GREENHOUSE GAS PROTOCOL

This is an approved version of the standard, but subject to publication quality review. A final, downloadable version will be available soon.

Global Protocol for Community-Scale Greenhouse Gas Emission Inventories

An Accounting and Reporting Standard for Cities

WORLD RESOURCES INSTITUTE

C40 CITIES CLIMATE LEADERSHIP GROUP

ICLEI Local Governments for Sustainability

LEAD AUTHORS

Wee Kean Fong	World Resources Institute
Mary Sotos	World Resources Institute
Michael Doust	C40 Cities Climate Leadership Group
Seth Schultz	C40 Cities Climate Leadership Group
Ana Marques	ICLEI - Local Governments for Sustainability
Chang Deng-Beck	ICLEI - Local Governments for Sustainability

CONTRIBUTING AUTHORS

Alex Kovac	World Resources Institute
Pankaj Bhatia	World Resources Institute
Brooke Russell	C40 Cities Climate Leadership Group
Emily Morris	C40 Cities Climate Leadership Group
Maryke van Staden	ICLEI - Local Governments for Sustainability
Yunus Arikan	ICLEI - Local Governments for Sustainability
Amanda Eichel	Bloomberg Philanthropies
Jonathan Dickinson	Columbia University
Rishi Desai	Oliver Wyman
Dan Hoornweg	The World Bank

ADVISORY COMMITTEE

Pankaj Bhatia, Chair	World Resources Institute
Seth Schultz	C40 Cities Climate Leadership Group
Yunus Arikan	ICLEI - Local Governments for Sustainability
Stephen Hammer	The World Bank
Robert Kehew	United Nations Human Settlements Program (UN-HABITAT)
Soraya Smaoun	United Nations Environment Program (UNEP)
Maria Varbeva-Daley	British Standards Institution (BSI)
Kyra Appleby (Larissa Bulla)	Carbon Disclosure Project (CDP)
Alvin Meijia	Clean Air Asia (CAI Asia)
Adam Szolyak	EU Covenant of Mayors
Michael Steinhoff	ICLEI – Local Governments for Sustainability USA
Junichi Fujino	Institute for Global Environmental Strategies and National Institute for Environmental Studies (IGES/NIES)
Victor Hugo Paramo	Instituto Nacional de Ecología y Cambio Climático (INECC) / Mexico City, Mexico
Kiyoto Tanabe	Intergovernmental Panel on Climate Change (IPCC)
Yoshiaki Ichikawa	International Organization for Standardization (ISO)
Jan Corfee-Morlot	Organization for Economic Co-operation and Development (OECD)
Christophe Nuttall	R20 Regions of Climate Action
Sergey Kononov	United Nations Framework Convention on Climate Change (UNFCCC)
Matthew Lynch	World Business Council on Sustainable Development (WBCSD)
Carina Borgström-Hansson	World Wide Fund for Nature (WWF)
Jean-Pierre Tabet	French Agency for Environment and Energy Management (ADEME)
Farhan Helmy	Indonesia Climate Change Center (ICCC)
Ragnhild Hammer	Arendal, Norway
Ines Lockhart	Buenos Aires, Argentina
Leah Davis	London, UK
Yuuko Nishida	Tokyo, Japan
Amanda Eichel	Bloomberg Philanthropies
Shirley Rodrigues	Children's Investment Fund Foundation (CIFF)
Stefan Denig	Siemens

Table of Contents

Detailed Table of Contents

The term “city” is used throughout this document to refer to geographically discernable subnational entities, such as communities, townships, cities, and neighborhoods. In this document, “city” is also used to indicate all levels of subnational jurisdiction as well as local government as legal entities of public administration.

List of Tables and Figures

TABLES

FIGURES

BOXES

EQUATIONS

Foreword

Cities are integral to tackling the global challenges of climate change, as both a major source of greenhouse gas emissions, and a major source of innovative climate solutions. An estimated 70 percent of the world's energy-related greenhouse gas emissions come from cities, a number that is likely to continue to increase as two-thirds of all people are expected to live in urban areas by mid-century. At the same time, cities are designing and implementing groundbreaking solutions to mitigate climate change — promoting sustainable development and increasing climate resilience while reducing emissions. In order to have maximum global impact, however, city leaders need a standard by which to measure their emissions and identify the most effective ways to mitigate them.

The *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories* (GPC) offers cities and local governments a robust, transparent and globally-accepted framework to consistently identify, calculate and report on city greenhouse gases. This includes emissions released within city boundaries as well as those occurring outside them as a result of activities taking place within the city.

The GPC establishes credible emissions accounting and reporting practices that help cities develop an emissions baseline, set mitigation goals, create more targeted climate action plans and track progress over time, as well as strengthen opportunities for cities to partner with other levels of government and increase access to local and international climate financing.

The GPC has already been adopted as a central component of the Compact of Mayors, the world's largest cooperative effort among mayors and city officials to reduce greenhouse gas emissions, track progress and prepare for the impacts of climate change. Launched in September 2014, the Compact aims to undertake a transparent and supportive approach to reduce greenhouse gas emissions and address climate risk, in a manner consistent with – and complementary to – the international climate negotiation process under the United Nations Framework Convention on Climate Change.

Urban areas are a logical setting for implementing and measuring climate action. Local governments can be more nimble where regional or national governments are more restricted by bureaucracy. Mayors, local councils and community leaders understand local needs and constraints, which often results in bolder, more effective action being taken. They can track the performance of city services, guide change in the community and set regulations that govern land use, building efficiency, and local transportation.

Thousands of cities are already taking action to reduce emissions and improve climate resilience. With the GPC, these cities and their advocates have a global standard to track greenhouse gas performance and lead the way to a more sustainable future.

Andrew Steer President and CEO, WRI	Eduardo Paes C40 Chair and Mayor of Rio de Janeiro	David Cadman President, ICLEI

Executive Summary

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. A city's ability to take effective action on mitigating 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 understand the emissions contribution of different activities in the community.

Introduction

Inventory methods that cities have used to date vary significantly. 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 and meaningful reporting, greater consistency in GHG accounting is required. The Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) responds to this challenge and offers a robust and clear framework that builds on existing methodologies for calculating and reporting city-wide GHG emissions.

The GPC requires cities to measure and disclose a comprehensive inventory of GHG emissions and to total these emissions using two distinct but complementary approaches. One captures emissions from both production and consumption activities taking place within the city boundary, including some emissions released outside the city boundary. The other categorizes all emissions into "scopes," depending on where they physically occur. Separate accounting of emissions physically released within the city boundary should be used for aggregation of multiple city inventories in order to avoid double counting.

The GPC is divided into three main parts:

- **Part I** introduces the GPC reporting and accounting principles, sets out how to define the inventory boundary, specifies reporting requirements and offers a sample reporting template

- **Part II** provides overarching and sector-specific accounting and reporting guidance for sourcing data and calculating emissions, including calculation methods and equations
- **Part III** shows how inventories can be used to set mitigation goals and track performance over time, and shows how cities can manage inventory quality

Note, the term "city" is used throughout this document to refer to any geographically discernable subnational entity, such as a community, town, city, or province, and covers all levels of subnational jurisdiction as well as local government as legal entities of public administration.

Defining an inventory boundary and emission sources

To use the GPC, cities must first define an inventory boundary. This identifies the geographic area, time span, gases, and emission sources, covered by a GHG inventory. Any geographic boundary may be used for the GHG inventory. 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, a metropolitan area, or another geographically identifiable entity. The GPC is designed to account for GHG emissions in a single reporting year and covers the seven gases covered by the Kyoto Protocol (Section 3.3 in the report).

GHG emissions from city activities shall be classified into six main sectors:

- Stationary energy
- Transportation
- Waste
- Industrial processes and product use (IPPU)
- Agriculture, forestry, and other land use (AFOLU)
- Any other emissions occurring outside the geographic boundary as a result of city activities. These emissions are not covered in this version of the GPC but may be reported separately

Table 1 breaks these six sectors down by sub-sector.

Table 1 Sectors and sub-sectors of city GHG emissions

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

Categorizing emissions

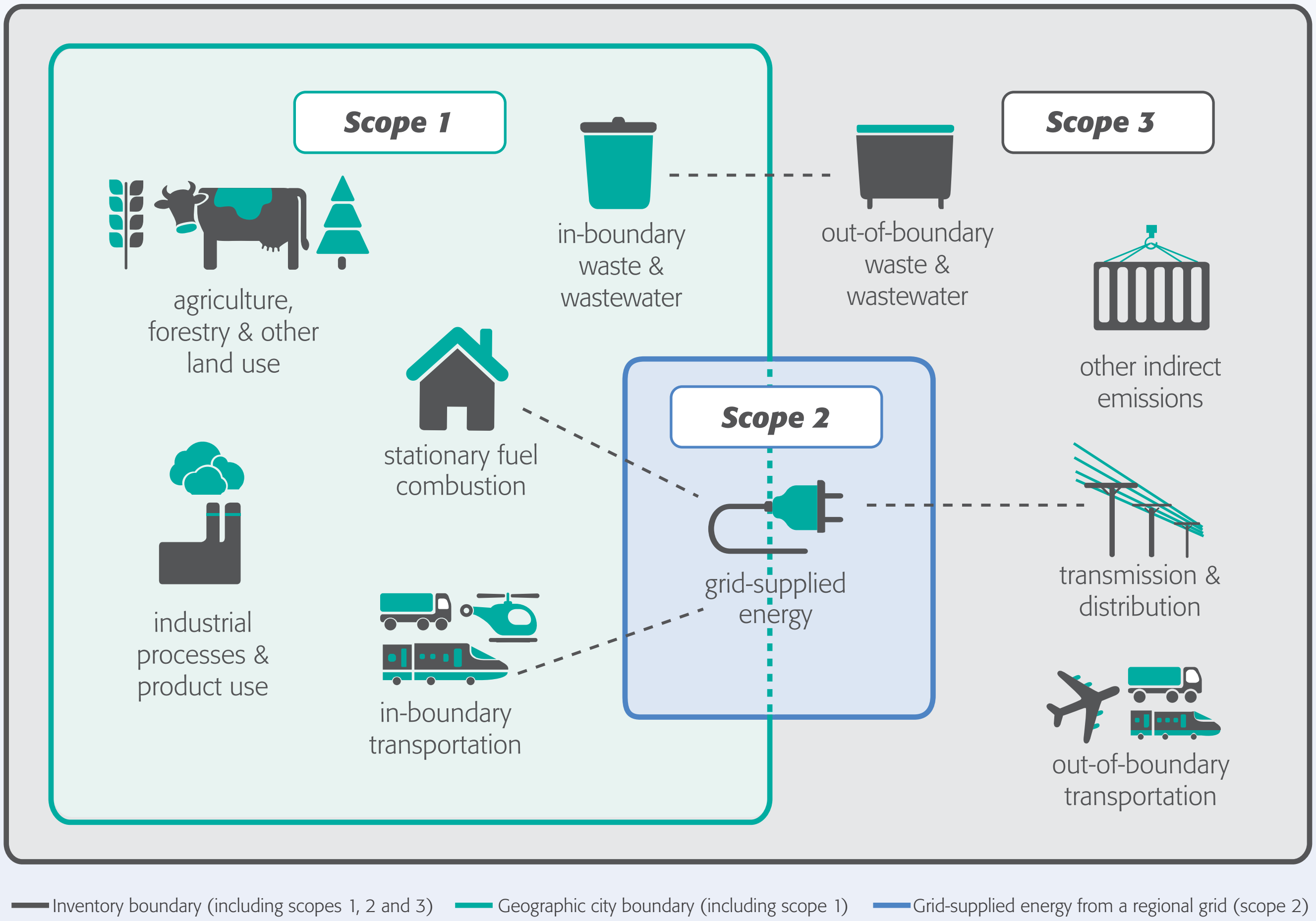
Activities taking place within a city can generate GHG emissions that occur inside the city boundary as well as outside the city boundary. To distinguish among them, the GPC groups emissions into three categories based on where they occur: scope 1, scope 2 or scope 3 emissions. Definitions are provided in Table 2, based on an adapted application of the scopes framework used in the GHG Protocol Corporate Standard.

The scopes framework helps to differentiate emissions occurring physically within the city (scope 1), from those occurring outside the city (scope 3) and from the use of electricity, steam, and/or heating/cooling supplied by grids which may or may not cross city boundaries (scope 2). Scope 1 emissions may also be termed "territorial" emissions because they occur discretely within the territory defined by the geographic boundary. Figure 1 illustrates which emission sources occur solely within the geographic boundary established for the inventory, which occur outside the geographic boundary, and which may occur across the geographic boundary.

Table 2 Scopes definitions for city inventories

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

Figure 1 Sources and boundaries of city GHG emissions



Aggregating city inventories

The GPC has been designed to allow city inventories to be aggregated at subnational and national levels in order to:

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

Aggregation of multiple city inventories can be accomplished by combining the scope 1 (territorial) emissions of cities whose inventory boundaries do not overlap geographically.

Reporting requirements

The GPC requires cities to report their emissions by gas, scope, sector and subsector, and to add up emissions using two distinct but complementary approaches:

- **Scopes framework:** This totals all emissions by scope 1, 2 and 3. Scope 1 (or territorial emissions) allows for the separate accounting of all GHG emissions produced within the geographic boundary of the city, consistent with national-level GHG reporting.
- **City-induced framework:** This totals GHG emissions attributable to activities taking place within the geographic boundary of the city. It covers selected scope 1, 2 and 3 emission sources representing the key emitting sources occurring in almost all cities, and for which standardized methods are generally available.

Chapter 4 of the GPC sets out reporting requirements and explains how to add up emission totals. Cities may also report emissions based on relevant local or program-specific requirements in addition to the requirements of the GPC. GHG inventories should be updated on a regular basis using the most recent data available. The GPC recommends that cities update their inventory on an annual basis, as it provides frequent and timely progress on overall GHG emissions.

Table 3 summarizes the emissions sources and scopes covered by the GPC for both city-level and territorial reporting. These represent the key emitting sources occurring in almost all cities, and for which standardized methods are generally available. Cities should aim to cover all emissions for which reliable data is available. To accommodate limitations in data availability and differences in emission sources between cities, the GPC requires 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.

The city-induced framework gives cities the option of selecting between two reporting levels: BASIC or BASIC+. The BASIC level covers scope 1 and scope 2 emissions from stationary energy and transportation, as well as scope 1 and scope 3 emissions from waste. BASIC+ involves more challenging data collection and calculation processes, and additionally includes emissions from IPPU and AFOLU and transboundary transportation. Therefore, where these sources are significant and relevant for a city, the city should aim to report according to BASIC+. The sources covered in BASIC+ also align with sources required for national reporting in IPCC guidelines.

Tick marks in Table 3 indicate which emissions sources are covered by the GPC, and cells are colored to indicate their inclusion in city-level BASIC or BASIC+ totals and the territorial total. Rows written in italics represent sub-sector emissions required for territorial emission totals but not BASIC/BASIC+. Gray cells in the scope 2 column indicate emission sources that do not have applicable GHG emissions in that scope category. Emission sources corresponding to the blank boxes in the scope 3 column are not required for reporting, but may be identified and disclosed separately under Other Scope 3.

The GPC provides a sample reporting template that covers all reporting requirements. Cities may report GHG emissions in a variety of additional formats depending on purpose and audience, and may also disaggregate emissions by fuel type, municipal operations within each sector or sub-sector, etc.

Figure 2 Sources and scopes covered by the GPC

Sectors and sub-sectors	Scope 1	Scope 2	Scope 3
STATIONARY ENERGY			
Residential buildings	✓	✓	✓
Commercial and Institutional buildings and facilities	✓	✓	✓
Manufacturing industries and construction	✓	✓	✓
Energy industries	✓	✓	✓
Energy generation supplied to the grid	✓		
Agriculture, forestry, and fishing activities	✓	✓	✓
Non-specified sources	✓	✓	✓
Fugitive emissions from mining, processing, storage, and transportation of coal	✓		
Fugitive emissions from oil and natural gas systems	✓		
TRANSPORTATION			
On-road	✓	✓	✓
Railways	✓	✓	✓
Waterborne navigation	✓	✓	✓
Aviation	✓	✓	✓
Off-road	✓	✓	
WASTE			
Disposal of solid waste generated in the city	✓		✓
Disposal of solid waste generated outside the city	✓		
Biological treatment of waste generated in the city	✓		✓
Biological treatment of waste generated outside the city	✓		
Incineration and open burning of waste generated in the city	✓		✓
Incineration and open burning of waste generated outside the city	✓		
Wastewater generated in the city	✓		✓
Wastewater generated outside the city	✓		
INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU)			
Industrial processes	✓		
Product use	✓		
AGRICULTURE, FORESTRY, AND LAND USE (AFOLU)			
Livestock	✓		
Land	✓		
Other agriculture	✓		
OTHER SCOPE 3			
Other Scope 3			

✓ Sources covered by the GPC

Sources required for BASIC reporting

+ Sources required for BASIC+ reporting

Sources required for territorial total but not for BASIC/BASIC+ reporting (*italics*)

Sources included in Other Scope 3

Non-applicable emissions

Calculating GHG emissions

Part II of the GPC provides overarching and sector-specific reporting guidance for sourcing data and calculating emissions. Cities should select the most appropriate methodologies based on the purpose of their inventory, availability of data, and consistency with their country's national inventory and/or other measurement and reporting programs in which they participate. The GPC does not require specific methodologies to be used to produce emissions data; rather it specifies the principles and rules for compiling a city-wide GHG emissions inventory. Where relevant, the GPC recommends using methodologies aligned with the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*.

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. 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. GHG emissions data shall be reported as metric tonnes of each GHG as well as CO_2 equivalents (CO_2e).

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 publicly-available, peer-reviewed and reputable sources, often available through government publications. 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 inventory boundary by adjusting for changes in activity using a scaling factor. Emission factors should be relevant to the inventory boundary and specific to the activity being measured.

Tracking progress and setting goals

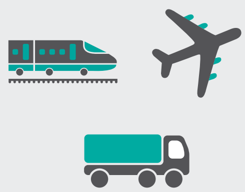
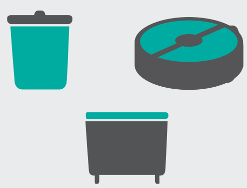
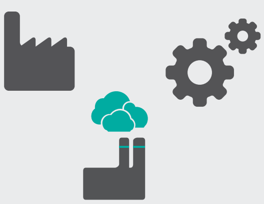
Inventories can be used as the basis for setting mitigation goals and tracking performance over time. For many cities with existing climate action plans and targets, the mitigation goal boundary used will be different to the inventory boundary outlined above or will apply to a subset of the GHGs, scopes, or emission sources set out in the GPC. Cities are encouraged to align their mitigation goal boundary to the GPC inventory boundary, but where the mitigation goal boundary remains different from the GPC inventory boundary, cities should explain the differences, and reason for the differences, to avoid any confusion.

Managing inventory quality and verification

The GPC does not require that cities verify their inventory results, but recommends that cities choose the level and type of verification that meets their needs and capacity. 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 data and research become available.

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. 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 can be performed by the same organization that conducted the GPC assessment (self-verification), or by an independent organization (third-party verification).

Figure 3 **Emission source sectors**

Sectors in the GPC	
STATIONARY ENERGY	
	Stationary energy sources are one of the largest contributors to a city's GHG emissions. These emissions come from the combustion of fuel in residential, commercial and institutional buildings and facilities and manufacturing industries and construction, as well as power plants to generate grid-supplied energy. This sector also includes fugitive emissions, which typically occur during extraction, transformation, and transportation of primary fossil fuels.
TRANSPORTATION	
	Transportation covers all journeys by road, rail, water and air, including inter-city and international travel. GHG emissions are produced directly by the combustion of fuel or indirectly by the use of grid-supplied electricity. Collecting accurate data for transportation activities, calculating emissions and allocating these emissions to cities can be a particularly challenging process. To accommodate variations in data availability, existing transportation models, and inventory purposes, the GPC offers additional flexibility in calculating emissions from transportation.
WASTE	
	Waste disposal and treatment produces GHG emissions through aerobic or anaerobic decomposition, or incineration. GHG emissions from solid waste shall be calculated by disposal route, namely landfill, biological treatment and incineration and open burning. If methane is recovered from solid waste or wastewater treatment facilities as an energy source, it shall be reported under Stationary Energy. Similarly, emissions from incineration with energy recovery are reported under Stationary Energy.
INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU)	
	GHG emissions are produced from a wide variety of non-energy related 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 and used as chemical feedstock). During these processes many different GHGs can be produced. In addition, certain products used by industry and end-consumers, such as refrigerants, foams or aerosol cans, also contain GHGs which can be released during use and disposal.
AGRICULTURE, FORESTRY AND OTHER LAND USE (AFOLU)	
	Emissions from the Agriculture, Forestry and Other Land Use (AFOLU) sector are produced through a variety of pathways, including livestock (enteric fermentation and manure management), land use and land use change (e.g., forested land being cleared for cropland or settlements), and aggregate sources and non-CO_2 emission sources on land (e.g., fertilizer application and rice cultivation). Given the highly variable nature of land-use and agricultural activity across geographies, GHG emissions from AFOLU are amongst the most complex categories for GHG accounting.

