information. Once a city has determined its policy on how it will recalculate base year emissions, it should apply this policy in a consistent manner.

12.0 Managing Inventory Quality and Verification

12.1 Managing inventory quality over time

To manage inventory quality over time, cities should establish a management plan for the inventory process. The design of an inventory management plan should provide for the selection, application, and updating of inventory methodologies as new research becomes available, or the importance of inventory reporting is elevated. This framework focuses on the following institutional, managerial, and technical components of an inventory. It includes data, methods, systems and documentation to ensure quality control and quality assurance throughout the process:

Methods: These are the technical aspects of inventory preparation. Communities should select or develop methodologies for estimating emissions that accurately represent the characteristics of their source categories. The GPC provides many default methods and calculation tools to help with this effort. The design of an inventory program and quality management system should provide for the selection, application, and updating of inventory methodologies as new research becomes available.

Data: This is the basic information on activity levels and emission factors. Although methodologies need to be appropriately rigorous and detailed, data quality is more important. No methodology can compensate for poor quality input data. The design of a community inventory program should facilitate the collection of high quality inventory data and the maintenance and improvement of collection procedures.

Inventory processes and systems: These are the institutional, managerial, and technical procedures for preparing GHG inventories. They include the team and processes charged with the goal of producing a high quality inventory. To streamline GHG inventory quality management, these processes and systems may be integrated, where appropriate, with other city-wide processes related to quality.

Documentation: This is the record of methods, data, processes, systems, assumptions, and estimates used to prepare an inventory. Since estimating GHG emissions is inherently technical (involving engineering and science), high quality, transparent documentation is particularly important to credibility. If information is not credible, or fails to be effectively communicated to either internal or external stakeholders, it will not have value. Communities should seek to ensure the quality of these components at every level of their inventory design.

Quality control

Quality control (QC) is a set of technical activities, which measure and control the quality of the inventory as it is being developed. They are designed to:

- Provide routine and consistent checks to ensure data integrity, correctness, and completeness
- Identify and address errors and omissions
- Document and archive inventory material and record all QC activities

QC activities include accuracy checks on data acquisition and calculations, and the use of approved standardized procedures for emission calculations, measurements, estimating uncertainties, archiving information and reporting. Higher tier QC activities include technical reviews of source categories, activity and emission factor data, and methods.

Quality assurance

Quality assurance (QA) activities include a planned system of review procedures conducted by personnel not directly involved in the inventory compilation/development process. Reviews, preferably performed by independent third parties, should take place when an inventory is finalized following the implementation of QC procedures. Reviews verify that data quality objectives were met and that the inventory represents the best possible estimates of emissions – and sinks given the current state of scientific knowledge and data available.

See Table 11.3 for an outline of procedures for ensuring QA/QC.

Table 11.3 Example QA/QC procedures

Data gathering, input, and handling activities
Check a sample of input data for transcription errors
Identify spreadsheet modifications that could provide additional controls or checks on quality
Ensure that adequate version control procedures for electronic files have been implemented
Others
Data documentation
Confirm that bibliographical data references are included in spreadsheets for all primary data
Check that copies of cited references have been archived
Check that assumptions and criteria for selection of boundaries, base years, methods, activity data, emission factors, and other parameters are documented
Check that changes in data or methodology are documented
Others
Calculating emissions and checking calculations
Check whether emission units, parameters, and conversion factors are appropriately labeled
Check if units are properly labeled and correctly carried through from beginning to end of calculations
Check that conversion factors are correct
Check the data processing steps (e.g., equations) in the spreadsheets
Check that spreadsheet input data and calculated data are clearly differentiated
Check a representative sample of calculations, by hand or electronically
Check some calculations with abbreviated calculations (i.e., back of the envelope calculations)
Check the aggregation of data across source categories, sectors, etc.
Check consistency of time series inputs and calculations
Others

12.2 Verification

Cities may choose to verify their GHG emissions inventory to demonstrate that it has been developed in accordance with the requirements of the GPC, and provide assurance to users that it represents a faithful, true, and fair account of their city's GHG emissions. This can be used to increase credibility of publicly reported emissions information with external audiences and increase confidence in the data used to develop climate action plans, set GHG targets and track progress.

Verification involves an assessment of the completeness, accuracy and reliability of reported data. It seeks to determine if there are any material discrepancies between reported data and data generated from the proper application of the relevant standards and methodologies, by making sure that the reporting requirements have been met, that the estimates are correct and that the data sourced is reliable.