If we want to turn the tide against climate change, cities will need to lead the way. Compact and efficient cities can dramatically reduce emissions and will drive innovation and sustained economic growth. Until recently there has been no consistent way to measure city-level emissions. Now, that has changed. We now have a common international standard to inform strategies to cut emissions and create better, more livable cities.

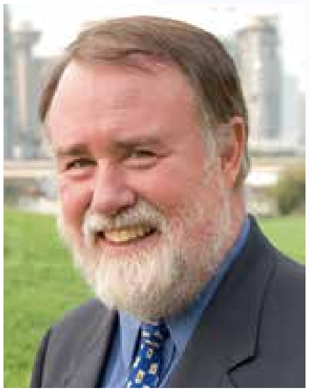
—Andrew Steer, President and CEO, WRI

As C40 Chair and Mayor of Rio de Janeiro, I know that building a greenhouse gas emissions inventory enables city leaders to manage their emissions reduction efforts, allocate resources and develop comprehensive climate action plans. With the launch of the GPC, cities now have a consistent, transparent and internationally recognized approach to measuring and reporting citywide emissions, allowing for credible comparison and aggregation across timescales and geographies. On behalf of C40, I would like to thank WRI and ICLEI for their partnership in building this powerful standard that will benefit cities across the globe. I strongly encourage other cities around the world to take up this new standard as a key step in the global fight against climate change.

—Eduardo Paes, C40 Chair and Mayor of Rio de Janeiro

With the launch of the GPC, we now have the most comprehensive greenhouse gas accounting and reporting framework for cities worldwide. Drafting and piloting since 2012, the GPC marks a historic international consensus on GHG accounting and reporting emissions, allowing local governments to measure and track their performances in a consistent standard, guided by international best practices. This published version would not have been possible without the excellent cooperation between WRI, C40 and ICLEI, as well as the practical insight and valuable feedback provided by the 35 pilot cities that tested earlier versions in their cities. ICLEI wants to thank these partners and cities for their indispensable contribution to this game-changing Protocol.

—David Cadman, President, ICLEI



PART I

Introduction and Reporting Requirements

1 Introduction

Cities are the global centers of communication, commerce and culture. They are also a significant, and growing, source of energy consumption and account for a large percentage of global greenhouse gas (GHG) emissions. With a majority 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 and responding to climate impacts.

1.1 Cities and climate change

A city's ability to take effective action on mitigating 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 understand the emissions contribution of different activities in the community. It 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 emission reduction targets, inform their climate action plans, and track their performance.

In addition, a city-wide 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 the carbon*n* Climate Registry (cCR) and 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. This Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) responds to this challenge, offering a robust and clear framework that builds on existing methodologies for calculating and reporting city-wide GHG emissions.

1.2 Purpose of the GPC

The GPC sets out requirements and provides guidance for calculating and reporting city-wide GHG emissions, consistent with the *2006 IPCC (Intergovernmental Panel on Climate Change) Guidelines for National Greenhouse Gas Inventories* (also referred to as just *IPCC Guidelines* throughout this report).The GPC seeks to:

- Help cities develop a comprehensive and robust GHG inventory in order to support climate action planning.
- Help cities establish a base year emissions inventory, set reduction targets, and track their performance.
- 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.[1]
- Demonstrate the important role that cities play in tackling climate change, and facilitate insight through benchmarking—and aggregation—of comparable data.

1.3 Who should use the GPC

The GPC can be used by anyone assessing the GHG emissions of a geographically defined, subnational 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 of these jurisdictions, unless otherwise specified. However, the GPC does not define what geographic boundary constitutes a "city". Similarly, the terms "community-scale" is used to refer to inventories encompassing any of these geographic designations, and is used interchangeably with "city-scale" or "city-wide" or inventories.

Policy makers at the regional or national level can also use this standard to understand how to aggregate multiple cities' emissions together to improve national inventory data, to inform mitigation goals or policies, or to track city emission trends.[2]

1.4 Using the GPC

The GPC provides a robust framework for accounting and reporting city-wide GHG emissions. It requires cities to measure and disclose a comprehensive inventory of GHG emissions and to aggregate these using two distinct but complementary frameworks: one focusing on geographically defined emissions, the other on city-induced emissions. The former allows for the aggregation of multiple city inventories while avoiding double counting. The GPC includes guidance on compiling city-wide GHG inventories and also offers a sample reporting template (see Table 4.3).

Specific methodology guidance for each sector is provided in PART II (Chapters 6–10). These chapters identify calculation methods and data options, and provide calculation equations or procedures where relevant. The GPC also references *IPCC Guidelines* and other resources to assist cities in completing these calculations and sourcing relevant data. Cities can implement the requirements of the GPC using a variety of local, national or default data depending on what is available. See Table 1.1 to identify key chapter themes and questions.

1. Aggregation of multiple city inventories can be used to: improve the data quality of a national inventory, particularly where major cities' inventories are reported; measure the contribution of city-wide mitigation actions. to regional or national GHG emission reduction targets; and identify innovative transboundary and cross-sectorial strategies for GHG mitigation.

2. Individual businesses, residents or institutions in a city can use this standard to understand the overall performance of the city, but should not calculate their individual footprint by taking GPC reported emissions divided by the population of the city. Instead, individuals or organizations should use corporate or institution-based methods for their own inventories.

1.4.1 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 compliance 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

1.5 Relationship to other city protocols and standards

The GPC builds upon the knowledge, experiences, and practices of existing standards used by cities to measure city-wide GHG emissions. An overview of these and how their requirements and boundaries relate to the GPC is provided in Appendix A. Upon publication, the GPC will supersede

Table 1.1 What parts of the GPC should I read?

Type of accounting	Purpose
How does the GPC compare to other inventory methods used by cities?	Ch. 1 and Appendix A
What are the key principles to follow in creating a GHG inventory?	Ch. 2
What are notation keys, and how should they be used?	Ch. 2 and Ch. 4
What activities should I include in my GHG inventory? What gases? What time frame?	Ch. 3
How do I distinguish emissions occurring within the geographic boundary of the inventory, vs. those outside of the boundary?	Ch. 3
What are the reporting requirements for a city-wide GHG inventory?	Ch. 4
How do I collect data for the inventory?	Ch. 5
How do I calculate emissions from stationary energy production and use?	Ch. 6
How do I calculate emissions from transportation?	Ch. 7
How do I calculate emissions from waste treatment?	Ch. 8
How do I calculate emissions from industrial processes and product use?	Ch. 9
How do I calculate emissions from agriculture, forestry and land use?	Ch. 10
How do I set a base year, set GHG emission reduction targets, and track emissions over time?	Ch. 11
How do I ensure inventory quality over time, and prepare for verification?	Ch. 12
How should I report emissions from local government operations?	Appendix B
Where do I find a quick overview of the methodologies recommend in the GPC?	Appendix C

the provisions related to community GHG emissions of the International Local Government Greenhouse Gas Emissions Analysis Protocol (developed by ICLEI), and the International Standard for Determining Greenhouse Gas Emissions for Cities (developed by The World Bank, United Nations Environment Programme (UNEP), and UN-HABITAT).

1.6 How this standard was developed

The GPC is the result of a collaborative effort between the GHG Protocol at 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.

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 (Pilot Version 1.0) and tested with 35 cities worldwide. Based on the pilot testing feedback, the GPC was revised and issued for a second public comment (Version 2.0) in July-August 2014.

Table 1.3 GPC development process

Date		Milestone
2011	June	Memorandum of Understanding between C40 and ICLEI
2012	March	GPC Draft Pilot (Version 0.9) released for public comment
	May	GPC Draft Pilot (Version 1.0) released
2013		Pilot testing with 35 cities worldwide
2014	July	GPC Draft (Version 2.0) released for public comment
	December	Final GPC 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 (scope 3 emissions). This will allow cities to take a broader and more

Table 1.2 GPC authors

Organization	Description
WRI and the GHG Protocol	• WRI is a global research organization that works closely with leaders to turn big ideas into action to sustain a healthy environment. 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 to develop internationally-accepted GHG accounting and reporting standards and tools.
C40	• C40 is a network of the world's megacities committed to addressing climate change both locally and globally. Established in 2005, C40 is comprised of 70 cities from around the world and offers an effective forum where cities 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 88 countries. ICLEI promotes local action for global sustainability and supports cities to become sustainable, resilient, resource-efficient, biodiverse, and low-carbon.

holistic approach to measuring their GHG impact, as well as identify opportunities for realizing more efficient urban supply chains.

1.7 Local government operations

In addition to compiling a city-wide GHG inventory, local governments may also want to measure GHG emissions from their own municipal operations via a local government operations (LGO) inventory. An LGO inventory allows local governments to identify GHG reduction opportunities across their jurisdiction and demonstrate leadership in taking action. While this is not a requirement of the GPC, LGO data may also be useful in compiling information for a city-wide inventory. For example, activity data from city-owned or operated buildings, facilities, landfills or land can be more precise than estimating activity data from those sectors based on scaled regional or national data. Appendix B provides further information on developing an LGO inventory.

2 Accounting and Reporting Principles

This chapter outlines the accounting and reporting principles for city-wide GHG emissions inventories. It also introduces notation keys, a disclosure practice which can help cities fulfill these principles.

Requirements in this chapter

> ***A city GHG inventory shall follow the principles of relevance, completeness, consistency, transparency and accuracy.***

2.1 Accounting and reporting principles

Accounting and reporting for city-wide GHG emissions is based on the following principles adapted from the *GHG Protocol Corporate Standard*[3] 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 patterns of the city. 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.

Completeness: Cities shall account for all required emissions sources within the inventory boundary. 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 Section 2.2).

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. Calculating emissions should follow the methodological approaches provided by the GPC. Any deviation from the preferred methodologies shall be disclosed and justified.

Transparency: Activity data, emission sources, emission factors, and accounting methodologies require adequate

3. See *GHG Protocol Corporate Standard*, 2004.

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, disclosed and justified.

Accuracy: The calculation of GHG emissions shall 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 shall 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 above may be required based on the objectives or needs of the city. For example, achieving a complete inventory may at times require using less accurate data (see Box 2.1). Over time, as both the accuracy and completeness of GHG data increase, the need for tradeoffs between these accounting principles will likely diminish.

Box 2.1 Kampala data challenges

Data limitations created a challenge for the city of Kampala, Uganda when it undertook its first GHG inventory in 2013.[4] Data from different years and sources were scaled or combined in order to complete the inventory. For instance, 2004 data from the Uganda Bureau of Statistics was scaled using a 2009 demographic and health survey from the same bureau. Commercial activities were estimated based on highly disaggregated data from a 2005 business register, while residential data was based on a household survey from the inventory year. In this instance Kampala decided to trade data accuracy for a broader data set to meet their objective of completing a city-wide inventory covering all relevant sectors.

4. Makerere University. Greenhouse Gas Emissions Inventory for Kampala City and Metropolitan Region, 2013. http://mirror.unhabitat.org/downloads/docs/12220_1_595178.pdf

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. In many cases, it will need to be adapted for the purposes of the inventory. The GPC recognizes these challenges and sets out data collection principles and approaches in Chapter 5, and overall inventory quality methods in Chapter 12. 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 requires the use of notation keys, as recommended in *IPCC Guidelines*. Where notation keys are used, cities shall provide an accompanying explanation to justify exclusions or partial accounting of GHG emission source categories.

Table 2.1 Use of notation keys[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 shall be noted in the explanation.
NE	Not Estimated	Emissions occur but have not been estimated or reported; justification for exclusion shall be noted in the explanation.
NO	Not Occurring	An activity or process does not occur or exist within the city.
C	Confidential	GHG emissions which could lead to the disclosure of confidential information and can therefore not be reported

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 reported. However, if the data are also included in another emissions source category or cannot be disaggregated, the notation key "IE" shall be used with appropriate explanation in order 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 were also reported under generation of energy for use in buildings. If the data are available but cannot be reported for reasons of data confidentiality and cannot be included in another emissions source category, the notation key "C" would be used. For instance, certain military operations or industrial facilities may not permit public data disclosure where this impacts security. Finally, if the data are not available and, therefore, the emissions are not estimated, the notation key "NE" would be used. The latter should be avoided by exploring multiple methodologies and data sources to estimate emissions. See Box 2.2 for an example of notation key usage in an inventory.

5. *2006 IPCC Guidelines* also includes the notation key "NA—Not Applicable" for activities that occur but do not result in specific GHG emissions. For the purposes of the GPC, 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.

Box 2.2 Use of notation keys—Johannesburg

Johannesburg, South Africa, completed its first GHG inventory in 2014, and used notation keys to explain where emissions data is missing for the sources listed in the GPC accounting and reporting framework. Owing to a lack of good quality data, the city was unable to estimate emissions from two sectors—Industrial Processes and Product Use (*IPPU*) and Agriculture, Forestry and Land Use (*AFOLU*). The notation key NE was used to indicate this. Furthermore, being a landlocked city with no major river or other waterway, there are no emissions from water-borne navigation and thus the notation key NO was used. Finally, grid-supplied energy data was available but only disaggregated by residential and non-residential buildings. Emissions from the use of grid-supplied energy in manufacturing industry and construction were therefore included in the total use of grid-supplied energy in commercial and institutional buildings and facilities. The city used notation key IE to indicate this and explain why no emissions were reported for grid-supplied energy use in manufacturing industry and construction.

3 Setting the Inventory Boundary

An inventory boundary identifies the gases, emission sources, geographic area, and time span covered by a GHG inventory. The inventory boundary is designed to provide a city with 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 shall include all seven Kyoto Protocol GHGs 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 boundary. Any geographic boundary may be used for the GHG inventory, and cities shall maintain the same boundary for consistent inventory comparison over time (see Chapter 11 for information about recalculating base years to reflect structural changes). 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, a metropolitan area, or another geographically identifiable entity. The boundary should be chosen independently of the location of any buildings or facilities under municipal—or other government—control, such as power generation facilities or landfill sites outside of the city's geographic boundary.

3.2 Time period

The GPC is designed to account for city GHG emissions within a single reporting year. The inventory shall 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 the city.

Calculation methodologies in the GPC generally quantify emissions released during the reporting year. In certain cases—in the *Waste* sector, for instance—the available or nationally-consistent methodologies may also estimate the future emissions that result from activities conducted within the reporting year (see waste emissions accounting in Chapter 8).

3.3 Greenhouse gases

Cities shall account for emissions of the seven gases currently required for most national GHG inventory reporting under the Kyoto Protocol: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen triflouride (NF_3).[6]

3.4 GHG emission sources

GHG emissions from city activities shall be classified into six main sectors, including:

- Stationary energy
- Transportation
- Waste
- Industrial processes and product use (*IPPU*)
- Agriculture, forestry, and other land use (*AFOLU*)
- Any other emissions occurring outside the geographic boundary as a result of city activities (collectively referred to as *Other Scope 3*). These emissions are not covered in this version of the GPC: see Section 3.6.

Emissions from these sectors shall be sub-divided into sub-sectors and may be further sub-divided into sub-categories. These designations include[7]:

- **Sectors**, for GPC purposes, define the topmost categorization of city-wide GHG sources, distinct from one another, that together make up the city's GHG emission sources activities.
- **Sub-sectors** are divisions that make up a sector (e.g., waste treatment methods, or transport modes such as aviation or on-road).
- **Sub-categories** are used to denote an additional level of categorization, such as vehicle types within the sub-sector of each transport mode, or buildings types within the stationary energy sector. Sub-categories provide opportunities to use disaggregated data, improve inventory detail, and help identify mitigation actions and policies.

Table 3.1 lists the six sectors and sub-sectors.

6. 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.

7. *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

Table 3.1 **Sectors and sub-sectors of city GHG emissions**

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

3.5 Categorizing emissions by scope

Activities taking place within a city can generate GHG emissions that occur inside the city boundary as well as outside the city boundary. To distinguish between these, the GPC groups emissions into three categories based on where they occur: scope 1, scope 2 or scope 3 emissions. Definitions are provided in Table 3.2, based on an adapted application of the scopes framework used in the *GHG Protocol Corporate Standard.*[8]

The GPC distinguishes between emissions that physically occur within the city (scope 1), from those that occur outside the city but are driven by activities taking place within the city's boundaries (scope 3), from those that occur from the use of electricity, steam, and/or heating/cooling supplied by grids which may or may not cross city boundaries (scope 2)., Scope 1 emissions may also be termed "territorial" emissions, because they are produced solely within the territory defined by the geographic boundary.

Figure 3.1 illustrates which emission sources occur solely within the geographic boundary established for the inventory, which occur outside the geographic boundary, and which may occur across the geographic boundary.

Table 3.2 **Scopes definitions for city inventories**

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

8. The scopes framework is derived from the *GHG Protocol Corporate Standard,* where the scopes are considered to be operational boundaries based on an inventory boundary established by the company's chosen consolidation approach. In the GPC, the geographic boundary serves as the boundary. See Appendix A for a comparison of how the scopes framework is applied in corporate GHG inventories compared to city GHG inventories.

Chapters 6 to 10 provide additional guidance on how to categorize emissions into scopes and sub-sectors and sub-categories.

3.5.1 Aggregating city inventories

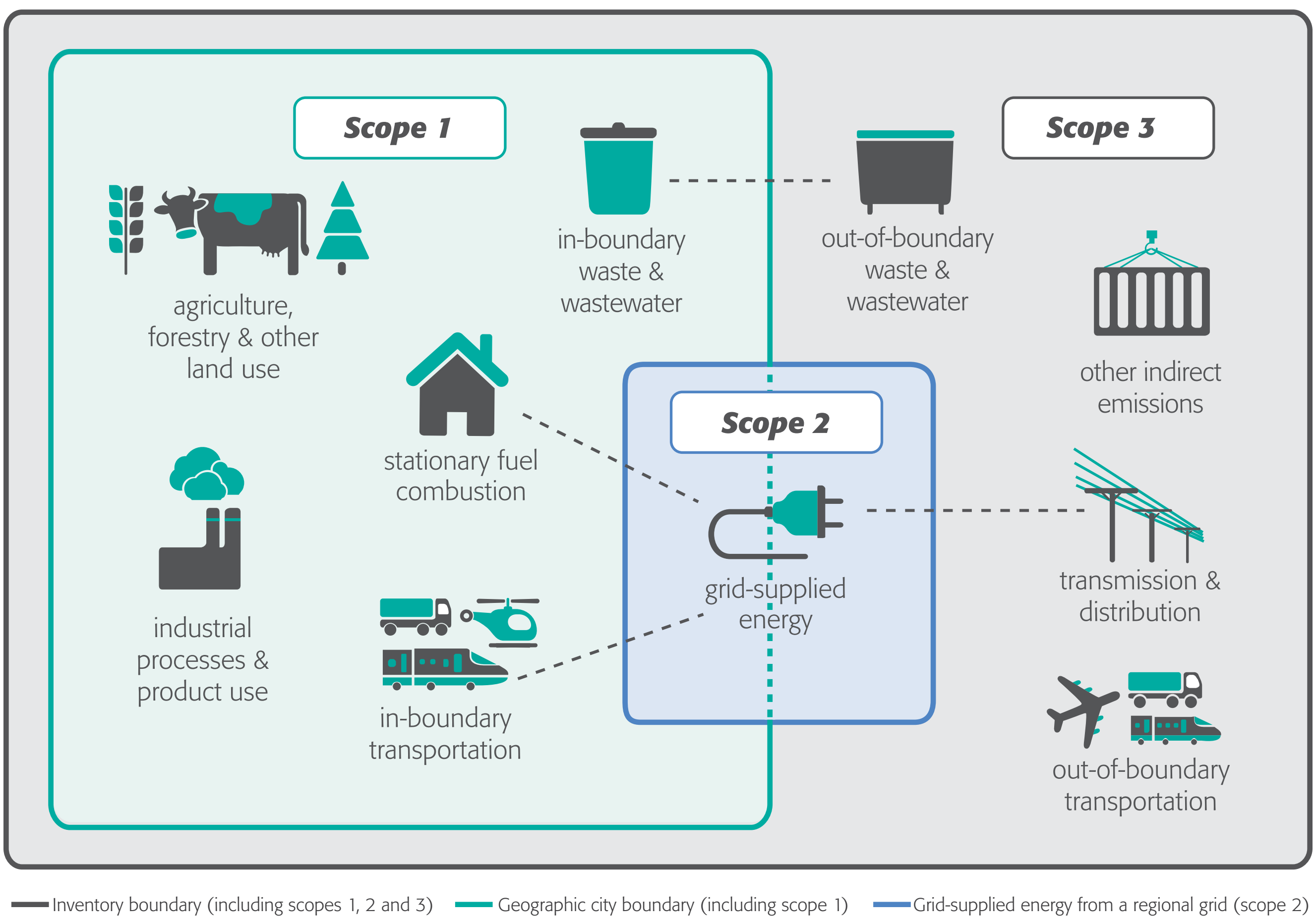
In addition, the GPC has been designed to allow city inventories to be aggregated at subnational and national levels in order to:

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

For policy makers or other national authorities, multiple city inventory aggregation is accomplished by combining only the scope 1 emissions reported by cities. This is also termed "territorial" accounting. Aggregating only scope 1 emissions from cities without overlapping geographic boundaries ensures that the aggregated results will not double count any emission sources, since emissions can only be physically generated in one location.[9]

9. For the transportation sector in particular, policy makers should seek to collect emissions data from cities based on comparable methods. For instance, the fuel sales method relies on discrete points of fuel sales located within city geographic boundaries and can more easily be aggregated together without double counting.

Figure 3.1 Sources and boundaries of city GHG emissions



3.6 Other scope 3 emissions

Cities, by virtue of their size and connectivity, inevitably give rise to GHG emissions beyond their boundaries. 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, including transmission and distribution losses associated with grid-supplied energy, and waste disposal and treatment outside the city boundary and transboundary transportation.

Cities may optionally report *Other Scope 3* sources associated with activity in a city—such as GHG emissions embodied in fuels, water, food and construction materials. To support cities in measuring these and other scope 3 emissions in a robust and consistent manner, the GPC authors anticipate providing additional guidance on estimating emissions from key goods and services produced outside the city boundary.

Consumption-based accounting is an alternative to the sector-based approach to measuring city emissions adopted by the GPC. This focuses on the consumption of *all* goods and services by *residents* of a city, and GHG emissions are reported by consumption category rather than the emission source categories set out in the GPC. The consumption-based approach allocates GHG emissions to the final consumers of goods and services, rather than to the original producers of those GHG emissions. As such GHG emissions from visitor activities and the production of goods and services within the city boundary that are exported for consumption outside the city boundary are excluded. 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. This approach is complementary to the GPC and provides a different insight into a city's GHG emissions profile (see Box 3.1). Please see Appendix A for references to existing methodologies used by cities.

3.7 Boundaries for mitigation goals

For many cities with existing climate action plans and targets, the mitigation goal boundary used can be different to the inventory boundary outlined above. However, cities are encouraged to align their mitigation goal boundary with the GPC inventory boundary. Mitigation goals can apply to a city's overall emissions or to a subset of the GHGs, scopes, or emission sources set out in the GPC.

Where the mitigation goal boundary differs from the GPC inventory boundary, cities should explain the differences, and reason for the differences, to avoid any confusion. See Chapter 4 for how cities can report offsetting measures, and Chapter 11 for how to set reduction targets.

Box 3.1 Scope 3 sources—King County

King County in the U.S. state of Washington carried out a study published in 2012[10] using 2008 data to estimate the emissions associated with all goods and services consumed by the region's two million residents, regardless of where the emissions were produced. This kind of "consumption-based" GHG inventory provides an additional view of a community's contribution to climate change. The consumption-based inventory used economic data on purchasing behaviors and "input-output" analysis to estimate the emissions released to produce, transport, sell, use and dispose of all the materials, goods, and services consumed by the region. Total emissions were estimated at 55 million $MTCO_2e$, over a quarter of which were released outside the United States. Overall, emissions associated with local consumption by residents, governments and businesses, including from the production of goods, food and services from outside the County, were more than twice as high as emissions that occurred inside the County's borders. King County's "geographic-plus" based inventory separately estimated regional emissions at 23 million $MTCO_2e$ using a methodology similar to the GPC. The difference in emissions reflects the different sources covered by the two methodologies. Note, some sources are included in both inventories and therefore the results should not be added together.

10. *Source:* King County and SEI (2012) Greenhouse Gas Emissions in King County: An updated Geographic-plus inventory, a Consumption-based Inventory, and an Ongoing Tracking Framework. http://your.kingcounty.gov/dnrp/library/dnrp-directors-office/climate/2008-emissions-inventory/ghg-inventory-summary.pdf

4 Reporting Requirements

The GPC provides a robust and transparent accounting and reporting system for city-wide GHG emissions.

The GPC requires cities to report their emissions using two distinct but complementary approaches:

- The **scopes framework** allows cities to comprehensively report all GHG emissions attributable to activities taking place within the geographic boundary of the city by categorizing the emission sources into in-boundary sources (scope 1, or "territorial"), grid-supplied energy sources (scope 2), and out-of-boundary sources (scope 3). Scope 1 allows for a territorial approach to aggregating multiple cities' inventories, consistent with national-level GHG reporting.
- The **city-induced framework** measures GHG emissions attributable to activities taking place within the geographic boundary of the city. This covers selected scope 1, 2 and 3 emission sources. It provides two reporting levels demonstrating different levels of completeness. The **BASIC** level covers emission sources that occur in almost all cities (*Stationary Energy*, in-boundary transportation, and in-boundary generated waste) and the calculation methodologies and data are more readily available. The **BASIC+** level has a more comprehensive coverage of emissions sources (BASIC sources plus *IPPU*, *AFOLU*, transboundary transportation, and energy transmission and distribution losses) and reflects more challenging data collection and calculation procedures.

This chapter sets out reporting requirements and explains how to aggregate emission totals for both frameworks. Cities may also report emissions based on relevant local or program-specific requirements in addition to the requirements of the GPC.

GHG inventories should be updated on a regular basis using the most recent data available. The GPC recommends cities update their inventory on an annual basis, as it provides frequent and timely progress on overall GHG emissions reduction efforts.

4.1 The scopes and city-induced frameworks

Table 4.1 provides an overview of the above-mentioned scopes and BASIC/BASIC+ frameworks as well as breakdowns by sector and sub-sector. These represent the key emitting sources occurring in almost all cities, and for which standardized methods are generally available. Cities should aim to cover all emissions for which reliable data is available. Notation keys shall be used to indicate any data gaps.

The GPC requires reporting for one of two reporting levels: BASIC and BASIC+. BASIC covers scope 1 and scope 2 emissions from *Stationary Energy* and *Transportation*, as well as in-boundary generated waste. BASIC+ reflects more challenging data collection and calculation processes, and additionally includes emissions from *IPPU, AFOLU,* transboundary transportation, and energy transmission and distribution losses. Where these sources are significant and relevant for a city, the city should aim to report according to BASIC+. The sources covered in BASIC+ also align with sources required for national reporting in *IPCC Guidelines*. Cities shall indicate the reporting level chosen for their inventory. A city choosing BASIC+ shall have no emissions from BASIC sources that are "Not Estimated."

Cities reporting additional scope 3 sources beyond the requirements of BASIC+ should classify these as *Other Scope 3* and document the methods they have used to estimate these emissions. These shall be reported separately from the BASIC/BASIC+ totals.

Note, for the BASIC and BASIC+ reporting levels, emissions from grid-supplied energy are calculated at the point of energy consumption and emissions from waste at the point of waste generation. For territorial (scope 1) accounting, emissions from grid-supplied energy are calculated at the point of energy generation and emissions from waste at the point of waste disposed. Box 4.1 below articulates the emission sources and scopes included in each reporting level.

Tick marks in Table 4.1 indicate which emissions sources are covered by the GPC, and cells are colored to indicate their inclusion in the BASIC or BASIC+ totals and the territorial (scope 1) total. Rows written in italics represent sub-sector emissions required for territorial emission totals but not BASIC/BASIC+. Gray cells in the scope 2 and scope 3 columns indicate emission sources that do not have applicable GHG emissions in that scope category. Emission sources corresponding to the orange boxes in the scope 3 column are not required for reporting, but may be identified and disclosed separately under *Other Scope 3*. In the case of *Waste*, *IPPU* or *AFOLU*, facilities in these sectors will likely use grid-supplied energy, but these emissions are reported

Box 4.1 Emission sources and scopes in BASIC and BASIC+

Emission sources and scopes included in **BASIC** totals:

- All scope 1 emissions from *Stationary Energy* sources (excluding energy production supplied to the grid, which shall be reported in the scope 1 total)
- All scope 1 emissions from *Transportation* sources
- All scope 1 emissions from *Waste* sources (excluding emissions from imported waste, which shall be reported in the scope 1 total)
- All scope 2 emissions from *Stationary Energy* sources and transportation
- Scope 3 emissions from treatment of exported waste

BASIC+ totals include all BASIC sources, plus:

- All scope 1 emissions from *IPPU*
- All scope 1 emissions from *AFOLU*
- Scope 3 emissions from *Stationary Energy* sources (only transmission and distribution losses), and from *Transportation*

Figure 4.1 Sources and scopes covered by the GPC

Sectors and sub-sectors	Scope 1	Scope 2	Scope 3
STATIONARY ENERGY			
Residential buildings	✓	✓	✓
Commercial and Institutional buildings and facilities	✓	✓	✓
Manufacturing industries and construction	✓	✓	✓
Energy industries	✓	✓	✓
Energy generation supplied to the grid	✓		
Agriculture, forestry, and fishing activities	✓	✓	✓
Non-specified sources	✓	✓	✓
Fugitive emissions from mining, processing, storage, and transportation of coal	✓		
Fugitive emissions from oil and natural gas systems	✓		
TRANSPORTATION			
On-road	✓	✓	✓
Railways	✓	✓	✓
Waterborne navigation	✓	✓	✓
Aviation	✓	✓	✓
Off-road	✓	✓	
WASTE			
Disposal of solid waste generated in the city	✓		✓
Disposal of solid waste generated outside the city	✓		
Biological treatment of waste generated in the city	✓		✓
Biological treatment of waste generated outside the city	✓		
Incineration and open burning of waste generated in the city	✓		✓
Incineration and open burning of waste generated outside the city	✓		
Wastewater generated in the city	✓		✓
Wastewater generated outside the city	✓		
INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU)			
Industrial processes	✓		
Product use	✓		
AGRICULTURE, FORESTRY, AND LAND USE (AFOLU)			
Livestock	✓		
Land	✓		
Other agriculture	✓		
OTHER SCOPE 3			
Other Scope 3			

✓ Sources covered by the GPC
Sources required for BASIC reporting
\+ Sources required for BASIC+ reporting
Sources required for territorial total but not for BASIC/BASIC+ reporting (*italics*)
Sources included in Other Scope 3
Non-applicable emissions

by commercial and institutional buildings and facilities sub-sector under *Stationary Energy.*

Chapters 6 to 10 provide additional guidance on how to categorize emissions from these sectors and sub-sectors into scopes.

4.2 Reporting requirements

City GHG inventories shall report the following information:

4.2.1 Description of the inventory boundary

- A description of the geographic boundary. Cities should include a map of the geographic boundary that includes a depiction of the region, and rationale used for selecting the geographic boundary.
- An outline of the activities included in the inventory, and if other scope 3 are included, a list specifying which types of activities are covered.
- Any specific exclusion of required sources, facilities, and/or operations. These shall be identified using notation keys (see Section 2.2), along with a clear justification for their exclusion.
- The continuous 12-month reporting period covered.
- The reporting level chosen (BASIC or BASIC+).
- An overview of the reporting city, including total geographic land area, resident population, and GDP. Cities should also include other information, such as an indication of the number of commuters in the city who are not residents, the composition of the economy, climate, and land use activities (accompanied by a land use map). This background can help cities report relevant ratio indicators about performance, such as emissions per geographic area, person, GDP, etc.

4.2.2 Information on emissions

Table 4.3 provides a sample reporting structure that covers all of these reporting requirements outlined above. Cities may report GHG emissions in a variety of additional formats depending on purpose and audience, and may also disaggregate emissions by fuel type, municipal operations within each sector or sub-sector, etc. However, they shall comply with the following requirements:

- **Emissions by sector:** GHG emissions shall be reported for each sector and sub-sector. Emissions sequestered by CO_2 capture and storage systems shall be excluded from emission totals for applicable sectors. However, cities may report these separately.
- **Emissions by scope**: GHG emissions shall be reported by scope 1, scope 2, and scope 3 separately. These scope totals shall be independent of any GHG trades such as sales, purchases, transfers, or banking of allowances.
- **Emissions by gas:** GHG emissions shall be reported in metric tonnes and expressed 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 its respective global warming potential (GWP), as described in Chapter 5.
- **Emissions by total**: GHG emissions shall be aggregated according to the scopes framework and the city-induced framework (BASIC+ or BASIC, based on the reporting level chosen).
- **Emissions from biogenic origin:** CO_2 emissions from combustion of materials of biogenic origin (e.g., biomass, biofuel, etc.) shall be reported separately from the scopes and other gases. For reference, this should be under column CO_2(b) in the reporting framework (Table 4.3), but not counted in emissions totals. See Box 4.2 for more on biogenic reporting.

Box 4.2 Reporting biogenic CO_2 emissions

Biogenic emissions are those that result from the combustion of biomass materials that naturally sequester CO_2, including materials used to make biofuels (e.g. crops, vegetable oils, or animal fats). For the purposes of national-level GHG inventories, land-use activities are recorded as both sinks and sources of CO_2 emissions. Reporting emissions from combusting these biogenic fuels would result in double counting on a national level. The GPC also records land-use changes, and combusted biofuels may be linked to land-use changes in its own inventory, or other cities' inventories.

4.2.3 Information on methodologies and data quality

- For methodologies used to calculate or measure emissions, cities shall provide a reference or link to any calculation tools used. For each emission source sector, cities shall provide a description of the types and sources of data, including activity data, emission factors, and global warming potential (GWP) values used to calculate emissions.
- Cities shall provide an assessment of data quality for activity data and emission factors used in quantification, following a High-Medium-Low rating (see Section 5.6). For reference, these are noted in Table 4.3 as Activity Data (AD) and Emission Factor (EF), respectively, under the data quality columns.

4.2.4 Information on emission changes

- If a city has set a mitigation goal, it shall identify the year chosen as the base year and report base year emissions.
- If the city is using an inventory to track progress toward a mitigation goal, the city shall identify a significance threshold that triggers base year emissions recalculation (such as acquisition of existing neighboring communities, changes in reporting boundaries or calculation methodologies, etc.). See Chapter 11 for choosing a base year and recalculation procedures. Cities should explain measures taken to ensure consistency when there is a change in methodologies (e.g., change in data collection method or calculation method).

4.3 Reporting recommendations

Where relevant, cities should also provide in the inventory:

- **Scope 2 emissions based on a market-based method calculation** (Table 4.4a). This reflects any electricity products or programs that city consumers participate in, generally provided by the electricity supplier serving the city. See Chapter 6 for a description on how to report this.
- **Offset credit transactions** (Table 4.4b). If offset credits are generated in the geographic boundary and sold, these should be documented separately from emissions reporting. In addition, any offsets purchased from outside the geographic boundary should be separately reported and not "netted" or deducted from the reported inventory results.
- **Renewable energy generation (in MWh or KWh) produced within the geographic boundary, or reflecting an investment by the city** (Table 4.4c). This information can help a city identify renewable production that otherwise only indirectly impacts scope 2 emissions (through a lower grid average emission factor) and that would not be visible in scope 1 emissions for energy generation (due to its zero emissions profile).

4.4 GPC reporting framework

The following tables highlight key reporting requirements and recommendations of the GPC and together represent the larger reporting framework. With the help of notation keys, a city shall report all of the required information from Table 4.1, Table 4.2, and Table 4.3. A city may also report data required in Tables 4.4, where such information is relevant and available.

Table 4.1 Inventory city information

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

Table 4.2 GHG Emissions Summary

Sector		Total by scope (tCO_2e)				Total by city-induced reporting level (tCO_2e)	
		Scope 1 (Territorial)	Scope 2	Scope 3 included in BASIC/ BASIC+	Other Scope 3	BASIC	BASIC+
Stationary Energy	Energy use (all emissions except I.4.4)						
	Energy generation supplied to the grid (I.4.4)						
Transportation (all II emissions)							
Waste	Generated in the city (all III.X.1 and III.X.2).						
	Generated outside city (all III.X.3)						
IPPU (all IV emissions)							
AFOLU (all V emissions)							
Total		(All territorial emissions)				(All BASIC emissions)	(All BASIC & BASIC+ emissions)

Sources required for BASIC reporting

\+ Sources required for BASIC+ reporting

Sources included in Other Scope 3

Sources required for territorial total but not for BASIC/BASIC+ reporting (*italics*)

Non-applicable emissions

This table summarizes the emission required for scopes totals and for the city-induced framework's BASIC/BASIC+ reporting levels. It references the line numbers and coloring from the detailed Table 4.3. *Note:* Aggregation of multiple city inventories is accomplished by combining the scope 1 (territorial) emissions of cities whose inventory boundaries do not overlap geographically.