To enable verification, the accounting and reporting principles set out in Chapter 2.0 need to be followed. Adherence to these principles and the presence of transparent, well-documented data (sometimes referred to as an audit trail) are the basis of a successful verification.

While verification is often undertaken by an independent organization (third-party verification), this may not always be the case. Many cities interested in improving their GHG inventories may subject their information to internal verification by staff who are independent of the GHG accounting and reporting process (self-verification). Both types of verification should follow similar procedures and processes. For external stakeholders, third-party verification is likely to significantly increase the credibility of the GHG inventory. However, self-verification can also provide valuable assurance over the reliability of information.

12.3 **Parameters of verification**

Verifiers should be selected based on previous experience and competence in undertaking GHG verifications, understanding and familiarity with the GPC, and their objectivity, credibility, and independence. However, before commencing with verification, a city should clearly define its goals and decide whether they are best met by self-verification or third-party verification. Verification of a GHG emissions inventory should include the following:

- Assessment boundary is clearly and correctly defined
- All required emission sources are included and notation keys have been used appropriately
- Calculations are consistent with the requirements of the GPC
- Data are time- and geographically-specific to the assessment boundary and technology-specific to the activity being measured
- Data are sourced from reliable and robust sources and referenced appropriately
- All assumptions are recorded

The verification process may also be used to examine more general data management and managerial issues, such as selection and management of GHG data, procedures for collecting and processing GHG data, systems and processes to ensure accuracy of GHG data, managerial awareness, availability of resources, clearly defined responsibilities, and internal review procedures. To enhance transparency and credibility, the objectives and remit of verification should be made publicly available.

12.4 **Verification process**

Verification will usually be an iterative process, where an initial review – highlighting areas of non-compliance and/or queries relating to the assessment – offers an opportunity to make any necessary updates to the GHG inventory before the verification report is produced and conformity with the GPC is determined.

Verification can take place at various points during the development and reporting of GHG inventories. Some cities may establish a semi-permanent internal verification team to ensure that GHG data standards are being met and improved on an on-going basis. Verification that occurs during a reporting period allows for any issues to be addressed before the final report is prepared. This may be particularly useful for cities preparing high-profile public reports.

All relevant documentation should be made available to support the GHG inventory during the verification process. Cities are responsible for ensuring the existence, quality and retention of documentation so as to create an audit trail of how the GHG inventory was compiled. Assumptions and calculations made, and data used, for which there is no available supporting documentation cannot be verified.[71]

If, following verification, the GHG inventory is deemed to be fully compliant with the principles and requirements set out in the GPC, then the city will be able to make a claim of conformity. However, if the verifiers and city cannot come to an agreement regarding outstanding areas of non-compliance, the city will not be able to make a claim of conformity.

The process of verification should be viewed as a valuable input to a path of continuous improvement. Whether verification is undertaken for the purposes of internal review, public reporting or to certify compliance with the GPC, it will likely contain useful information and guidance on how to improve and enhance a city's GHG accounting and reporting practices.

[71] If a city issues a specific base year against which it assesses future GHG performance, it should retain all relevant historical records to support the base year data. These issues should be kept in mind when designing and implementing GHG data processes and procedures.

Appendix A: Survey of Programs/Platforms and GPC

Appendix A summarizes the main features of existing GHG accounting and reporting standards and compares those features with the GPC. Some of the most commonly used or referenced standards include:

1. Global Protocol for Community-Scale GHG emissions (GPC)
2. 1996/2006 IPCC Guidelines for National GHG Inventories (IPCC Guidelines)
3. International Local Government GHG Emissions Analysis Protocol (IEAP)
4. International Standard for Determining GHG Emissions for Cities (ISDGC)
5. Baseline Emissions Inventory/Monitoring Emissions Inventory methodology (BEI/MEI)
6. U.S. Community Protocol for Accounting and Reporting of GHG Emissions (USA Community Protocol)
7. PAS 2070: Specification for the assessment of greenhouse gas emissions of a city
8. GHG Protocol Corporate Standard

IPCC Guidelines, developed for national GHG inventories, provide detailed guidance on emission and removal categories, calculation formulae, data collection methods, default emission factors, and uncertainty management. Both national- and city-level GHG inventories represent geographically explicit entities, and can share the same boundary setting principles and emission calculation methodologies. A key difference between city-level accounting and national-level accounting is that due to relatively smaller geographic coverage, "in-boundary" activities for a country can become trans-boundary activities for a city. This means that scope 2 and scope 3 emissions may account for a larger percentage in a city and should not be neglected. Another important difference is that statistical data at the city level may not be as comprehensive as national-level data, thus requiring more data collection from the bottom-up.

The *GHG Protocol Corporate Standard*[72] created the "scopes" framework for corporate accounting, dividing emissions into scope 1, 2 and 3 to fully cover all the relevant corporate activities and avoid double counting within the same inventory. The scopes framework is widely adopted for corporate inventories and is also applicable to city-based GHG accounting and reporting. Table A.1 shows the application of scopes terminology for corporate and community-level inventories.

Table A.1 Scope definitions for corporate and community

	Corporate	Community
Scope 1	All direct emissions from sources that are owned or controlled by the company	All GHG emissions from sources located within the boundary of the city
Scope 2	Energy-related indirect emissions from generation of purchased electricity, steam and heating/cooling consumed by the company	All GHG emissions occurring as a consequence of the use of grid-supplied electricity, heating and/or cooling within the city boundary
Scope 3	All other indirect emissions that are a consequence of the activities of the	All other GHG emissions that occur outside the city boundary as a result of activities

[72] See GHG Protocol *Corporate Standard*, 2004.

	company	within the city's boundary

Almost all city-wide GHG accounting and reporting standards are – to varying degrees -- combinations of the IPCC Guidelines and the scopes framework. Some standards use frameworks or requirements that differ from the GPC, including:

- **IEAP** requires two levels of reporting: city-level emissions, and emissions from the operations of local government;
- **ISDGC** requires that upstream GHG emissions embedded in food, water, fuel and building materials consumed in cities be reported as additional information items. It recommends cities or urban regions with populations over 1 million persons to use its reporting standard, and cities with populations below 1 million may use less detailed reporting tables such as BEI/MEI;
- **BEI/MEI** only requires mandatory quantification of CO_2 emissions due to final energy consumption. Reporting of emissions from non-energy sectors and non-CO_2 emissions are not mandatory. It was specifically designed for the signatory cities participating in the EU Covenant of Mayors Initiative to track their progress toward the goal set under the initiative, and therefore doesn't cover interactions with other policies such as EU ETS in its framework;
- **U.S. Community Protocol** introduces the concepts of "sources" and "activities" rather than the scopes framework, where "sources" is equivalent to scope 1, and "activities" is equivalent to the total of scope 1, 2 and 3. The U.S. Community Protocol uses different emission categories than IPCC Guidelines and also provides a reporting framework with Five Basic Emissions Generating Activities and some additional and voluntary reporting frameworks (see table A.2);
- **PAS** 2070 provides two methodologies to assess city GHG emissions: a direct plus supply chain (DPSC) methodology which is consistent with GPC, and a consumption-based (CB) methodology.

Some other important features, including applicability, use of the "scopes" framework, inclusion of trans-boundary emissions and emission sources categories are also compared and summarized below.

Applicability

The standards reviewed are developed for accounting and reporting of city-level, national-level and corporate or organizational-level inventories.

Most of the standards were developed for global use, while two standards were designed to target specific groups. The BEI/MEI was designed for EU cities that participated in the Covenant of Mayors Initiative and track their progress to achieve their SEAP goal. The U.S. Community Protocol was designed to inspire and guide U.S. local government to account for and report their GHG emissions associated with the communities they represent.

Adoption of 'scopes' framework and inclusion of trans-boundary emissions

All standards reviewed adopt the scopes framework except for the U.S. Community Protocol, which includes two central categories of emissions: 1) GHG emissions that are produced by community-based "sources" located within the community boundary, and 2) GHG emissions produced as a consequence of community "activities". To better illustrate these two concepts using the scopes framework, emissions from sources refer to scope 1 emissions, emissions from activities refer to all in-boundary and trans-boundary emissions regardless of the scopes.

All standards cover both in-boundary and trans-boundary emissions, except for the BEI/MEI method, which only considers scope 1 and scope 2 emissions.

Emission source categories

2006 IPCC guidelines divide emissions sources into 4 sectors: Energy, IPPU, Waste and AFOLU. All other reviewed standards generally followed this division method, except for some minor adaptations, which include using two major categories Stationary and Mobile instead of Energy, and adding an additional major category of Upstream Emissions. IPCC categories of emissions sources is a good practice for cities to follow for their inventories due to three main reasons: 1) the IPCC offers full coverage of all emissions/removals across all aspects of people's social and economic activities; 2) it clearly defines and divides those emission sources which easily cause confusion (e.g., energy combustion in cement production and emissions from the producing process itself shall be categorized under Energy and IPPU separately; use from waste-generated energy shall be categorized under Energy rather than Waste; and CO_2 emissions from biomass combustion shall be accounted for but reported separately as an information item because the carbon embedded in biomass is part of the natural carbon cycle; 3) consistency with national inventories is conducive for cities to conduct longitudinal comparison and analysis.