Table 4.3 GHG Emissions Report

GPC ref No.	Scope	GHG Emissions Source (By Sector and Sub-sector)	Notation keys
I		**STATIONARY ENERGY**	
I.1		Residential buildings	
I.1.1	1	Emissions from fuel combustion within the city boundary	
I.1.2	2	Emissions from grid-supplied energy consumed within the city boundary	
I.1.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	
I.2		Commercial and institutional buildings and facilities	
I.2.1	1	Emissions from fuel combustion within the city boundary	
I.2.2	2	Emissions from grid-supplied energy consumed within the city boundary	
I.2.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	
I.3		Manufacturing industries and construction	
I.3.1	1	Emissions from fuel combustion within the city boundary	
I.3.2	2	Emissions from grid-supplied energy consumed within the city boundary	
I.3.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	
I.4		Energy industries	
I.4.1	1	Emissions from energy used in power plant auxiliary operations within the city boundary	
I.4.2	2	Emissions from grid-supplied energy consumed in power plant auxiliary operations within the city boundary	
I.4.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption in power plant auxiliary operations	
I.4.4	1	*Emissions from energy generation supplied to the grid*	
I.5		Agriculture, forestry and fishing activities	
I.5.1	1	Emissions from fuel combustion within the city boundary	
I.5.2	2	Emissions from grid-supplied energy consumed within the city boundary	
I.5.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	
I.6		Non-specified sources	
I.6.1	1	Emissions from fuel combustion within the city boundary	
I.6.2	2	Emissions from grid-supplied energy consumed within the city boundary	
I.6.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	
I.7		Fugitive emissions from mining, processing, storage, and transportation of coal	
I.7.1	1	Emissions from fugitive emissions within the city boundary	
I.8		Fugitive emissions from oil and natural gas systems	
I.8.1	1	Emissions from fugitive emissions within the city boundary	
II		**TRANSPORTATION**	
II.1		On-road transportation	
II.1.1	1	Emissions from fuel combustion on-road transportation occurring within the city boundary	
II.1.2	2	Emissions from grid-supplied energy consumed within the city boundary for on-road transportation	
II.1.3	3	Emissions from portion of transboundary journeys occurring outside the city boundary, and transmission and distribution losses from grid-supplied energy consumption	
II.2		Railways	
II.2.1	1	Emissions from fuel combustion for railway transportation occurring within the city boundary	
II.2.2	2	Emissions from grid-supplied energy consumed within the city boundary for railways	
II.2.3	3	Emissions from portion of transboundary journeys occurring outside the city boundary, and transmission and distribution losses from grid-supplied energy consumption	
II.3		Waterborne navigation	
II.3.1	1	Emissions from fuel combustion for waterborne navigation occurring within the city boundary	
II.3.2	2	Emissions from grid-supplied energy consumed within the city boundary for waterborne navigation	
II.3.3	3	Emissions from portion of transboundary journeys occurring outside the city boundary, and transmission and distribution losses from grid-supplied energy consumption	
II.4		Aviation	
II.4.1	1	Emissions from fuel combustion for aviation occurring within the city boundary	
II.4.2	2	Emissions from grid-supplied energy consumed within the city boundary for aviation	
II.4.3	3	Emissions from portion of transboundary journeys occurring outside the city boundary, and transmission and distribution losses from grid-supplied energy consumption	
II.5		Off-road transportation	
II.5.1	1	Emissions from fuel combustion for off-road transportation occurring within the city boundary	
II.5.2	2	Emissions from grid-supplied energy consumed within the city boundary for off-road transportation	
III		**WASTE**	
III.1		Solid waste disposal	
III.1.1	1	Emissions from solid waste generated within the city boundary and disposed in landfills or open dumps within the city boundary	
III.1.2	3	Emissions from solid waste generated within the city boundary but disposed in landfills or open dumps outside the city boundary	
III.1.3	1	*Emissions from waste generated outside the city boundary and disposed in landfills or open dumps within the city boundary*	
III.2		Biological treatment of waste	
III.2.1	1	Emissions from solid waste generated within the city boundary that is treated biologically within the city boundary	
III.2.2	3	Emissions from solid waste generated within the city boundary but treated biologically outside of the city boundary	
III.2.3	1	*Emissions from waste generated outside the city boundary but treated biologically within the city boundary*	
III.3		Incineration and open burning	
III.3.1	1	Emissions from solid waste generated and treated within the city boundary	
III.3.2	3	Emissions from solid waste generated within the city boundary but treated outside of the city boundary	
III.3.3	1	*Emissions from waste generated outside the city boundary but treated within the city boundary*	
III.4		Wastewater treatment and discharge	
III.4.1	1	Emissions from wastewater generated and treated within the city boundary	
III.4.2	3	Emissions from wastewater generated within the city boundary but treated outside of the city boundary	
III.4.3	1	*Emissions from wastewater generated outside the city boundary but treated within the city boundary*	
IV		**INDUSTRIAL PROCESSES and PRODUCT USES (IPPU)**	
IV.1	1	Emissions from industrial processes occurring within the city boundary	
IV.2	1	Emissions from product use occurring within the city boundary	
V		**AGRICULTURE, FORESTRY and OTHER LAND USE (AFOLU)**	
V.1	1	Emissions from livestock within the city boundary	
V.2	1	Emissions from land within the city boundary	
V.3	1	Emissions from aggregate sources and non-CO_2 emission sources on land within the city boundary	
VI		**OTHER SCOPE 3**	
VI.1	3	Other Scope 3	

Gases (in tonnes)									Data Quality		Explanatory comments (i.e. description of methods used, or emission exclusions)
CO_2	CH_4	N_2O	HFC	PFC	SF_6	NF_3	Total CO_2e	$CO_2(b)$	AD	EF	

Sources required for BASIC reporting

\+ Sources required for BASIC+ reporting

Sources required for territorial total but not for BASIC/BASIC+ reporting

Sources included in Other Scope 3

Non-applicable emissions

Optional information items

Table 4.4(a) **Scope 2 emissions based on market-based method**

Contractual instrument or program type	Quantity of energy (kWh, MWh, BTU, etc.)	Emission factor conveyed by the instrument	Total GHG emissions (tCO_2e)
TOTAL market-based scope 2 emissions (in tCO_2e)			

Table 4.4(b) **Offset credit transactions**

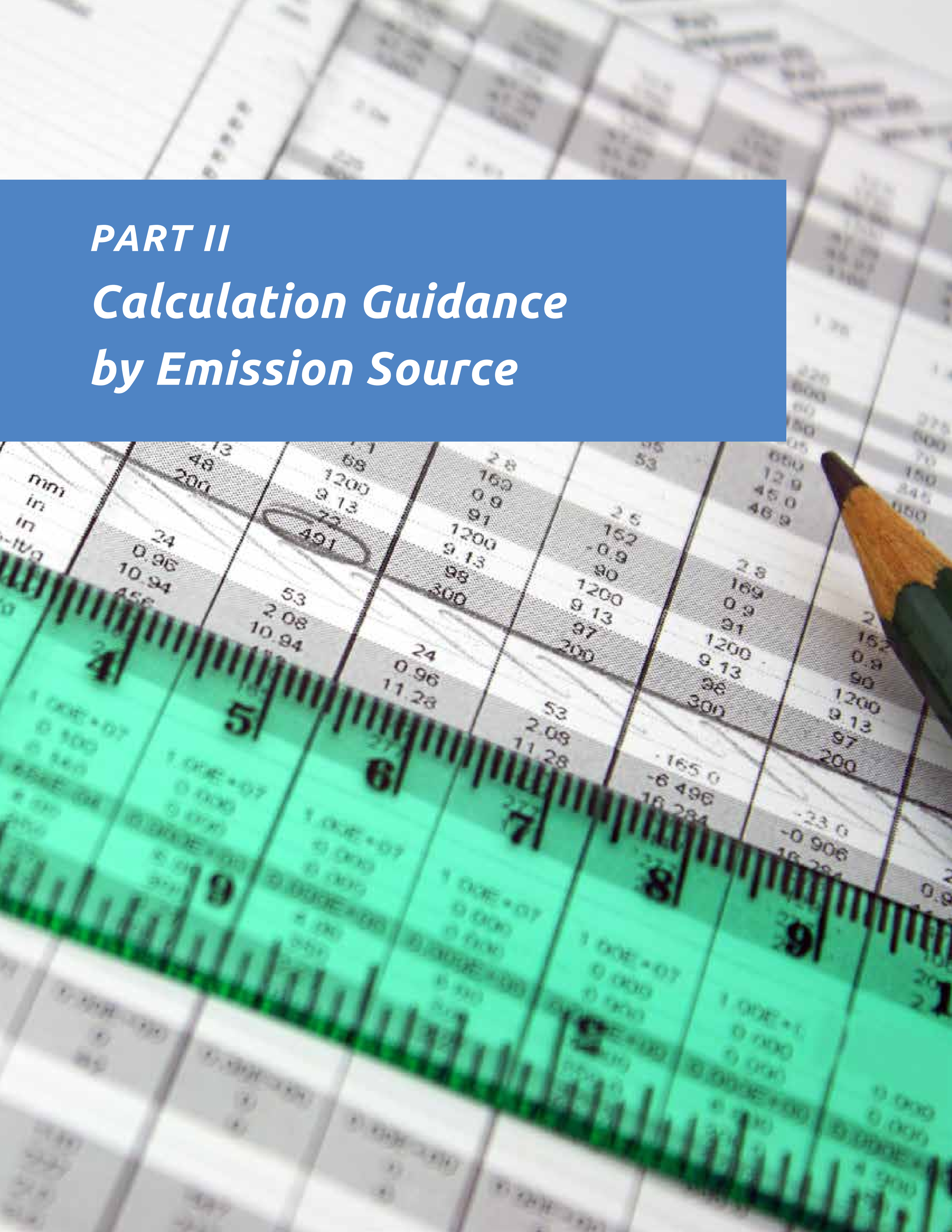
Offset credits generated within the geographic boundary and sold	Total GHG emissions (tCO_2e)

Offset credits purchased from outside the geographic boundary (e.g., to meet a city reduction goal)	Total GHG emissions (tCO_2e)

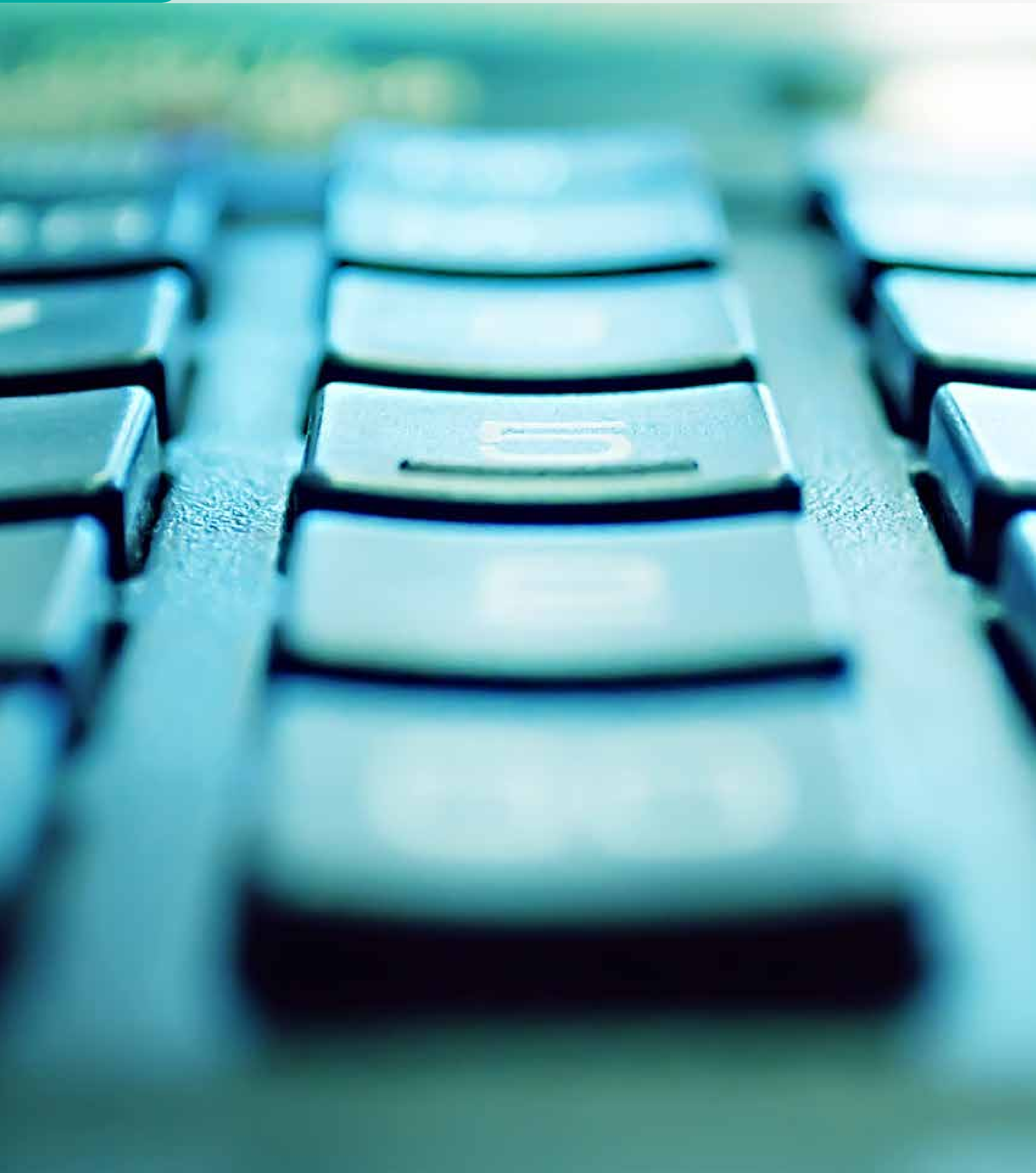
Table 4.4(c) **Renewable energy production or investments**

Technology type	Total annual production of grid-delivered energy	Located in geographic boundary?	If outside boundary, percentage of ownership by city?

PART II
Calculation Guidance by Emission Source



5 Overview of Calculating GHG Emissions



The GPC specifies the principles and rules for compiling a city-wide GHG emissions inventory; it does not require specific methodologies to be used to produce emissions data. This chapter provides overarching guidance for sourcing activity data and calculating emission factors. It also sets out guidance for calculating GHG emissions consistent with the requirements set out in Chapters 6 to 10.

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 their inventory, availability of data, and consistency with their country's national inventory and/or other measurement and reporting programs in which they participate. An overview of methodologies outlined in the GPC is provided in Appendix C.

5.1.1 *IPCC Guidelines* and methodology tiers

Unless stated otherwise, calculation methodologies referenced in the GPC are consistent with the *IPCC Guidelines*. Where different methodologies are used, cities should ensure they meet the requirements of the GPC and document the methodologies they have used in their inventory report.

In *IPCC Guidelines*, three hierarchical tiers are used 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*.

5.1.2 Calculation overview

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 × 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 solid 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.

Table 5.1 Data collection principles[11]

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 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.

5.3 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 inventory 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 publicly-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[12], sampling activities, or surveys. Surveys may be the best option for most emission sources, given the tailored data needs of city-wide GHG inventories,

11. Adapted from *2006 IPCC Guidelines*, Chapter 2.

12. For example, direct measurement of point source GHG emissions from an industrial or waste treatment facility.

although they can be relatively expensive and time-consuming without proper guidance.[13]

5.3.1 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 inventory boundary by adjusting for changes in activity using a scaling factor. The scaling factor represents the ratio between the available data and the required inventory data, and should reflect a high degree of correlation to variations in the data. Scaled data can be useful and relevant where data for the inventory year, or city-specific data, are unavailable or incomplete.[14, 15]

Cities should use calendar year data whenever available in conformance with national inventory practices. 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 well-documented and used consistently over time to avoid bias in the trend. These do not need to be adjusted.

The general formula for scaling data is found in Equation 5.2.

References are made throughout Chapters 6–10 on how to scale data from a national or regional level to the city for different emission sectors. Recommended scaling factors are also provided, including how to account for energy use changes based on weather.[16] If a city chooses a different scaling factor than the one recommended, the relationship between the alternate scaling factor and activity data for the emissions source should be documented in the

Equation 5.2 Scaling methodology

$$\textbf{Inventory data} = \frac{\text{Factor}_{\text{Inventory data}}}{\text{Factor}_{\text{Available data}}} \times \text{Available data}$$

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

$$\textbf{City household waste data 2014} = \frac{\text{City Population}_{2014}}{\text{City Population}_{2013}} \times \text{City household waste data 2013}$$

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

13. 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

14. 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.

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

16. For example, 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. The 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. This should only be carried out where energy use data can clearly be allocated to heating or cooling. Where this allocation is not clear, no weather correction should be made.

inventory report. In all cases the original data, scaling factor data points, and data sources should be documented.

5.4 Emission factors

Emission factors convert activity data into a mass of GHG emissions; tonnes of CO_2 released per kilometer travelled, for example, or the ratio of CH_4 emissions produced to amount of waste landfilled. Emission factors should be relevant to the inventory 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, cities 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]

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.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.

5.5 Conversion of data to standard units and CO_2 equivalent

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 tonnes of each GHG as indicated in Table 4.3, as well as CO_2 equivalents (CO_2e). Where only the latter is available, this shall be clearly identified and justified in order to be in conformance with the GPC. The same applies where emission factors or emissions data are unavailable for specific gases. 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 latest version of the *IPCC Guidelines* or the version used by the country's national inventory body (see Table 5.2). 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.

Any changes in GWP values used should be reflected in the city's historical emissions profile (see Section 11.3).

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
Nitrogen trifluoride	NF_3	-	-	17,200	16,100

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

5.6 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 IPCC uses "tiers" to rank methodology, and increasing accuracy in methodology often requires more detailed or higher quality data. In the GPC, where relevant, references are provided within each emission source category chapter (Chapters 6–10) to the corresponding IPCC methodology tiers and methods.

In addition to identifying the method used to calculate emissions, cities shall 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. See Table 5.3 for an overview of these overall quality indicators.

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

5.7 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.

6 Stationary Energy

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

Requirements in this chapter

For BASIC:

Cities shall report all GHG emissions from Stationary Energy *sources and fugitive emissions in scope 1, and those 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 grid-supplied electricity, steam, heating, and cooling.

Emissions from energy generation supplied to the grid shall be reported as part of total scope 1 emissions, but not included in BASIC/BASIC+ totals.

6.1 Categorizing stationary energy sector emissions by scope

Scope 1: Emissions from fuel combustion and fugitive emissions in the city

Scope 1 includes emissions from the combustion of fuels[23] 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, including any offshore exploration that occurs within the city boundary, is also included in scope 1.

The inventory boundary of certain cities may contain non-urban areas that include agricultural, forestry, and fishing activities. Emissions from stationary fuel combustion 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 in the city

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

For scope 2 reporting, cities shall report emissions from *all* grid-supplied energy consumption within the boundary, regardless of where the energy is produced. Cities that set GHG targets related to energy consumption "net" of energy produced within the city should report these emissions separately as an information item.

Scope 3: Distribution losses from grid-supplied electricity, steam, heating and cooling in the city

Scope 3 emissions include transmission and distribution losses from the use of grid-supplied electricity, steam, heating and cooling in a city. Other upstream emissions from electricity supply may be reported in *Other Scope 3*.

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 under BASIC or BASIC+, but may be reported in *Other Scope 3.*

These emission sources and their scope categorization are summarized in Table 6.1.

6.2 Defining energy source sub-sectors

The *Stationary Energy* sector can be divided into nine sub-sectors. Seven of these nine produce emissions from both energy production and consumption, while the remaining two relate to fugitive emissions from fuel-related activities. Table 6.2 below provides detailed descriptions of *Stationary Energy* source sub-sectors. Cities may adopt additional city- or country-specific categories where data allows, but should clearly describe the differences and assumptions in inventories. Cities may further subdivide these sub-sectors into sub-categories that are more useful for mitigation action planning.

23. Non-energy uses of fossil fuel are reported under the *IPPU* sector. To differentiate energy and non-energy use of fossil fuel, please see Chapter 9.

Table 6.1 Stationary Energy Overview

GHG Emission Source	Scope 1	Scope 2	Scope 3
STATIONARY ENERGY	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 the use of grid-supplied 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
Energy generation supplied to the grid	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		

Sources required for BASIC reporting

\+ Sources required for BASIC+ reporting

Sources included in Other Scope 3

Sources required for territorial total but not for BASIC/BASIC+ reporting (*italics*)

Non-applicable emissions

6.3 Calculating stationary fuel combustion emissions

Emissions from *Stationary Energy* sources are calculated by multiplying fuel consumption (activity data) by the corresponding emission factors for each fuel, by gas. For activity data, 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. Depending on the type of fuel dispensary, fuel sales may be for *Stationary Energy* sources *or* for mobile *Transportation* sources. Cities should ensure sales information is disaggregated between these two sectors.
- **A representative sample set of real consumption data from surveys.** While surveying for fuel consumption for each sub-sector, determine the built space (i.e., square meters of office space and other building characteristics) 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.
- **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 city, 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 (or other indicators such as industrial output, floor space, etc.) served by real data to scale-up the partial data for total city-wide energy consumption.

- 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 or other indicators.**

The rest of Section 6.3 applies this emissions calculation method to each energy sub-sector, identifying further sub-categories and clarifying where emissions from multi-functional buildings or related sectoral operations should be reported.

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 use in households
I.2 Commercial buildings and facilities	All emissions from energy use in commercial buildings and facilities
I.2 Institutional buildings and facilities	All emissions from energy use in public buildings such as schools, hospitals, government offices, highway street lighting, and other public facilities
I.3 Manufacturing industries and construction	All emissions from energy 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 energy production and energy use in energy industries
1.4.4 Energy generation supplied to the grid	All emissions from the generation of energy for grid-distributed electricity, steam, heat and cooling
I.5 Agriculture, forestry, and fishing activities	All emissions from energy use in agriculture, forestry, and fishing activities
I.6 Non-specified sources	All remaining emissions from facilities producing or consuming energy 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 *Note:* 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 the city
I.8 Oil and natural gas systems	Fugitive emissions from all oil and natural gas activities occurring in the city. The primary sources of these emissions may include fugitive equipment leaks, evaporation losses, venting, flaring and accidental releases

6.3.1 Residential, commercial, and institutional buildings and facilities

Commercial and institutional buildings and facilities (e.g. public or government-owned facilities) provide public services for community needs, including safety, security, communications, recreation, sport, education, health, public administration, religious, cultural and social.[24] This includes commercial buildings and establishments, such as retail outlets, shopping complexes, office buildings; institutional buildings, such as schools, hospitals, police stations, government offices; and facilities, such as street lighting on 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.

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.

Emissions from energy used in informal settlements or social housing shall be reported in the residential sub-sector, even if the settlements' local government pays for that energy use.