Despite minor adaptations when it comes to sub-categories, similarities can also be observed. The Stationary Energy sector is usually divided into residential, commercial/institutional, industrial and others, and the Mobile Energy sector is usually divided by transportation types into on-road, railways, aviation, waterborne and other. Classifications in the Waste sector are highly consistent with IPCC Guidelines, consisting of MSW, biological treatment, incineration and wastewater.

Gases covered: Most standards cover the GHG gases specified by the Kyoto Protocol, which now include seven gases. The BEI/MEI methodology only requires reporting of CO_2 emissions.

Detailed guidance on calculations methodologies: IPCC Guidelines, LEAD, U.S. Community Protocol and GPC provide detailed chapters/sections on the calculation formulae and data collection methods for different emissions sectors. Other standards only provide general requirements on accounting and reporting of GHG emissions.

Calculation tools: The U.S. Community Protocol provides an Excel-based 'Scoping and Reporting Tool' to assist cities in scoping out their inventory and showing calculation results. The Excel table does not have computing functions but only records emissions results in CO_2e and utilizes "notation keys" to indicate why a source or activity was included or excluded. The GPC provides a country-specific, Excel-based tool in China to help users calculate emissions automatically. The China tool was designed to take Chinese conditions into consideration, embedding computing functions and default local emission factors, while keeping emissions sources categories consistent with national inventory.

Guidance on setting reduction targets: Only GHGP Corporate Standard and GPC provide guidance on how to set an emissions reduction goal for a company or city.

Table A.2 Review of existing standards on GHG accounting and reporting

Program/platform	Author	Target audience	Consistency with major IPCC emission sources categories	Adoption of in-boundary /out-of-boundary framework	In-boundary emissions	Out-of-boundary emissions	Gases	Detailed guidance on calculation methodologies	Guidance on setting reduction targets	Other information
Global Protocol for Community-Scale GHG Emissions GPC (Version 2.0)	C40 ICLEI WRI (2014)	Communities worldwide	Yes	Yes	Yes	Yes	Seven gases	No	Yes	• In-boundary and transboundary emissions, and Scope 1,2,3 framework • Provides BASIC, BASIC+ reporting levels • Considered best practices and lessons learned from 35 pilot cities
1996/2006 IPCC Guidelines for National Greenhouse Gas Inventories	IPCC (1996/2006)	National governments	NA	Yes [73]	Yes	Yes	Six gases	Yes	No	• Provides detailed guidance on emission/removal categories, calculation formula, data collection, default emission factors, and uncertainty management
International Local Government GHG Emissions Analysis Protocol (Version 1.0)	ICLEI (2009)	Local governments and communities	Yes[74]	Yes	Yes	Yes	Six gases	Yes	No	• Requires two levels of reporting: - the operations of local government - community-level
International Standard for Determining Greenhouse Gas Emissions for Cities (Version 2.1)	UNEP UN-HABITAT World Bank (2010)	Communities	Yes	Yes	Yes	Yes[75]	Six gases	No	No	• Simplified description, with a lot of reference to other standards (e.g., IPCC Guidelines) • Suggests cities or urban regions with populations over 1 million persons to use this reporting standard and cities with populations below 1 million to use less detailed reporting tables, such as BEI/MEI.
Baseline Emissions Inventory/Monitoring Emissions Inventory Methodology	The Covenant of Mayors Initiative[76] (2010)	Cities in the EU	Yes/No [77]	Yes	Yes	No	CO_2; other gases optional	No	No	• Designed especially for the Covenant of Mayors Initiative in the EU as one of the main measures for signatory cities to achieve their SEAP targets • Only requires quantification of CO_2 emissions due to final energy consumption • Considers interactions with other policies such as EU ETS
U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions (Version 1.0)	ICLEI USA (2012)	Cities and communities in the U.S.	No[78]	No	Yes	Yes	Six gases	Yes	No	• Created the concepts of "sources," which could be interpreted as in-boundary emissions, and "activities", which could be interpreted as both in-boundary and out-of-boundary emissions • Provides various reporting frameworks including the Five Basic Emissions Generating Activities, local government significant influence, community-wide activities, household consumption, in-boundary sources, government consumption, full consumption-based inventory, life cycle emissions of community businesses, and individual industry sectors
PAS 2070: 2013	BSI (2013)	Cities	Yes	Yes	Yes	Yes	Six gases	No	No	• Provides two methodologies to assess city GHG emissions: - Direct plus supply chain methodology, which is consistent with GPC - Consumption-based methodology
Bilan Carbone	ADEME[79] (since 2001)	Companies, local authorities, and regions, in France	No				Six gases		Yes	
Manual of Planning against Global Warming for Local Governments	Ministry of Environment, Japan (2009）	Sub-national governments	Yes[80]	Yes	Yes	Yes	Six gases	Yes	Yes	

73 IPCC emission sources categories include all in-boundary emissions and international aviation and water-borne related out-of-boundary emissions.
74 Sub-category (government) not consistent with IPCC categorization
75 Upstream embedded GHG emissions
76 The Joint Research Centre (JRC) of the European Commission
77 Does not include industry energy, air transport, water-borne sources, includes waste but not agriculture, forestry and industrial processes
78 Basic emissions generating activities - no carbon sinks
79 Managed by the Association Bilan Carbone (ABC) since 2011
80 Sectors: industry, residential, commercial, transport, IPPU, waste, LUCF

Table A.3 Comparison of emissions sources categories

IPCC classification		GPC classification (Scope 1)	
	Energy		**Stationary energy**
1A4b	Residential	I.1	Residential buildings
1A4a	Commercial/institutional	I.2	Commercial and institutional buildings/facilities
1A2	Manufacturing industries and construction	I.3	Manufacturing industries and construction
1A1	Energy industries	I.4	Energy industries
1A4c	Agriculture/forestry/fishing/fish farms	I.5	Agriculture, forestry, and fishing activities
1A5a	Non-specified	I.6	Non-specified sources
1B1	Solid fuels (fugitive emissions)	I.7	Fugitive emissions from mining, processing, storage, and transportation of coal
1B2	Oil and natural gas (fugitive emissions)	I.8	Fugitive emissions from oil and natural gas systems
			Transportation
1A3b	Road transportation	II.1	On-road
1A3c	Railways	II.2	Railways
1A3d	Water-borne navigation	II.3	Water-borne navigation
1A3a	Civil aviation	II.4	Aviation
1A3e	Other transportation	II.5	Off-road
4	**Waste**		**Waste**
4A	solid waste disposal	III.1	Solid waste disposal
4B	biological treatment of solid waste	III.2	Biological treatment of waste
4C	Incineration and open burning of waste	III.3	Incineration and open burning
4D	Wastewater treatment and discharge	III.4	Wastewater treatment and discharge
2	**IPPU**		**IPPU**
2A 2B 2C 2E	Mineral industry Chemical industry Metal industry Electronics industry	IV.1	Industrial processes
2D 2F 2G 2H	Non-energy products from fuels and solvent use Product uses as substitutes for ozone depleting substances Other product manufacture and use Other	IV.2	Product use
3	**AFOLU**		**AFOLU**
3A	Livestock	V.1	Livestock
3B	Land	V.2	Land
3C 3D	Aggregate sources and non-CO2 emissions sources on land Other	V.3	Other agriculture
			OTHER INDIRECT EMISSIONS

Appendix B: Inventories for local government operations

Introduction

Local government operations and key functions vary worldwide, but there are several essential community services that typically fall under the responsibility of local governments, including: water supply, residential waste collection, sanitation, mass transit systems, roads, primary education and healthcare. These local government operations represent activities over which the city has either direct control or strong influence. This presents an opportunity to measure and manage emissions, demonstrate to tax payers a responsible and efficient use of resources, and demonstrate city leadership.

To guide local governments on accounting and reporting GHG emissions from their operations, ICLEI created the *International Local Government GHG Emissions Analysis Protocol* (IEAP) in 2009. It focuses on the specificities of local government operations (LGO), tailoring general guidance corporate GHG accounting to the needs of cities. This appendix summarizes the guidance given in IEAP for local government operations, with slight changes to ensure consistency with the revised GPC 2.0 and promote comparability of local government operations' GHG emissions inventories with national and subnational GHG inventories. For additional guidance please refer to the IEAP chapters which address local government operations.[81] It is ICLEI's intention to progressively phase-out the use of IEAP by including the necessary guidance on a future version of GPC.