Multi-function uses for buildings and facilities

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 outlined in Section 2.1 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 when their main purpose is to provide residence. 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 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 continue to report them with the associated industrial or construction activities.

24. The Council for Scientific and Industrial Research. "Guidelines for Human Settlement Planning and Design." 2000: Chapter 5.5. Online at www.csir.co.za/Built_environment/RedBook.

The GPC does not provide specific definitions for *permanent* and *temporary* workers quarters. Cities should adopt the definitions used in their local regulations. In the absence of local definitions, 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).

- **Residential units in agricultural farms**
  When the jurisdictions of cities cover rural areas, there may be individual residential units in 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 subdivide this based on average household energy use or average farm equipment usage.

6.3.2 Manufacturing industries and construction

This sub-sector includes energy use in manufacturing industries and construction activities. Fuel combustion occurs in stationary equipment, including 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 *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.

Industrial facilities may incur emissions that are included in other sectors of the GPC. Cities should distinguish between the following when classifying emissions:

- **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). 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).

  Off-road transportation activities should be categorized according to the area where they occur. For instance, 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-

Table 6.3 Definitions of temporary and permanent workers quarters

Type of premises	Temporary	Permanent
Industries	Quarters built and demolished within a period 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 otherwise specified in local regulations

Table 6.4 Detailed sub-categories of manufacturing industries and construction sub-sector, from the International Standard Industrial Classification (ISIC)[25]

Sub-categories[26]	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
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

sector, *agriculture, forestry, and fishing activities* sub-sector, *non-specified* sub-sector, and *off-road transportation* sub-sector (under *Transportation* sector).

25. Further descriptions of each subcategory can be found in the *International Standard Industrial Classification (ISIC) of All Economic Activities*, Revision 3.

26. *2006 IPCC Guidelines for National Greenhouse Gas Inventories*

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 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

- **Relationship between 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. Wastewater collection, treatment, and supply systems consume energy to power water pumps, boilers, mechanical separation equipment at material recovery facilities, water treatment facilities, and other equipment. GHG emissions from energy use for these operations should be reported under *institutional* (public facility) or *industrial* (private industrial facility) sub-sectors. If the energy use is from on-site fuel combustion, these emissions are reported as scope 1. Electricity use in these facilities is reported as scope 2 emissions.

  This also applies to direct fuel combustion for operating off-road vehicles, machinery, and buildings within the waste facility (which should be reported as scope 1 emissions). Typical off-road machinery includes compactors and bulldozers, which spread and compact 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).

6.3.3 Energy industries

Energy industries include three basic types of activities[27]:

- Primary fuel production (e.g., coal mining, and oil and gas extraction)
- Fuel processing and conversion (e.g., crude oil to petroleum products in refineries, coal to coke and coke oven gas in coke ovens)
- Energy production supplied to a grid (e.g., electricity generation and district heating) or used on-site for auxiliary energy use

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

Emissions from the following energy generation types may be classified and reported as follows:

- **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. Emissions from this combustion shall

27. *2006 IPCC Guidelines for National Greenhouse Gas Inventories*

Table 6.6 Detailed sub-categories of energy industries sub-sector[28]

Sub-categories	Descriptions	Detailed breakdown
Energy, including electricity, steam, heat/ cooling	Emissions from main activity producers of electricity generation, combined heat and power generation, and heat plants. Main activity producers (often termed 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. However, 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 (such as industrial, or institutional). Auto-producers may be under public or private ownership.	**Energy generation sold and distributed** comprises emissions from all fuel use for electricity generation from main activity producers (reported under I.4.4) 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. This subcategory is required for scope 1 (territorial) reporting, but not BASIC/BASIC+.
		Auxiliary energy use on the site of energy production facilities (e.g., a small administrative office adjacent to a power plant). Energy produced at power plants is used "on-site" for auxiliary operations before being sold and distributed to a grid (reported under I.4.1). It is therefore not grid-distributed energy consumption. 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.	N/A
Manufacture of solid fuels and other energy industries	This includes 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 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 extraction and the processing and upgrading of natural gas. This category also includes emissions from pre-combustion processing for CO_2 capture and storage.

28. *2006 IPCC Guidelines for National Greenhouse Gas Inventories*

be reported in scope 1 for grid-supplied energy production (1.4.4), and for added transparency, cities can identify the portion of those scope 1 emissions attributable to heat/steam vs. electricity production.[29] 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 is linked to corresponding land use change or carbon stock change). If waste decomposition or treatment is not used for energy generation, emissions are reported in scope 1 in the *Waste* sector (see Chapter 8).

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

Table 6.7 provides an overview of principles to help avoid double counting between *Waste*, *Stationary Energy*, and *AFOLU* sectors.

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). These 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 6.7 An overview of reporting categorization for waste-to-energy and bioenergy emissions

Activity	Purpose	CO_2	CH_4 and N_2O
Landfill gas combustion	As part of waste disposal process	Report biogenic CO_2 emissions under Waste sector (separately from any fossil CO_2 emissions)	Report emissions under Waste sector
	Energy generation	Report biogenic CO_2 under Stationary Energy sector (separately from any fossil CO_2 emissions)	Report emissions under Stationary Energy sector
Waste incineration	Waste disposal (no energy recovery)	Report CO_2 emissions under Waste sector (with biogenic CO_2 reported separately from any fossil CO_2 emissions)	Report emissions as Waste sector
	Energy generation	Report CO_2 emissions under Stationary Energy sector (with biogenic CO_2 reported separately from any fossil CO_2 emissions)	Report emissions under Stationary Energy sector
Biomass incineration	Waste disposal	Report biogenic CO_2 emissions under Waste sector (separately from any fossil CO_2 emissions)	Report emissions under Waste sector
	Energy generation	Report biogenic CO_2 emissions under Stationary Energy sector (separately from any fossil CO_2 emissions)	Report emissions under Stationary Energy sector

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 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*. When calculating fugitive emissions, cities should take into account any fugitive emission removals or sequestration that may be required by law.

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) 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 recovered methane 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, and then apply emission

factors per unit of production for mining and post-mining fugitive emissions.[30]

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 inventory boundary.

The following emissions are *not* 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 those 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.*

30. 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 Calculating emissions from grid-supplied energy consumption

Scope 2 represents all grid-supplied electricity, steam, heating and cooling consumed within the city boundary. Electricity is the most common form of grid-supplied energy, used in almost all homes, offices, other buildings, and outdoor lighting. Grid-supplied energy in the form of direct steam (heating) and/or chilled water (cooling) is typically provided by district energy systems, which may cover a smaller geographic area than electricity grids, which are typically regional. In all cases, using grid-supplied energy entails emissions produced at generation facilities *off-site* from the consumption facilities. Depending on the city and the structure of the grid, these energy generators can be located outside the geographic boundary at various locations tied to or exporting to the regional grid, or from generators located *within* the city boundary.

6.5.1 Location-based and market-based calculation methods

With regional grid networks, energy consumers can assess emissions from their consumption based on two methods: a location-based method or a market-based method. Both methods serve to allocate emissions from the point of generation to their final point of use. A location-based method is based on average energy generation emission factors for defined locations, including local, sub-national or national boundaries. It yields a grid average emission factor representing the energy produced in a region, and allocates that to energy consumers in that region.

Cities shall use the location-based method for scope 2 calculations in the GPC, and may separately document emissions from the market-based method (see Box 6.1). The supplemental market-based figure can help cities understand the choices of individual consumers, businesses and institutions, growing the market demand for low-carbon energy.

6.5.2 Relationship between energy generation (scope 1) and energy consumption (scope 2)

Cities may have energy generation facilities located inside the geographic boundary for the inventory, but in most instances a city cannot prove that its energy consumption is supplied by the resources located within the boundary. While it is generally the case that a city's aggregate energy demand will be met with a set of relatively local generation resources, cities cannot assume that their aggregate electricity consumption from regional electricity grids is met in full or in part by energy produced within the city boundary. This is not possible to guarantee due to fluctuating regional demand at any given moment, grid constraints, exports and other contractual arrangements.[31]

Therefore, cities shall report scope 2 emissions from *all* grid-supplied energy consumed in the city. Cities may also separately report this total energy consumption in MWh/kWh/BTU, etc. for added transparency.

Box 6.1 The market-based method for scope 2 accounting

As described in the GHG Protocol *Scope 2 Guidance*, the market-based method for scope 2 based on allocating emissions from energy generators to consumers based on "contractual instruments" such as utility-specific emission factors, energy attribute certificates, or other contracts. In many countries, energy suppliers or utilities can provide consumers with emissions factors for either their standard portfolio or for any low-carbon or renewable energy consumer labels, tariffs, or other programs. The method reflects contractual relationships between energy suppliers and customers, so a city-wide market-based scope 2 total would reflect emissions from only those resources that individual consumers have matched with contractual instruments.

If these instruments follow the GHG Protocol *Scope 2 Guidance* requirements on Quality Criteria, market-based scope 2 accounting can provide an indication of the emissions from energy choices that businesses, institutions, or residential consumers have made, and provide an incentive for the market to create more low-carbon energy.

BASIC/BASIC+ reporting avoids double counting by excluding scope 1 emissions from energy generation supplied to the grid. Cities shall report scope 1 and scope 2 separately and not sum them together (see Section 3.5).

6.5.3 Calculating grid-supplied electricity emissions

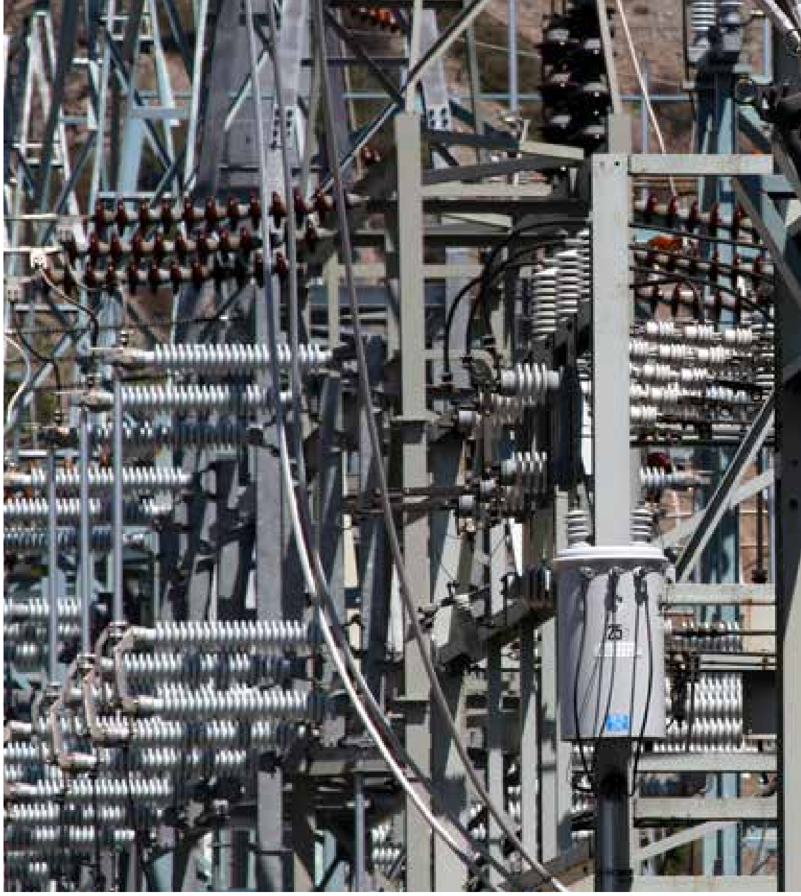
Electricity is the most common form of grid-supplied energy, used in almost all homes, offices, other buildings, and outdoor lighting. This section provides guidance on calculating scope 2 emissions from each sector and sub-sector, which are mainly based on bottom-up methods using activity data of each source. To calculate scope 2 emissions, cities should obtain activity data following the list of preferred data here:

31. See NERC website, "Understanding the Grid": http://www.nerc.com/page.php?cid=1|15

- **Real consumption data from utility providers, disaggregated by building type or non-building facility for Stationary Energy:**
    - 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. However, it should be noted that different building uses have very different energy intensity values, particularly when comparing commercial and institutional buildings with residential uses.
- **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.

For an example of identifying electricity consumption data from tariff codes, see Box 6.2.

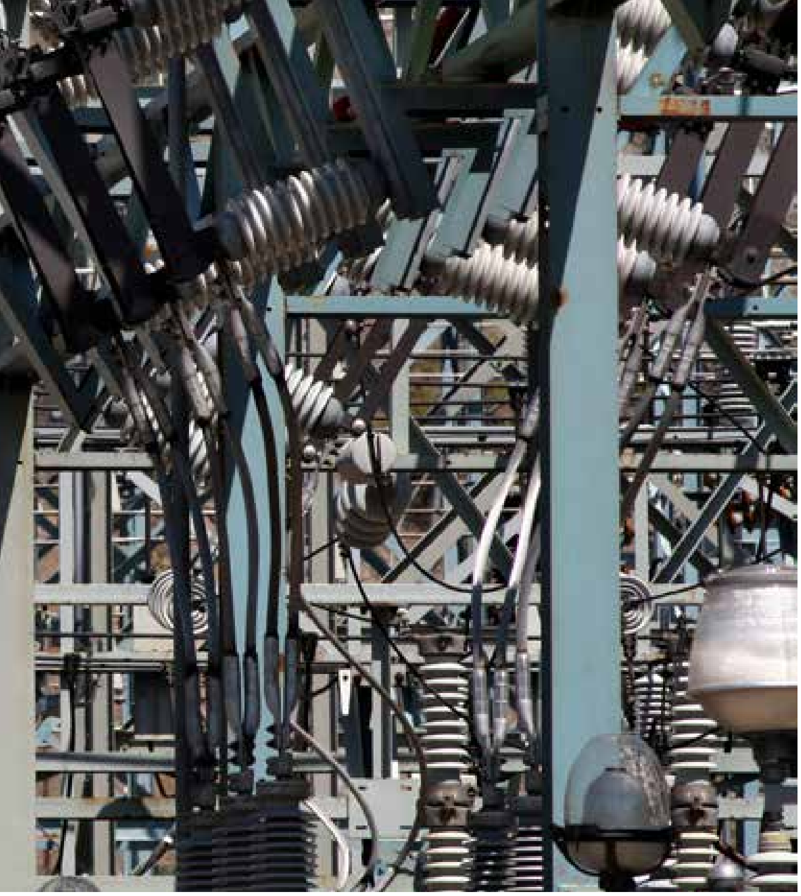
Cities should use regional or sub-national grid average emissions factors. If these are not available, national electricity production emission factors may be used.



Box 6.2 Identifying electricity consumption data—Ekurhuleni Metropolitan Municipality

Ekurhuleni Metropolitan Municipality in South Africa used tariff codes associated with end users to disaggregate 2011 electricity use by sector.[32] Electricity in Ekurhuleni is delivered by Eskom, a public utility and electricity producer, and then redistributed by the municipality to the relevant end users. Some of the tariff descriptions enabled Ekurhuleni to categorize electricity consumption into residential, commercial, or industrial sub-sectors. However, some of the tariff descriptions did not provide adequate information for categorization. To allocate emissions to some of the end users lacking tariff code data, Ekurhuleni classified high voltage, large energy consumers as industrial users, and classified low-voltage, small energy consumers as residential.

32. ICLEI—Africa. "Local Renewables: South-south cooperation between cities in India, Indonesia and South Africa," 2013. Online at: http://carbonn.org/uploads/tx_carbonndata/LocalRenewables_EMM_Energy%20Urban%20Profile_Final%20Draft_5April2013_stdPDF_09.pdf



Box 6.3 Local electricity grid emission factors– Waterloo Region

The Waterloo Region of Canada used provincial emission factors for Ontario to determine emissions from electricity consumption in the community[34]. Canada's national electricity consumption emission factor in 2010 was 0.21 kg CO_2e/kWh, but provincial data are available. Therefore, Waterloo Region used the most recent provincial emission factors provided by Environment Canada's Annual National Inventory Report. The emission factor for electricity consumed in the province of Ontario was estimated to be 0.15 kg CO_2e/kWh. The provincial level emission factor is a more accurate reflection of the energy mix supplying Waterloo Region.

See Box 6.3 for an example of the application of sub-national location-based emission factors.

6.5.4 Calculating grid-supplied steam, heating and cooling emissions

Many cities consume energy through district steam, heating and/or cooling systems. GHG emissions from the steam/heat/cooling consumed in city shall be counted as scope 2 emissions, categorized by the sub-sector consuming the energy (see Section 6.3.3). The emission factors should reflect the average emissions rate for the energy generation facilities supplying the district steam, heating and/or cooling systems, which should be available through the local energy utility or district grid operator.[33]

6.6 Calculating transmission and distribution loss emissions

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. 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 these emissions requires a grid loss factor,[35] which is usually provided by local utility or government publications. Multiplying total consumption for each grid-supplied energy type (activity data for scope 2) by their corresponding loss factor yields the activity data for transmission and distribution (T&D) losses. This figure is then multiplied by the grid average emissions factors.

33. See footnote 26.

34. The Climate Collaborative. "Discussion Paper: Community GHG Inventory and Forecast for Waterloo Region," May 2012. Online at: http://www.regionofwaterloo.ca/en/aboutTheEnvironment/resources/CommunityGHGInventoryForecastforWaterlooRegion_DiscussionPaper_May2012.pdf

35. Transmission and distribution losses vary by location, see The World Bank's 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 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 combustion of fuels in transportation occurring within the city boundary in scope 1, and GHG emissions from grid-supplied electricity used for transportation within the city boundary for transportation in scope 2.

For BASIC+:

Cities shall also report all GHG emissions from transboundary transportation in scope 3.

7.1 Categorizing transportation emissions by scope

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 buses and trains) 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. But 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 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.

Depending on the available data and objectives of the inventory, different methods can be used to quantify and allocate transportation emissions. 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. As with other GPC emissions sectors, reporting transport emissions in either scope 1 or 3 should only reflect emissions from combustion-only emissions. The upstream emissions from fuels used (including exploration of mineral oil, refinery processes, etc.) may be reported in *Other Scope 3*.

Transportation emissions accounting should reflect the following scopes:

Scope 1: Emissions from transportation occurring in the city

Scope 1 includes all GHG emissions from the transport of people and freight occurring within the city boundary.

Scope 2: Emissions from grid-supplied electricity used in the city for transportation

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

Scope 3: Emissions from the portion of transboundary journeys occurring outside the city, and transmission and distribution losses from grid-supplied energy from electric vehicle use

This includes the out-of-city portion of all transboundary GHG emissions from trips that either originate or terminate within the city boundaries. This may include the out-of-city portion of on-road transit that burns fuel, or any out-of-city stops for an electric railway.

The transportation 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. Emissions from energy use at buildings or facilities related to transportation, such as docks, mass transit stations, airports and marine ports, should be reported in *Stationary Energy* sector.

These emission sources and their scope categorization are summarized in Table 7.1.

7.2 Defining transport modes

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

- **On-road transportation,** including electric and fuel-powered cars, taxis, buses, etc.
- **Railway,** including trams, urban railway subway systems, regional (inter-city) commuter rail transport, national rail system, and international rail systems, etc.
- **Water-borne transportation,** including sightseeing ferries, domestic inter-city vehicles, or international water–borne vehicles.
- **Aviation,** including helicopters, domestic inter-city flights, and international flights, etc.
- **Off-road transportation,** including airport ground support equipment, agricultural tractors, chain saws, forklifts, snowmobiles, etc.

Cities should identify the applicable sub-categories within each transit mode, and report emissions for these sub-categories as well as sub-sectors if data is available.

Table 7.1 Transportation Overview

GHG Emission Source	Scope 1	Scope 2	Scope 3
TRANSPORTATION	Emissions from fuel combustion for transportation occurring in the city	Emissions from consumption of grid-supplied energy for in-boundary transportation	Emissions from portion of transboundary journeys occurring outside the city, and transmission and distribution losses from grid-supplied energy
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.3.1	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	

Sources required for BASIC reporting

+ Sources required for BASIC+ reporting

Sources included in Other Scope 3

7.3 Calculating on-road transportation emissions

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, motorcycles, on-road waste collection and transportation vehicles (e.g. compactor trucks), etc. 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 scope 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. Charging stations might be at homes or workplaces that are already included in the *Stationary Energy* sector. Cities should ensure that energy used for electric vehicle charging is separate from, and not double counted with, energy used in these other *Stationary Energy* sub-sectors.

7.3.1 Transportation methodology options

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 7.2, and shall clearly document the methods used in the inventory reports. 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).

36. GIZ (2012) *Balancing Transport Greenhouse Gas Emissions in Cities—A Review of Practices in Germany*

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.

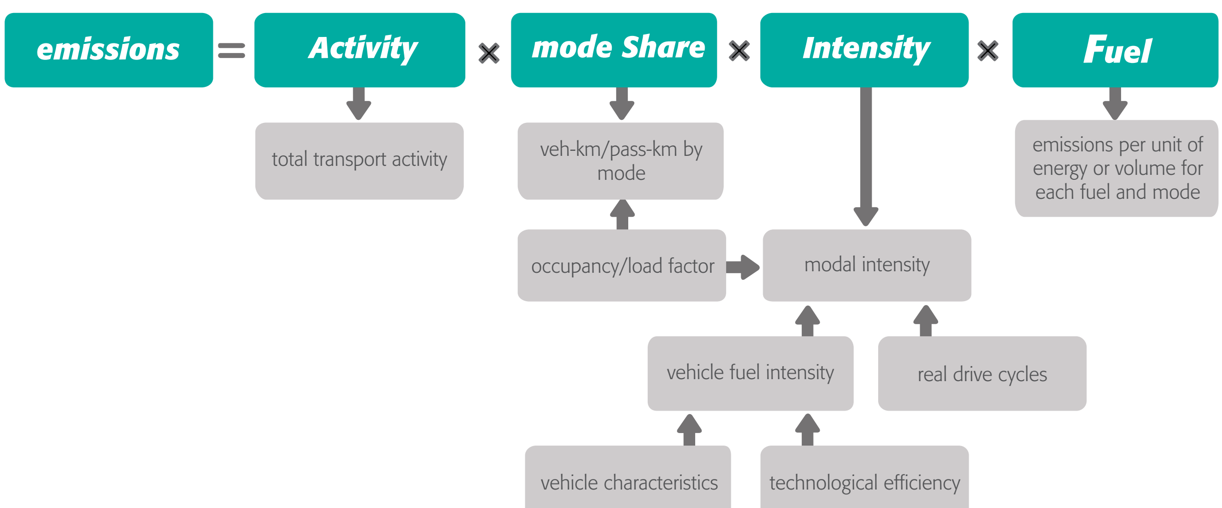
Figure 7.3 illustrates which type of transportation activity is reflected in each method. Table 7.3 further shows how to allocate these activity emissions in scopes 1, 2 and 3.

Fuel sales method

This method calculates on-road transportation emissions based on the total fuel sold within the city boundary. In theory, this approach treats sold fuel as a proxy for transportation 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 vehicle ownership data or other appropriate scaling factors. 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

Figure 7.1 ASIF framework[39]



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.

39. Ibid

registrations within the city, then state or region, and finally national), survey or other methods.

All fuel sales from in-boundary fuel dispensaries should be accounted for in scope 1, even though fuel purchases may be for transboundary trips. Maintaining all fuel sales emissions in scope 1 also enables more effective multi-city aggregation. However, cities may conduct surveys or use other methods to allocate total fuel sales into scope 1 and scope 3 emissions.

Induced activity method

This method seeks to quantify transportation emissions *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 in two ways:

1. **Reporting 50% of transboundary trips (and excluding pass-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. One hundred percent 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). One challenge of this approach is that due to differences in traffic models, there may be portions of a trip that occur in the city boundary but are not reflected in scope 1. As illustrated in Figure 7.2, "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. See Box 7.1 for one city's application of a travel demand model.

2. **Reporting departing on-road trips only.** For simplicity, cities may account for only departing on-road trips. Here, 100% of the trip is counted, with in-boundary section as scope 1 and out-of-boundary section as scope 3.

40. Ibid

Box 7.1 On-road calculation based on models—North Park

The community of North Park in San Diego, California, was chosen as the study area to test methodology for generating VMT (vehicle miles traveled) data from a regional travel demand model. The San Diego Association of Regional Governments (SANDAG) developed an approach for using traffic modeling software to generate VMT data disaggregated into trip types compatible with the origin-destination approach. Emissions from trips that start and end in the study area (internal-internal) are fully allocated to the city. Emissions from trips that have one trip-end within the study area (internal-external and external-internal) are allocated to the city at 50%. Pass-through trips (external-external) are excluded from the analysis.[41]

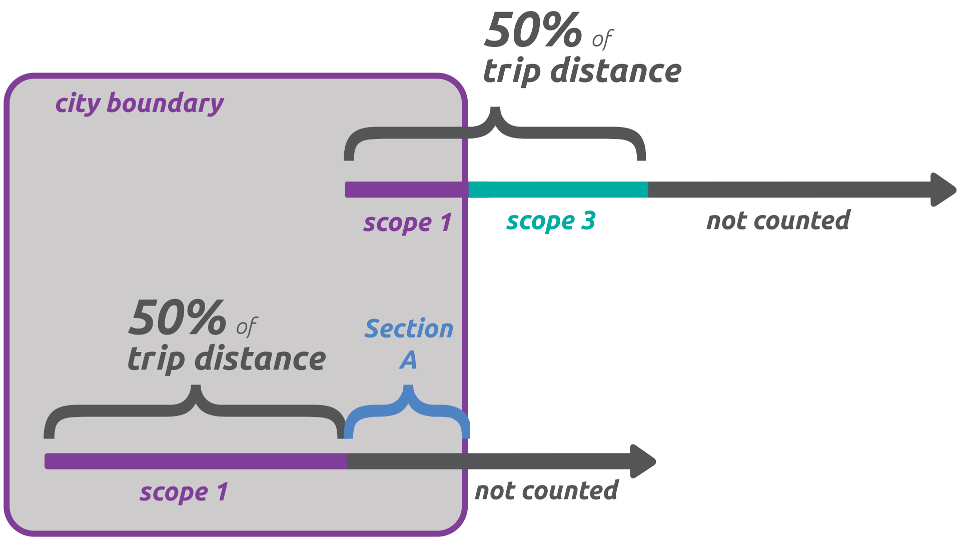
Geographic or territorial method

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[42] quantify these emissions primarily for

41. For more information, see the technical white paper "Vehicle Mile Traveled Calculations Using SANDAG Regional Travel Demand Model" [pdf]: http://www.sandag.org/uploads/publicationid/publicationid_1795_16802.pdf

42. Ibid Schipper, L., Fabian, H., & Leather, J. *Transport and Carbon Dioxide Emissions: Forecasts, Options Analysis, and Evaluation*. 2009.

Figure 7.2 Induced activity allocation



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.

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, their 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 to allocate emissions from resident travel over scope 1 and 3.

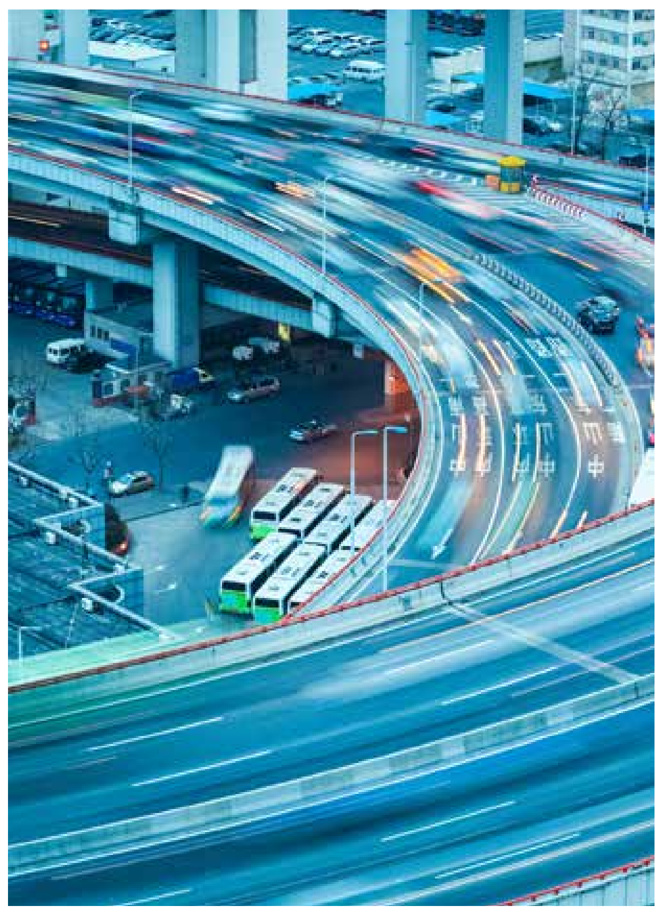
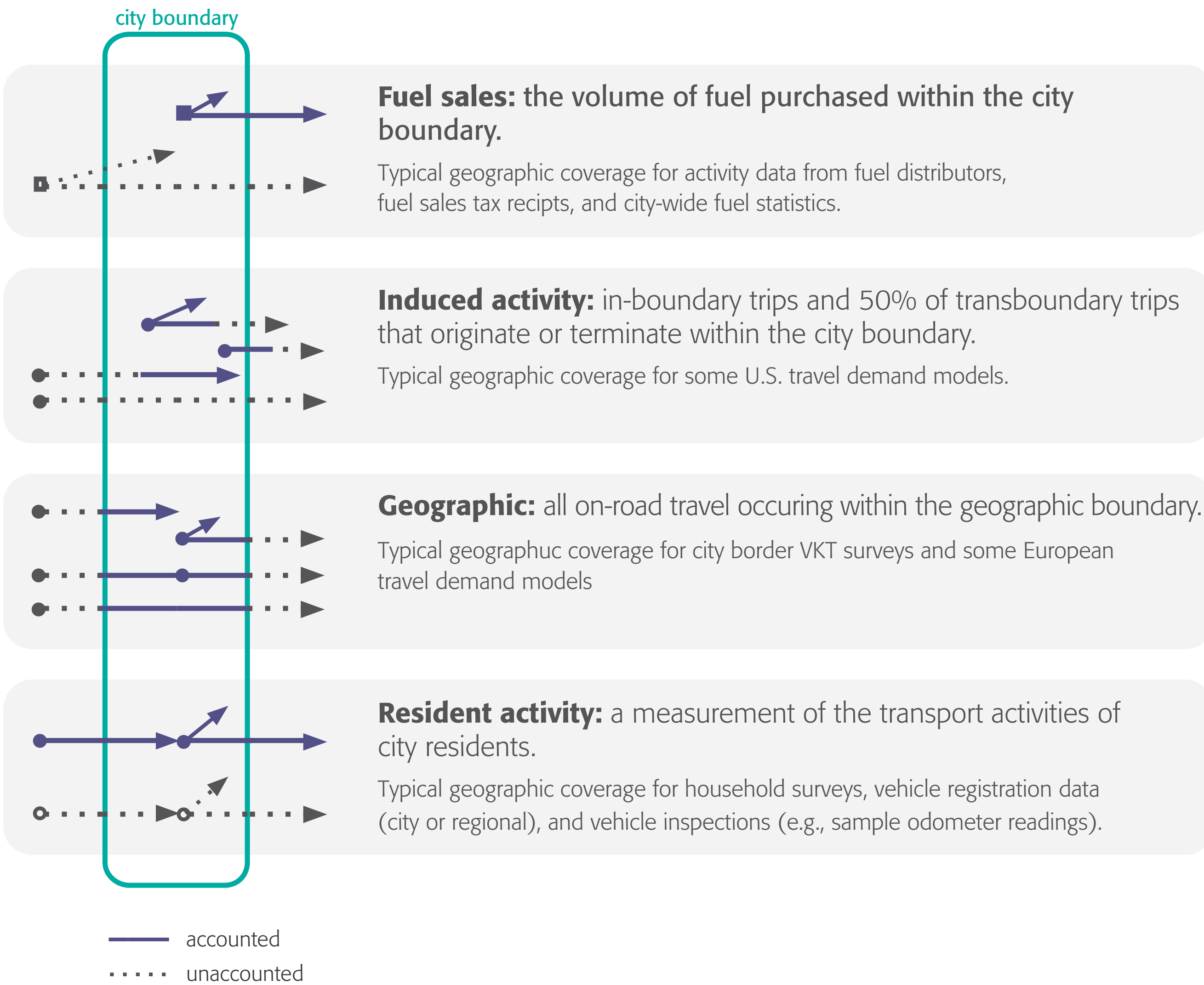


Figure 7.3 Methodology system boundaries



7.3.2 How to select on-road calculation methodologies

To determine which methodologies to use for on-road transportation, cities should first consult any transport models developed by city transportation planners. In the absence of a transportation model, cities can use the fuel sales method.

The scale of differences in emission results based on these methods may be significant. 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. For instance, fuel sales can be more accurate to show overall reductions in fuels consumption, while models and surveys can give detailed information on how specific transportation sectors are evolving and help prioritize mitigation actions. See Table 7.3 for a comparison of these approaches. Cities should seek consistent methods over time or document when methods have changed (see base year recalculation in Chapter 11).

Table 7.2 Boundary types and scopes allocation

<table>
<tr><th>Method</th><th>Allocation principle</th><th>Scope 1</th><th>Scope 2</th><th>Scope 3</th></tr>
<tr><td>Fuel Sales Approach</td><td>Not applicable unless additional steps taken</td><td>All emission from fuel sold within boundary</td><td rowspan="5">Any electric charging station in the city boundary</td><td>Not applicable unless fuel sales allocated between scope 1 and 3 by specified method</td></tr>
<tr><td rowspan="2">City-induced Activity (e.g. US demand models)</td><td rowspan="2">Origin-Destination</td><td>In-boundary trips and in-boundary portion of 50% of transboundary trips (pass-through trips excluded)</td><td>Out-of-boundary portion of 50% of transboundary trip</td></tr>
<tr><td>In-boundary trips and in-boundary portion of all departing transboundary trips (pass-through trips excluded)</td><td>Out-of-boundary portion of all departing transboundary trips</td></tr>
<tr><td>Geographic/ Territorial (e.g., European demand models)</td><td>Not applicable</td><td>All traffic occurring within city boundaries, regardless of origin or destination</td><td>Not applicable unless additional steps taken</td></tr>
<tr><td>Resident Activity</td><td>Options</td><td>Either resident activity is all scope 1, or use origin-destination</td><td>N/A or origin-destination used</td></tr>
</table>

Table 7.3 Comparing top-down and bottom-up methodologies for on-road transportation

Methodology	Advantages	Disadvantages
Fuel sales	• More consistent with national inventory practices • Well suited to aggregation with other city's transportation inventories if all fuel sold in boundary is classified as scope 1. • Less costly • Less time-consuming to conduct • Do not require high level of technical capacity	• Does not capture all on-road travel, as vehicles may be fueled at locations outside the city boundary but driven within the city • Does not disaggregate the reasons for travel emissions, e.g., origin, destination, vehicle efficiency changes, modal shift, etc. • Does not comprehensively demonstrate mitigation potential • Does not allow for allocating emissions by scope (unless additional steps are taken)
VKT and model-based (induced activity, territorial, resident activity)	• Can produce detailed and more actionable data for transportation planning • Integrates better with existing city transport models and planning processes	• More expensive, time consuming, and less comparable between cities due to variation in models used

7.3.3 Changing transportation methodologies over time

Over time, cities may be able to obtain more accurate or relevant data using new technologies, methods, or models. As new means for improving the accuracy of activity data and emission factors become available, cities may switch the methodology in the inventory and should clearly indicate the method used.

Changing methodologies can pose challenges for cities using base year inventory results to track progress toward implementing goals. Cities should follow base year recalculation procedures described in Chapter 11, disclosing the reason for recalculation. Alternatively, if recalculated base year emissions are not possible to develop due to limitations on historic data or limitations in modeling, cities may continue to report transportation emissions over time with methods used in the base year.

7.4 Calculating railway transportation emissions

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.

The allocation principle for railway broadly reflects an assessment of "induced activity," but reports all in-city railway travel as scope 1 while the out-of-boundary portion of transboundary railway journeys can be apportioned on the basis of city passengers or goods.

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.

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

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:

- 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 city activity may be determined through local, state, or national statistics or transportation agencies for the city.
- Scale down regional transit system fuel consumption based on:
    - Population served by the region's model and the population of the city, 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 city's geopolitical boundary.
- Scale down national railway fuel consumption based on city population or other indicators.

43. Diesel locomotives also consume lubricant oils, emissions from which are included in *IPPU*.

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 Calculating waterborne navigation emissions

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 city. 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.

IPCC 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. 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 includes 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 city activity may be determined through local, state, or national statistics or transportation agencies for the city.
- 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 appropriate scaling factors.
  - National marine navigation data may be found through national maritime (marine) administration agencies.

7.5.2 Calculating scope 2 emissions

Scope 2 includes emissions from 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

In this case, Scope 3 covers emissions from departing transboundary trips powered by direct fuel combustion, apportioned to cover those departing trips that are attributable to the city. Cities can estimate the proportion of passengers and cargo traveling from the city, using official records, manifests, or surveys to determine the apportionment. Emissions from transboundary 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

Cities shall transparently document the methods used in the inventory reports.

7.6 Calculating aviation emissions

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 city 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 report just the portion of scope 3 aviation emissions produced by travelers departing the city. This is in line with the origin and destination model described with the induced activity method in Section 7.3.1. Cities shall transparently document the methods used in the inventory reports.

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.

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.

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 aircraft 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 emission factors.[45]

7.6.2 Calculating scope 2 emissions

Scope 2 includes any grid-supplied energy consumed by aircraft charging at airports.[46] Any grid-supplied energy consumed at airport facilities should be included in *Stationary Energy* (institutional or commercial facilities).

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

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

7.6.3 Calculating scope 3 emissions

Scope 3 includes emissions from departing flights at airports that serve the city, whether the airport is located within the geographic boundary or outside of it. Cities should identify 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.

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.

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. Cities shall transparently document the methods used in the inventory reports.

7.7 Calculating off-road transportation emissions

Off-road vehicles are those designed or adapted for travel on unpaved terrain. This category typically includes all-terrain vehicles, landscaping and construction equipment, tractors, bulldozers, amphibious vehicles, snowmobiles and other off-road recreational vehicles. For the purposes of the GPC, only activities in the city (scope 1 and scope 2) emissions are included.

Cities should only report under the *off-road transportation* sub-sector emissions from off-road transportation activities within transportation facility premises such as airports, harbors, bus terminals, and train stations. Other off-road transportation activities within industrial premises and construction sites, agriculture farms, forests, aquaculture farms, and military premises, are reported under *Stationary Energy* (see Table 6.5 Overview of reporting guidance for off-road transportation activities for guidance on classifying these emissions).

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

Box 7.2 Reporting emissions from regional transport hubs—London

London, United Kingdom, is a major international transport hub. It has two international airports located within the city boundary (London Heathrow and London City) and four international airports located outside the city boundary (London Gatwick, London Luton, London Stansted and London Southend).

To calculate GHG emissions from transboundary air travel, the distance travelled by departing aircraft from these airports is apportioned to London based on the percentage of air travel at each airport serving the city, i.e. those flights used by residents, workers and visitors. The latter is obtained from a survey[47] conducted by the UK Civil Aviation Authority on the origin/destination patterns of terminating passengers at major UK airports. This survey suggests that airports further afield also serve London but to a very limited extent and are therefore not included in the calculations.