Other standards and guidance documents have provided similar guidance on a local or national level, including the US-focused *GHG Protocol U.S. Public Sector Protocol* and the *Local Government Operations Protocol* written by the California Air Resources Board, The Climate Registry and ICLEI – Local Governments for Sustainability USA. LGO inventories should conform with international standards and best practices.

Purpose of an LGO Inventory

An LGO inventory accounts GHGs from operations, activities and facilities that governments own or operate, such as from own municipal fleets or buildings or from waste management services provided by the municipality to the community. Emissions from local government operations are typically a subset of community emissions, though rare exceptions can occur. For example, if the local government is the operator or owner of facilities that are simultaneously located outside of its geopolitical boundary and serve other communities.

The majority of emissions from local government operations are a subset of community emissions, typically ranging from 3 to 7% of total community emissions. Although this is a relatively small fraction of the community's emissions, it clearly shows that for local governments must use their influence over operations that are not under their direct control (e.g., improving the energy performance of private buildings through the municipal building code). GHG reduction targets can be set for both LGO performance and community-wide emissions.

[81] Available online at: http://archive.iclei.org/index.php?id=ghgprotocol

An LGO inventory can be used to:

- Develop a baseline (and base year) against which GHG developments can be compared.
- Regularly reflect and report a true account of emissions generated by LGO
- Identify problem areas in local government operations through facility and activity benchmarking, e.g. identify opportunities to improve energy efficiency in municipal buildings or water supply.
- Demonstrate leadership in climate change mitigation by setting a GHG reduction target for LGO
- Increase consistency and transparency in GHG accounting and reporting among institutions

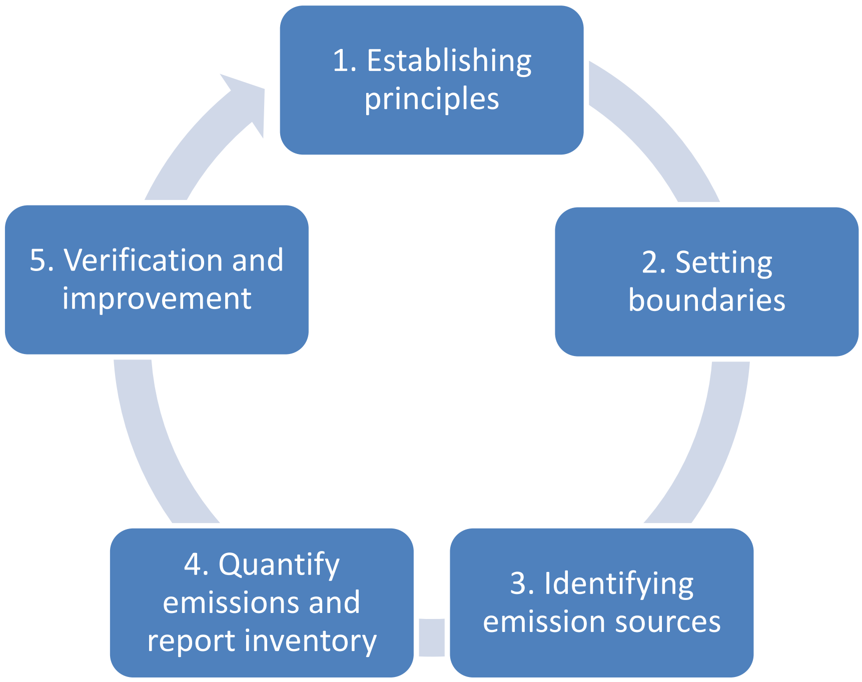
Conducting a Local Government Operations Inventory

Overall, an LGO inventory follows the five steps described in Figure 1. This appendix will only illustrate the special requirements for LGO emissions inventory in steps 1, 2 and 3. For guidance on steps 4 and 5, local governments can consult the community-scale emission

Establishing principles

An LGO inventory draws on the same accounting and reporting principles as a city-level inventory: Relevance, Completeness, Consistency, Transparency and Accuracy, as well as the same procedures for inventory Quality Control and Quality Assurance.

Figure B.1 Major steps for LGO inventories



Setting boundaries

Facilities controlled or influenced by local government are typically fall within a community's geographical boundary (see GPC chapter 4 on assessment boundaries). In some cases, such as electricity use and waste disposal, emissions can occur outside the geopolitical boundary of the city territory. Regardless of where the emissions occur, however, all LGO emissions must be included in the analysis.