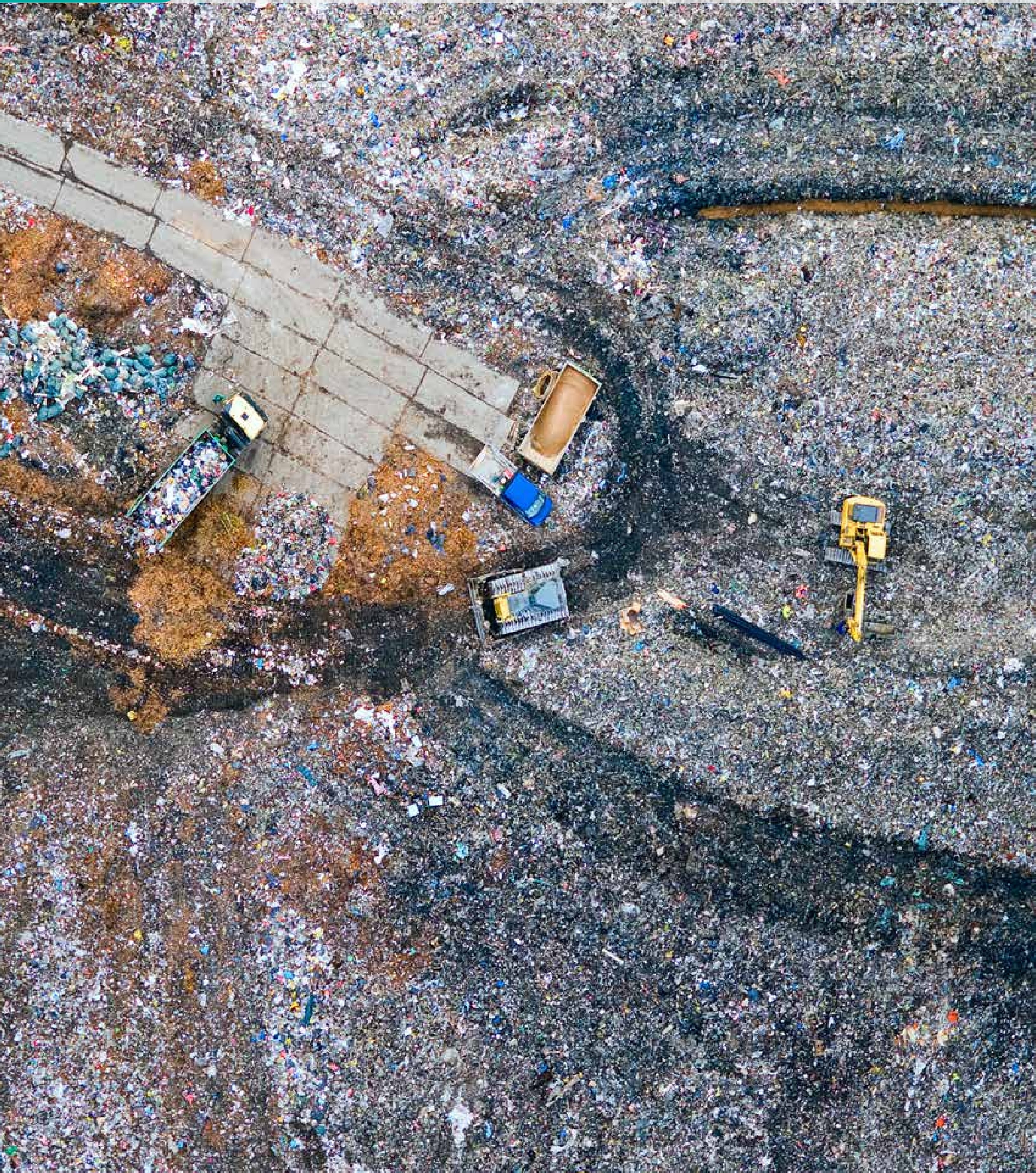
electricity used to power off-road vehicles shall be reported under scope 2 emissions.

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 households, construction, and relevant businesses to capture gardening, landscaping, construction, and recreational equipment.
  - Use population served by the survey to scale for the city, generally. More specifically, aggregate scale of sub-sectors for increased accuracy:
    - Construction permits served by the survey to scale for total permits issued for the city
    - Number of households (or population) served by the survey to scale for total city 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 city 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.htm
- Scale national off-road mobile fuel consumption down according to population share.

47. *Source:* BSI (2014) Application of PAS 2070—London, United Kingdom: An assessment of greenhouse gas emissions of a city. http://shop.bsigroup.com/upload/PAS2070_case_study_bookmarked.pdf

8 Waste



Cities produce solid waste and wastewater (together referred to collectively as "waste") that may be disposed of and/or treated at facilities inside the city boundary, or transported to other cities for treatment. Waste disposal and treatment produces GHG emissions through aerobic or anaerobic decomposition, or incineration.

Requirements in this chapter:

For BASIC:

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

Emissions from waste imported from outside the city but treated inside the city shall be* excluded *from BASIC/BASIC+ totals. These emissions shall still be reported in total scope 1 emissions.

8.1 Categorizing waste and wastewater emissions

Solid waste and wastewater may be generated and treated within the same city boundary, or in different cities. For accounting purposes, the following rules apply:

Scope 1: Emissions from waste treated inside the city
This includes all GHG emissions from treatment and disposal of waste within the city boundary regardless whether the waste is generated within or outside the city boundary. Only GHG emissions from waste generated by the city will be reported under BASIC/BASIC+. GHG emissions from imported waste shall be reported as scope 1, but not added to BASIC/BASIC+ totals.

Scope 2: Not applicable
All emissions from the use of grid-supplied electricity in waste treatment facilities within the city boundary shall be reported under scope 2 in *Stationary Energy*, *commercial* and *institutional buildings and facilities* (I.2.2).

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

Figure 8.1 illustrates boundary considerations for emission sources in the *Waste* sector. In this figure, the blue border represents the city's geographic boundary and:

- **A** illustrates waste generated outside of the city boundary and treated within the boundary
- **B** illustrates waste generated and treated within the city's boundary
- **C** illustrates waste 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 emissions generated within the city boundary)
- Scope 3 emissions = emissions from **C**
- Emissions reported for BASIC and BASIC+ = emissions from **B+C** (all emissions resulting from waste generated by the city)

Waste emission sources and their scope categorizations are summarized in Table 8.1.

Figure 8.1 Boundaries for imported and exported waste

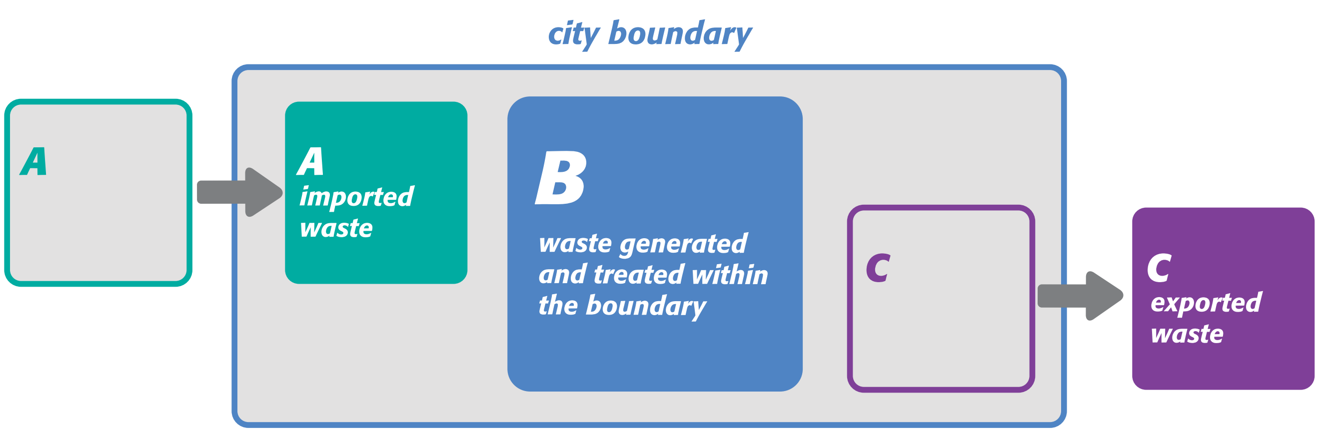


Table 8.1 Waste Overview

GHG Emission Source	Scope 1	Scope 2	Scope 3
WASTE	Emissions from in-boundary waste treatment		Emissions from waste generated in the city but treated out-of-boundary
Solid waste generated in the city disposed in landfills or open dumps	III.1.1		III.1.2
Solid waste generated outside the city disposed in landfills or open dumps	III.1.3		
Solid waste generated in the city that is treated biologically	III.2.1		III.2.2
Solid waste generated outside the city that is treated biologically	III.2.3		
Solid waste generated in the city incinerated or burned in the open	III.3.1		III.3.2
Solid waste generated outside the city incinerated or burned in the open	III.3.3		
Wastewater generated in the city	III.4.1		III.4.2
Wastewater generated outside the city	III.4.3		

Sources required for BASIC reporting

\+ Sources required for BASIC+ reporting

Sources required for territorial total but not for BASIC/BASIC+ reporting (*italics*)

Non-applicable emissions

8.2 Defining Solid Waste types and general calculation procedures

This chapter provides accounting guidance for city governments to estimate CO_2, CH_4, and N_2O from the following waste management activities:

1. Solid waste disposal in landfills[48] or dump sites, including disposal in an unmanaged site, disposal in a managed dump or disposal in a sanitary landfill
2. Biological treatment of solid waste
3. Incineration and open burning of waste
4. Wastewater treatment and discharge

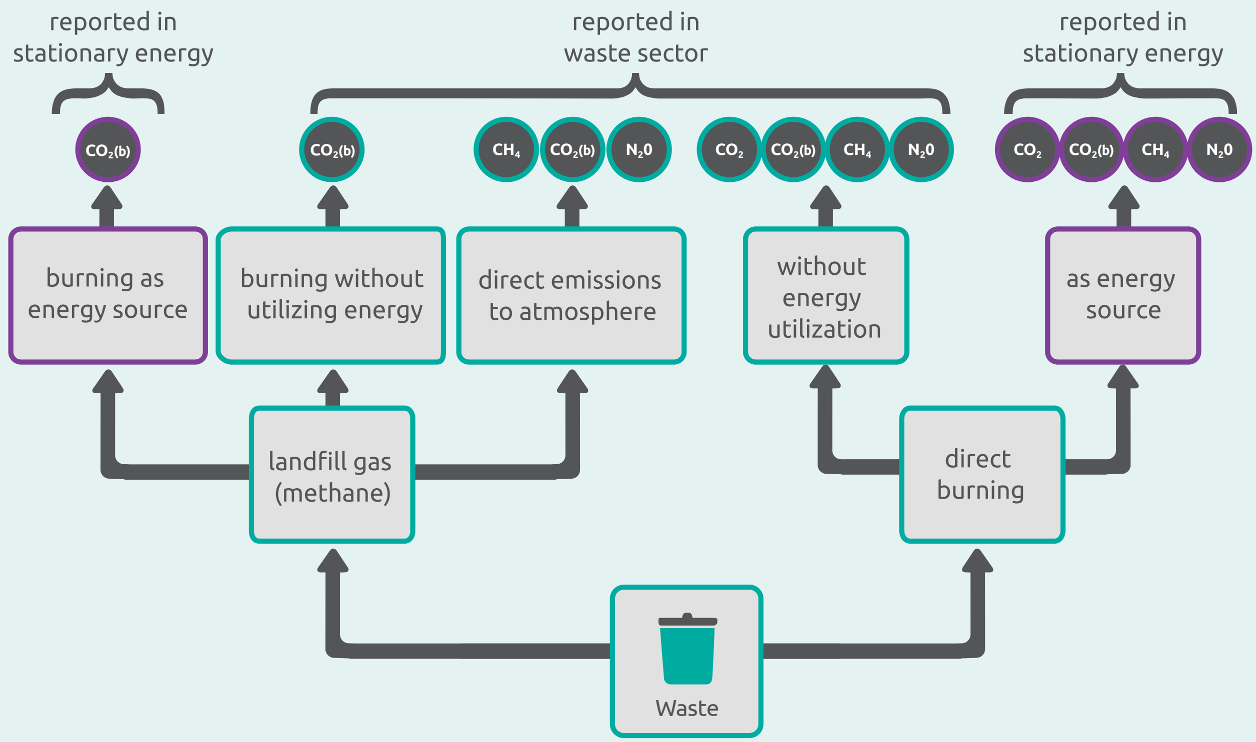
48. In many cities, a portion of solid waste generated is not formally treated by the city and ends up in open dumps or other unmanaged sites. The term "landfill" is used as shorthand for both managed and unmanaged solid waste disposal sites. Similarly, waste may be incinerated at formal incineration facilities as well as informal open burning sites. As described in Sections 8.3 to 8.6, cities should calculate emissions from managed disposal, treatment or incinerations sites first, and separately document emissions from unmanaged disposal sites.

8.2.1 Defining solid waste types

Waste type categories and waste collection methods vary by country. Cities should identify city-specific waste composition and waste generation data where possible, to achieve more accurate calculation results. However, for cities without data on current or historic solid waste generation quantities and composition, or waste treatment methods, the GPC provides a set of default solid waste types and definitions (outlined below) consistent with *IPCC Guidelines*. Cities should also consult *IPCC Guidelines* for guidance on conducting waste composition analyses in addition to default values for specific countries/regions. 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. These default types of solid waste include:

Box 8.1 **Waste and stationary energy emissions**

As described in Chapter 6, *Stationary Energy* (Table 6.7), if methane is recovered from solid waste or wastewater treatment facilities as energy sources, those GHG emissions shall be reported under *Stationary Energy*. Emissions from waste incineration without energy recovery are reported under the *Waste* sector, while emissions from incineration with energy recovery are reported in *Stationary Energy*, both with a distinction between fossil and biogenic carbon dioxide (CO_2(b)) emissions. See below for an illustrated explanation of these differences.



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. Cities should indicate this classification 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 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 cover a range of materials including plastic syringes, animal tissues, 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 General emissions quantification steps

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. In the case of incineration, the two main factors for quantifying emissions are the mass of waste disposed and the amount of fossil carbon it contains.

Detailed guidance for quantifying waste mass and degradable organic content includes the following steps:

- **Determine the quantity (mass) of waste generated by the city and how and where it is treated.** For all disposal and treatment types, cities should identify the quantity of waste generated in the analysis year. For solid waste disposed in landfills/open dumps, historic waste quantity data or estimates may also be needed depending on the calculation method chosen. In instances where multiple cities are contributing waste to the same disposal sites, each city will apportion those emissions based on the ratio of historical waste contributed to the landfill (See Box 8.2 for an example of emissions apportionment between cities).

  In the absence of local or country-specific data on waste generation and disposal, 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).[49]

- **Determine the emission factor.** Disposal and treatment 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.[50] 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 for methane emissions calculation, but cities should consult IPCC or other local resources to calculate other GHGs like N_2O.

  For solid waste disposal, the emission factor is illustrated as methane generation potential (L_0), which is a function of degradable organic content (DOC). This factor is further explained in Section 8.2.3.

- **Multiply quantity of waste disposed by relevant emission factors to determine total emissions.** Distinct components of the waste stream (e.g., waste disposed in managed sites versus waste disposed in unmanaged dumps) should be paired with appropriate emission factors and associated emissions should be

49. *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

50. 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

Box 8.2 Reporting scope 1 emissions from the Waste sector—Lahti

In Lahti, Finland, municipally-owned Päijät-Häme Waste Disposal Ltd serves not only the city of Lahti, but 21 other municipalities and 200,000 residents around the Päijät-Häme region as well. 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.

calculated separately. The following sections provide more detailed information on how these steps should be conducted.

8.2.3 Determining solid waste composition and degradable organic content (DOC)

The preferred method to determine the composition of the solid waste stream is to undertake a solid 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, *IPCC Guidelines* provide sample regional and country-specific data to determine waste composition and carbon factors in the weight of wet waste.[51]

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.

Equation 8.1 estimates DOC using default carbon content values.

Equation 8.1 Degradable organic carbon (DOC)[52]

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

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

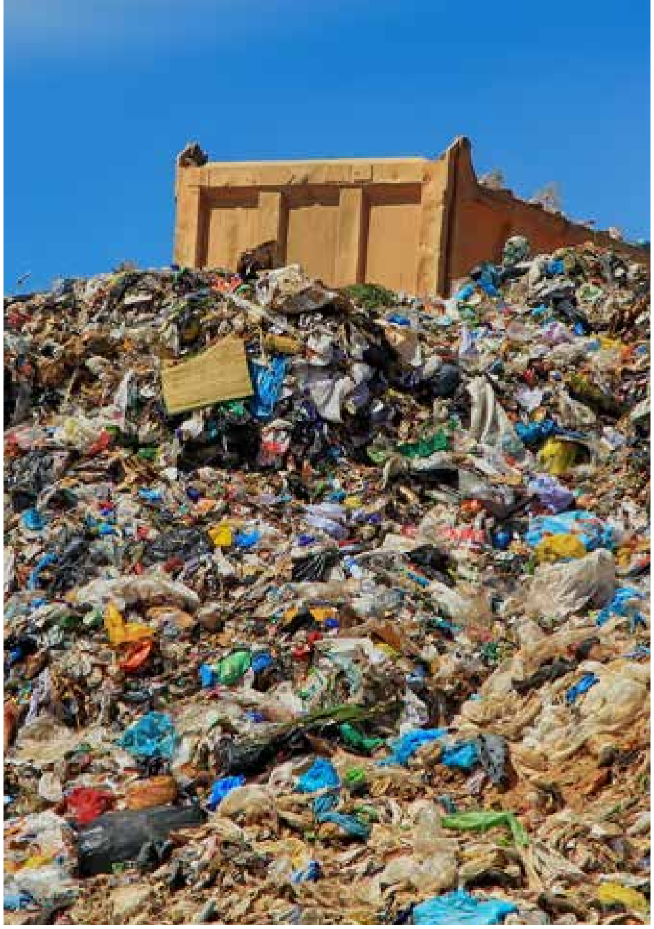
8.3 Calculating emissions from solid waste disposal

Solid waste may be disposed of at managed sites (e.g., sanitary landfill and managed dumps), and at unmanaged disposal sites (e.g., open dumps, including above-ground piles, holes in the ground, and dumping into natural features, such as ravines). Cities should first calculate emissions from managed disposal sites, and separately calculate and document emissions from unmanaged disposal sites.

Activity data on quantities of waste generated and disposed at managed sites can be calculated based on records from waste collection services and weigh-ins at the landfill. Waste disposed at unmanaged sites (e.g., open dumps) can be estimated by subtracting the amount of waste disposed at managed sites from the total waste generated. Total waste generated can be calculated by

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

52. 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. For city specific waste generation and waste composition data user can also consult World Bank paper: *What a Waste: A Global Review of Solid Waste Management*



multiplying the per capita waste generation rate (tonnes/capita/yr) by the population (capita). Guidance on collecting this information is available in *IPCC Guidelines*.

Accounting methods

Methane emissions from landfills continue several decades (or sometimes even centuries) after waste disposal. Waste disposed in a given year thereby contributes to GHG emissions in that year and in subsequent years. Likewise, methane emissions released from a landfill in any given year include emissions from waste disposed that year, as well as from waste disposed in prior years.

Therefore, the GPC provides two commonly acceptable methods for estimating methane emissions from solid waste disposal: first order of decay and methane commitment.

- **First order of decay (FOD)** assigns landfill emissions based on emissions during that year. It counts GHGs actually emitted that year, regardless of when the waste was disposed. The FOD model assumes that the degradable organic component (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 emissions—and is recommended in *IPCC Guidelines*—but it requires historical waste disposal information that might not be readily available. Cities may estimate historic data by method provided in section 8.3.1.
- **Methane commitment (MC)** assigns landfill emissions based on waste disposed in a given year. It takes a lifecycle and mass-balance approach and 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). For most cities, the MC method will consistently overstate GHG emissions by assuming that all DOC disposed in a given year will decay and produce methane immediately.

Table 8.2 provides a simplified comparison between these two methods based on user considerations, including consistency with national inventories, data availability, etc.

8.3.1 First order of decay (FOD) model

Due to the complexity of this model, the GPC recommends that cities use the IPCC Waste Model[53] (2006), 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 may yield different results.