To measure the impact of an emissions reduction measure in LGOs for future years, the corresponding emission source must be included in the base year inventory. For example, if the local government wishes to consider a measure which addresses employee commuting in its mitigation action plan, then emissions from employee commuting need to be included in the base year inventory and following inventories.

Where facilities are jointly used by multiple levels of government, the local government should account for all quantified GHG emissions from the facilities over which it has financial and/or operational control, using the energy bills (electricity, natural gas, etc.) as the source of activity data. Where such disaggregated activity data is not available, or not applicable due to the nature of the facilities, local governments should account its proportion of GHG emissions based on the local governments' equity share or ownership of the facilities. Both methods for consolidation of facility level GHG emissions are recognized as valid by ISO 14064-1:2006 (greenhouse gases - guidance at the organization level).

Emissions from contracted services:

These emissions should be included in an LGO inventory if they contribute to an accurate understanding of local government emissions trends, or if they are particularly relevant to developing a comprehensive GHG management policy. Determining whether to include emissions from a contractor in an LGO inventory should be based on three considerations:

1. Is the service provided by the contractor a service that is normally provided by local government? If so, the local government must include these emissions to allow accurate comparison with other local governments.

2. In any previous emissions inventory, was the contracted service provided by the local government and therefore included in the earlier inventory? If so, these emissions must be included to allow an accurate comparison to the historical base year inventory.

3. Are the emissions resulting from the contractor a source over which the local government exerts significant influence? If so, these emissions must be included in order to provide the most policy relevant emissions information.

Transferable emission units (e.g. offsets)

A local government should document and disclose information, in alignment with GPC 2.0 guidance for city-scale inventories, for any transferable emissions units sold from projects included in the LGO inventory or purchased to apply to an LGO inventory. This ensures transparency and prevent "double counting" of emissions reductions.

Identify emission sources and sinks

After setting boundaries for an LGO inventory, a local government should identify the emission sources and sinks associated with each included activity or facility. The categorization of GHG emissions according to scope for local government operations in IEAP is based on the degree of control, whereas a city-scale inventory is uses the scopes based on the geographic boundaries of the territory which is under the jurisdiction of the local government. For LGO inventories, IEAP requires local governments to report emissions according to scope and according to the following sectors:

- Stationary Energy

- Transportation
- Waste
- Industrial Processes and Product Use (IPPU)
- Agriculture, Forestry and other Land Use (AFOLU)

Considering the activities usually performed by local governments, the GHG emissions inventory should be further disaggregated into the following categories, when applicable:

- Electricity or district heating/cooling generation
- Street lighting and traffic signals
- Buildings
- Facilities (only energy consumption from facilities operation), which can include:
  - Water supply facilities (collection, treatment and distribution)
  - Wastewater facilities (drainage, treatment and disposal)
  - Solid waste facilities (processing, treatment and disposal)
  - Any other facilities which are part of the local government operations and are not included in the other stationary energy categories mentioned above
- Vehicle fleet (which can be further disaggregated, for example, to single-out the solid waste collection fleet)
- Employee commute
- Wastewater and solid waste (only emissions from biodegradation)
- Other (this sector recognizes the diversity of local government functions and allows for consideration of any sources of emissions not included elsewhere)

For internal reporting purposes, a local government may aggregate the energy emissions from the operation of waste management facilities (GPC's/IPCC's Energy – Stationary Energy sector) with emissions from the biodegradation of waste during treatment /disposal (GPC's/IPCC's Waste sector), but this should not be done for external reporting purposes if a city wishes to comply with the GPC and IPCC guidelines. Not all local governments provide the same functions, and consequently some governments will not have any emissions from some sectors. The 'Other' sector recognizes the diversity of local government functions and allows for consideration of any sources of emissions not included elsewhere.

In order to facilitate accurate comparisons between inventories of different years, local governments should ensure that sites are assigned to the same sector in each year.

1 Abbreviations

AFOLU	Agriculture, forestry and other land use
BOD	Biochemical oxygen demand
C40	C40 Cities Climate Leadership Group
cCCR	carbonn Cities Climate Registry
CCHP	Combined cooling, heat and power (trigeneration)
CDD	Cooling degree days
CEM	Continuous emissions monitoring
CH_4	Methane
CHP	Combined heat and power (cogeneration)
CNG	Compressed natural gas
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
DOC	Degradable organic carbon
EF	Emission factor
EFDB	Emissions factor database
FAO	Food and Agriculture Organization of the United Nations
FOD	First order decay
GDP	Gross domestic product
GHG	Greenhouse Gas
GPC	Global Protocol for Community-scale Greenhouse Gas Inventories
GWP	Global warming potential
HDD	Heating degree days
HFCs	Hydrofluorocarbons
ICLEI	ICLEI Local Governments for Sustainability
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial processes and product use
ISIC	International Standard Industrial Classification
ISO	International Organization for Standardization
LGO	Local Government Operations
MC	Methane commitment
MMS	Manure management system
MSW	Municipal solid waste
N_2O	Nitrous oxide
NF_3	Nitrogen triflouride
NMVOCs	Non-methane volatile organic compounds
ODS	Ozone depleting substances
ODU	Oxidized during use
PFCs	Perfluorocarbons
QA	Quality assurance
QC	Quality control

SF_6	Sulphur hexafluoride
SWD	Solid waste disposal
SWDS	Solid waste disposal sites
T&D	Transmission and distribution
TAZ	Traffic analysis zone
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UN-HABITAT	United Nations Human Settlement Programme
US EPA	United States Environmental Protection Agency
US FMC	United States Federal Maritime Commission
VKT	Vehicle kilometers traveled
WBCSD	World Business Council for Sustainable Development
WRI	World Resources Institute
WWTP	Wastewater treatment plant

1 Glossary

Activity data	A quantitative measure of a level of activity that results in GHG emissions. Activity data is multiplied by an emissions factor to derive the GHG emissions associated with a process or an operation. Examples of activity data include kilowatt-hours of electricity used, quantity of fuel used, output of a process, hours equipment is operated, distance traveled, and floor area of a building.
Allocation	The process of partitioning GHG emissions among various outputs
Assessment boundary	The assessment boundary of a GHG inventory identifies the gases, emission sources, geographic area, and time span covered by the GHG inventory
Base year	A historical datum (e.g., year) against which a city's emissions are tracked over time.
BASIC	An inventory reporting level that includes all scope 1 sources except from energy generation, imported waste, IPPU, and AFOLU, as well as all scope 2 sources
BASIC+	An inventory reporting level that covers all BASIC sources, plus scope 1 AFOLU and IPPU, and scope 3 in the stationary energy and transportation sectors.
Biogenic emissions (CO_2(b))	Produced by living organisms or biological processes, but not fossilized or from fossil sources
City	Used throughout the GPC to refer to geographically discernable subnational entities, such as communities, townships, cities, and neighborhoods.
City boundary	See geographic boundary
CO_2 equivalent	The universal unit of measurement to indicate the global warming potential (GWP) of each greenhouse gas, expressed in terms of the GWP of one unit of carbon dioxide. It is used to evaluate the climate impact of releasing (or avoiding releasing) different greenhouse gases on a common basis.
Emission factor(s)	A factor that converts activity data into GHG emissions data (e.g., kg CO2e emitted per liter of fuel consumed, kg CO2e emitted per kilometer traveled, etc.).
Emission	The release of greenhouse gases into the atmosphere.
Geographic boundary	A geographic boundary that identifies the spatial dimensions of the inventory's assessment boundary. This geographic boundary defines the physical perimeter separating in-boundary emissions from out-of-boundary and transboundary emissions

Global warming potential	A factor describing the radiative forcing impact (degree of harm to the atmosphere) of one unit of a given GHG relative to one unit of CO_2.
Greenhouse gas inventory	A quantified list of a city's GHG emissions and sources.
Greenhouse Gases (GHG)	For the purposes of this standard, GHGs are the seven gases covered by the UNFCCC: carbon dioxide (CO_2); methane (CH_4); nitrous oxide (N_2O); hydrofluorocarbons (HFCs); perfluorocarbons (PFCs); sulphur hexafluoride (SF_6); and Nitrogen Triflouride (NF_3).
In-boundary	Occurring within the established geographic boundary
Out-of-boundary	Occurring outside of the established geographic boundary
Proxy data	Data from a similar process or activity that is used as a stand-in for the given process or activity without being customized to be more representative of that given process or activity.
Reporting	Presenting data to internal and external users such as regulators, the general public or specific stakeholder groups.
Reporting year	The year for which emissions are reported.
Scope 1 emissions	All GHG emissions from sources located within the boundary of the city In-boundary emissions, or those emissions produced within the defined geographic boundary
Scope 2 emissions	All GHG emissions occurring as a consequence of the use of grid-supplied electricity, heating and/or cooling within the city boundary
Scope 3 emissions	All other GHG emissions that occur outside the city boundary as a result of activities within the city's boundary
Transboundary emissions	Emissions from sources that cross the geographic boundary

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