Cities should seek to identify actual historical waste disposal information, but in its absence cities can estimate historic waste and related emissions based on total waste in place,

53. An Excel version of the IPCC Waste Model tool can be downloaded online at: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/IPCC_Waste_Model.xls

Table 8.2 Comparing Methane Commitment to First Order Decay method

User Consideration	Methane commitment (MC)	First Order of Decay (FOD)
Simplicity of implementation, data requirements	**Advantage:** Based on quantity of waste disposed during inventory year, requiring no knowledge of prior disposal.	**Disadvantage:** Based on quantity of waste disposed during inventory year as well as existing waste in landfill(s). Requires historic waste disposal information.
Consistency with annualized emissions inventories	**Disadvantage:** Does not represent GHG emissions during inventory year. Rolls together current and future emissions and treats them as equal. Inconsistent with other emissions in the inventory.	**Advantage:** Represents GHG emissions during the inventory year, consistent with other emissions in the inventory.
Decision-making for future waste management practices	**Disadvantage:** May lead to overestimation of emission reduction potential	**Advantage:** Spreads benefits of avoided landfill disposal over upcoming years.
Credit for source reduction/recycling	**Advantage:** Accounts for emissions affected by source reduction, reuse, and recycling.	**Disadvantage:** For materials with significant landfill impacts, FOD not as immediately sensitive to source reduction, reuse, and recycling efforts.
Credit for engineering controls, heat/power generation	**Disadvantage:** Doesn't count current emissions from historic waste in landfills, thus downplaying opportunities to reduce those emissions via engineering controls.	**Advantage:** Suitable for approximating amount of landfill gas available for flaring, heat recovery, or power generation projects.
Credit for avoided landfill disposal	**Disadvantage:** Overstates short-term benefits of avoided landfill disposal.	**Advantage:** Spreads benefits of avoided landfill disposal over upcoming years, minimizing overestimation of emission reduction potential.
Accuracy	**Disadvantage:** Requires predicting future gas collection efficiency and modeling parameters over the life of future emissions.	**Advantage:** More accurate reflects total emissions occurring in the inventory year.

years of operation, and population data over time. The starting and ending years for the annual disposal inputs to the FOD model can be determined as long as any of the following additional data are available:

1. Site opening and closing year
2. Site opening year, total capacity (in m^3), and density conversion (Mg/m^3)
3. Current waste in place and site closure date or capacity (with conversion to Mg)

With this information, the IPCC Waste Model (2006) model outlined above can be used. The iterative process of FOD model is illustrated in Equation 8.2.

8.3.2 Methane commitment model

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

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

Equation 8.2 First order of decay (FOD) model estimate for solid waste sent to landfill

$$CH_4 \text{ emissions} = \{ \sum_x [MSW_x \times L_0(x) \times ((1 - e^{-k}) \times e^{-k(t-x)})] - R(t)\} \times (1 - OX)$$

Description			Value
CH_4 emissions	=	Total CH_4 emissions in tonnes	Computed
x	=	Landfill opening year or earliest year of historical data available	User input
t	=	Inventory year	User input
MSW_x	=	Total municipal solid waste disposed at SWDS in year x in tonnes	User input
R	=	Methane collected and removed (ton) in inventory year	User input
L_0	=	Methane generation potential in tonnes CH_4 $L_0 = MSW_x \times MCF(x) \times DOC(x) \times DOC_F \times F \times 16/12$	Consult equation 8.4
k	=	Methane generation rate constant, which is related to the time taken for the DOC in waste to decay to half its initial mass (the "half-life")	User Input or consult default value in table 3.4 of 2006 IPCC guidelines, vol. 3: waste, chapter 3: solid waste disposal, p. 3.17
OX	=	Oxidation factor	0.1 for well-managed landfills; 0 for unmanaged landfills

Source: IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (2000)

Equation 8.3 Methane commitment estimate for solid waste sent to landfill

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

Description			Value
CH_4 emissions	=	Total CH_4 emissions in metric tonnes	Computed
MSW_x	=	Mass of solid waste sent to landfill in inventory year, measured in metric tonnes	User input
L_0	=	Methane generation potential in tonnes CH_4	Equation 8.4 Methane generation potential
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*

Equation 8.4 **Methane generation potential, L_0**

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

Description			Value
L_0	=	Methane generation potential, in tonnes of CH4	Computed
MSW_x	=	Mass of waste deposited, in year x, in tonnes	User input
MCF	=	Methane correction factor based on type of landfill site for the year of deposition (managed, unmanaged, etc., fraction)	Managed = 1.0 Unmanaged (≥5 m deep) = 0.8 Unmanaged (<5 m deep) = 0.4 Uncategorized = 0.6
DOC	=	Degradable organic carbon in year of deposition, fraction (tonnes C/tonnes 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).

given amount of waste than managed landfills because a larger fraction of waste decomposes aerobically in the top layers of a landfill. Wetter waste (including precipitation impacts) will correspond with a lower DOC. L_0 can be determined using the IPCC equation (see equation 8.4).

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. In cases where a city does not incinerate or biologically treat the waste, these emissions categories can be labeled as “Not Occurring.”

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

8.5 Calculating emissions from waste incineration and open burning

Incineration is a controlled, industrial process, often with energy recovery where inputs and emissions can be measured and data is often available. By contrast, open burning is an uncontrolled, often illicit process with different emissions and can typically only be estimated based on collection rates. Users should calculate emissions from incineration and open burning separately, using different data. Cities shall report the CH_4, N_2O and non-biogenic CO_2 emissions associated with waste combustion based

Equation 8.5 Direct emissions from biologically treated solid waste

$$\textbf{CH}_4\textbf{ Emissions} = (\textstyle\sum_i (m_i \times F\_CH4_i) \times 10^{-3} - R)$$

$$\textbf{N}_2\textbf{O Emissions} = (\textstyle\sum_i (m_i \times EF\_N2O_i) \times 10^{-3})$$

Description			Value
CH_4 emissions	=	Total CH4 emissions in tonnes	Computed
N_2O emissions	=	Total N2O emissions in tonnes	Computed
m	=	Mass of organic waste treated by biological treatment type i, kg	User input
EF_ CH4	=	CH_4 emissions factor based upon treatment type, i	User input or default value from table 8.3 Biological treatment emission factor
EF_ N2O	=	N_2O emissions factor based upon treatment type, i	User input or default value User input or default value from table 8.3 Biological treatment emission factor
i	=	Treatment type: composting or anaerobic digestion	User input
R	=	Total tonnes of CH4 recovered in the inventory year, if gas recovery system is in place	User input, measured at recovery point

Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5, Chapter 4: Biological Treatment of Solid Waste

Table 8.3 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 for National Greenhouse Gas Inventories, Volume 5, Chapter 4: Biological Treatment of Solid Waste

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, cities 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 incinerated in the city, and the portion of 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 8.6 Non-biogenic CO_2 emissions from the incineration of waste

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

Description			Value
CO_2 emissions	=	Total CO_2 emissions from incineration of solid waste in tonnes	Computed
m	=	Mass of waste incinerated, in tonnes	User input
WF_i	=	Fraction of waste of consisting of type i matter	User input[54]
dm_i	=	Dry matter content in the type i matter	User input (default values provided in Table 8.4 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.	

Note: $\sum_i WF_i = 1$

Source: 2006 IPCC Guidelines

54. Default data available in *2006 IPCC Guidelines*, Vol. 5, Ch. 2, Table 2.4

Table 8.4 **Default data for CO_2 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

Note 1: Use default data from Default data available in *2006 IPCC Guidelines*, Vol. 5, Ch. 2, 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) in *2006 IPCC Guidelines*, Vol. 5, Ch. 5

Note 2: Default data by industry type is given in *2006 IPCC Guidelines*, Vol. 5, Ch. 2 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: Fossil liquid waste is here defined as industrial and municipal residues, based on mineral oil, natural gas or other fossil fuels. It includes waste formerly used as solvents and lubricants. It does not include wastewater, unless it is incinerated (e.g., because of a high solvent content) 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: *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, Volume 5, chapter 5: Incineration and Open Burning of Waste

Equation 8.7 **CH_4 Emissions from the incineration of waste**

$$CH_4 \text{ Emissions} = \sum(IW_i \times EF_i) \times 10^{-6}$$

Description			**Value**
CH_4 Emissions	=	CH_4 emissions in inventory year, tonnes	Computed
IW_i	=	Amount of solid waste of type i incinerated or open-burned, tonnes	User Input
EF_i	=	Aggregate CH_4 emission factor, g CH_4/ton of waste type i	User Input (default values provided in Table 8.5 below)
10^{-6}	=	Converting factor from gCH_4 to t CH_4	
i	=	Category or type of waste incinerated/open-burned, specified as follows: MSW municipal solid waste, ISW: industrial solid waste, HW: hazardous waste, CW: clinical waste, SS: sewage sludge, others (that must be specified	User input

Table 8.5 **CH_4 emission factors for incineration of MSW**

Type of premises	Temporary	Permanent
Continuous incineration	stoker	0.2
	fluidised bed Note1	~0
Semi-continuous incineration	stoker	6
	fluidised bed	188
Batch type incineration	stoker	60
	fluidised bed	237

Note: In the study cited for this emission factor, the measured CH4 concentration in the exhaust air was lower than the concentration in ambient air.
Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5, chapter 5 :Incineration and Open Burning of Waste

Equation 8.8 **N_2O Emissions from the incineration of waste**

$$N_2O \text{ Emissions} = \sum(IW_i \times EF_i) \times 10^{-6}$$

Description			Value
N_2O Emissions	=	N_2O emissions in inventory year, in tonnes	Computed
IW_i	=	Amount of solid waste of type i incinerated or open-burned, in tonnes	User Input
EF_i	=	Aggregate N2O emission factor, g CH_4/ton of waste type i	User Input (default values provided in Table 8.6 below)
i	=	Category or type of waste incinerated/open-burned, specified as follows: MSW: municipal solid waste, ISW: industrial solid waste, HW: hazardous waste, CW: clinical waste, SS: sewage sludge, others (that must be specified)	User input

Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5, chapter 5 :Incineration and Open Burning of Waste

Table 8.6 **Default N_2O emission factors for different types of waste and management practices**

Type of waste	Technology / Management practice	Emission factor (g N_2O / t waste)	weight basis
MSW	continuous and semi-continuous incinerators	50	wet weight
MSW	batch-type incinerators	60	wet weight
MSW	open burning	150	dry weight
Industrial waste	all types of incineration	100	wet weight
Sludge (except sewage sludge)	all types of incineration	450	wet weight
Sewage sludge	incineration	990	dry weight
		900	wet weight

Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5, chapter 5 :Incineration and Open Burning of Waste

8.6 Calculating emissions from wastewater treatment

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 GHGs 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, and cities must report emissions from both. Domestic wastewater is defined as wastewater from household water use, while industrial wastewater is from industrial practices only. Industrial wastewater may be treated on-site or released into domestic sewer systems. Any wastewater released into the domestic sewer system, those emissions should be included with the domestic wastewater emissions.

8.6.1 Calculating methane emissions from wastewater treatment and handling

In order to quantify the methane emissions from both industrial and domestic wastewater treatment, cities will need to know:

- The quantity of wastewater generated
- How wastewater and sewage are treated (see Box 8.3 for information on wastewater discharge directly into open bodies of water)
- The wastewater's source and its organic content. This can be estimated based on population of the cities served and the city's composition in the case of domestic wastewater, or the city's industrial sector in the case of industrial waste water.
- Proportion of wastewater treated from other cities at facilities located within the city's boundaries (this can be estimated based upon other cities' population served).

Box 8.3 Estimating emissions from wastewater directly discharged into an open body of water

In many developing countries, wastewater is directly discharged into open lakes, rivers or oceans. Cities may assume negligible GHG emissions from this action due to the low concentration of organic content. However, if the wastewater is discharged into a stagnant open body of water, GHG emissions can be estimated using the specific COD/BOD value from the water body outlined in Equation 8.9.

The organic content of wastewater differs depending on whether the treatment is industrial or residential, as shown in Equation 8.9. The income group suggested in variable *I* influences the usage of treatment/pathway, and therefore influences the emission factor.

Equation 8.9 **CH_4 generation from wastewater treatment**

$$CH_4 \text{ emissions} = \sum_i [(TOW_i - S_i) EF_i - R_i] \times 10^{-3}$$

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[Note 1] **For industrial wastewater:** total organically degradable material in wastewater from industry i in inventory year, kg COD/yr	Equation 8.10
EF_i	=	Emission factor kg CH4 per kg BOD or kg CH4 per kg COD[Note 2]	Equation 8.10
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 8.10

Note 1: 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 BOD5.
Note 2: Chemical Oxygen Demand (COD): COD measures the total material available for chemical oxidation (both biodegradable and non-biodegradable).
Source: Chapter 6: Wastewater Treatment and Discharge, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*.

Equation 8.10 Organic content and emission factors in domestic wastewater[55]

$$\mathbf{TOW_i =}$$
$$P \times BOD \times I \times 365$$

$$\mathbf{EF_j =}$$
$$B_o \times MCF_j \times U_i \times T_{i,j}$$

Description			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[56]
BOD	=	City-specific per capita BOD in inventory year, g/person/day	User input
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.[57]
EF_j	=	Emission factor for each treatment and handling system	Computed
B_o	=	Maximum CH_4 producing capacity	User input or default value: • 0.6 kg CH_4/kg BOD • 0.25 kg CH_4/kg COD
MCF_j	=	Methane correction factor (fraction)	User input[58]
U_i	=	Fraction of population in income group i in inventory year	User input[59]
$T_{i,j}$	=	Degree of utilization (ratio) of treatment/discharge pathway or system, j, for each income group fraction i in inventory year	

Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5, chapter 6: Wastewater Treatment and Discharge

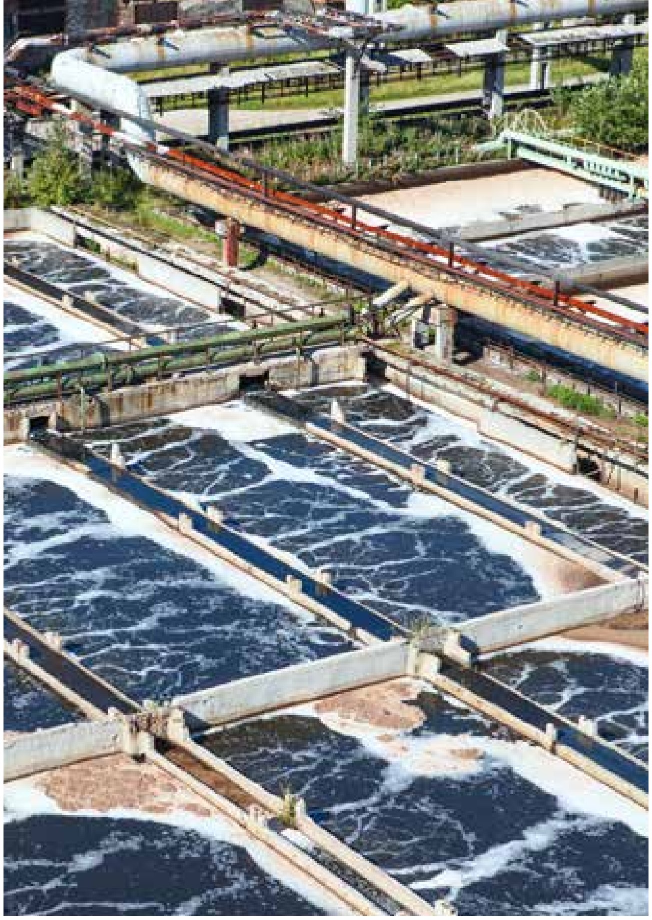
55. Due to the complexity, the GPC only provides guidance for assumption of TOW and EF for domestic wastewater treatment. For industrial wastewater treatment please consult section 6.2.3 of chapter 6, volume 5 of *IPCC Guidelines for National Greenhouse Gas Inventories*.

56. 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)

57. 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.

58. 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)

59. 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)



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 seas. Direct emissions from nitrification and denitrification at wastewater treatment plants are considered as a minor source and not quantified here. Therefore, this section addresses indirect N_2O emissions from wastewater treatment effluent that is discharged into aquatic environments.

Equation 8.11 Indirect N_2O emissions from wastewater effluent

$$N_2O \text{ emissions} = [(P \times Protein \times F_{NPR} \times F_{NON-CON} \times F_{IND-COM}) - N_{SLUDGE}] \times EF_{EFFLUENT} \times 44/28 \times 10^{-3}$$

Description			Value
N_2O emissions	=	Total N_2O emissions in tonnes	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 N_2O	0.005
44/ 28	=	The conversion of kg N_2O-N into kg N_2O	

Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5, chapter 6: Wastewater Treatment and Discharge

9 Industrial Processes and Product Use

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 *IPPU*.

Requirements in this chapter

For BASIC+:

Cities shall report all IPPU emissions in scope 1.

Scope 3: Other out-of-boundary emissions
Emissions from *IPPU* outside the city are not included in the inventory boundary but may be reported under *Other Scope 3* emissions as appropriate.

These emission sources and their scope categorization are summarized in Table 9.1.

9.1 Categorizing IPPU emissions by scope

Scope 1: Emissions from industrial processes and product uses occurring within the city

Scope 2: Not applicable
All emissions from the use of grid-supplied electricity in industrial or manufacturing facilities within the city boundary shall be reported under scope 2 in *Stationary Energy, manufacturing industry and construction* (I.3.2).

9.2 Defining industrial processes and product uses

The industrial processes and product uses included in this category are summarized in Table 9.2.

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.

Table 9.1 **IPPU Overview**

GHG Emission Source	Scope 1	Scope 2	Scope 3
INDUSTRIAL PROCESSES AND PRODUCT USE	Emissions from industrial processes and product use occurring within the city boundary		
Industrial processes	IV.1		
Product use	IV.2		

Sources required for BASIC+ reporting

Non-applicable emissions

Sources included in Other Scope 3

Table 9.2 **Example industrial processes and product uses**

GHG emission sources	Example industrial processes or products use
GHG emissions from industrial processes	• Production and use of mineral products (Section 9.3) • Production and use of chemicals (Section 9.4) • Production of metals (Section 9.5)
GHG emissions from product use	• Lubricants and paraffin waxes used in non-energy products (Section 9.6) • FC gases used in electronics production (Section 9.7) • Fluorinated gases used as substitutes for Ozone depleting substances (Section 9.8)

The GPC follows *IPCC Guidelines*,[60] 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*.

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

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 GHGs, including CO_2, CH_4, N_2O, HFCs and 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 for the mineral calcite (or calcium carbonate) is shown in Equation 9.1.

Equation 9.1 Calcination example

$$CaCO_3 + \text{heat} \rightarrow CaO + CO_2$$

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

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

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.

Simplified formulae for calculating emissions from these mineral industrial processes are illustrated in Equations 9.2–9.4.

Table 9.3 Calculating mineral industry emissions

Emission sources	GHG emissions	Simplest approach for quantifying emissions[61]	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*

61. 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*, Volume 5, chapter 6: Wastewater Treatment and Discharge.

Equation 9.2 **Emissions from cement production**

$$CO_2 \text{ emissions} = M_{cl} \times EF_{cl}$$

Description			Value
CO_2 emissions	=	CO_2 emissions in tonnes	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**

$$CO_2 \text{ emissions} = \sum(EF_{lime,i} \times M_{lime,\,i})$$

Description			Value
CO_2 emissions	=	CO_2 emissions in tonnes	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. CO_2/tonne lime of type i)	User input or default value

Equation 9.4 **Emissions from glass production**

$$\text{CO2 emissions} = M_g \times EF \times (1-CR)$$

Description			Value
CO_2 emissions	=	CO_2 emissions in tonnes	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 CO_2/tonne glass melted	User input or default value
CR_i		Cullet ratio[62] for manufacturing of glass of type i	User input or default value

62. 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.

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 the city boundaries
- 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.

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 the city boundaries
- 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 9.4 **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*

Table 9.5 Metal industry

Emission sources	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 may 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 SF_6 consumption in the magnesium industry segment is emitted as SF Estimate SF_6 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[63]	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*

63. Others include fluorinated ketone and various fluorinated decomposition products e.g., PFCs

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
Lubricants	Lubricants used in transportation and industry	CO_2
Paraffin waxes	Candles, corrugated boxes, paper coating, board sizing, adhesives, food production, packaging	CO_2
Bitumen; road oil and other petroleum diluents	Used in asphalt production for road paving	NMVOC,[64] CO
White spirit,[65] kerosene,[66] some aromatics	As solvent, e.g., for surface coating (paint), dry cleaning	NMVOC , CO

9.4 Calculating product use emissions

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 types of fuel usage and their emissions can be seen in Table 9.6.

64. NMVOC is not covered by this document, neither is it required under GPC.

65. Also known as mineral turpentine, petroleum spirits, or industrial spirit ("SBP").

66. Also known as paraffin or paraffin oils (UK, South Africa).

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 the city boundaries
- 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.

Equation 9.5 **CO_2 emissions from non-energy product uses**

$$CO_2 \text{ Emissions} = \sum_i (NEU_i \times CC_i \times ODU_i) \times 44/12$$

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

CO_2 emissions from all product uses can be estimated by following Equation 9.5.

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.

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 the city boundaries
- 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.

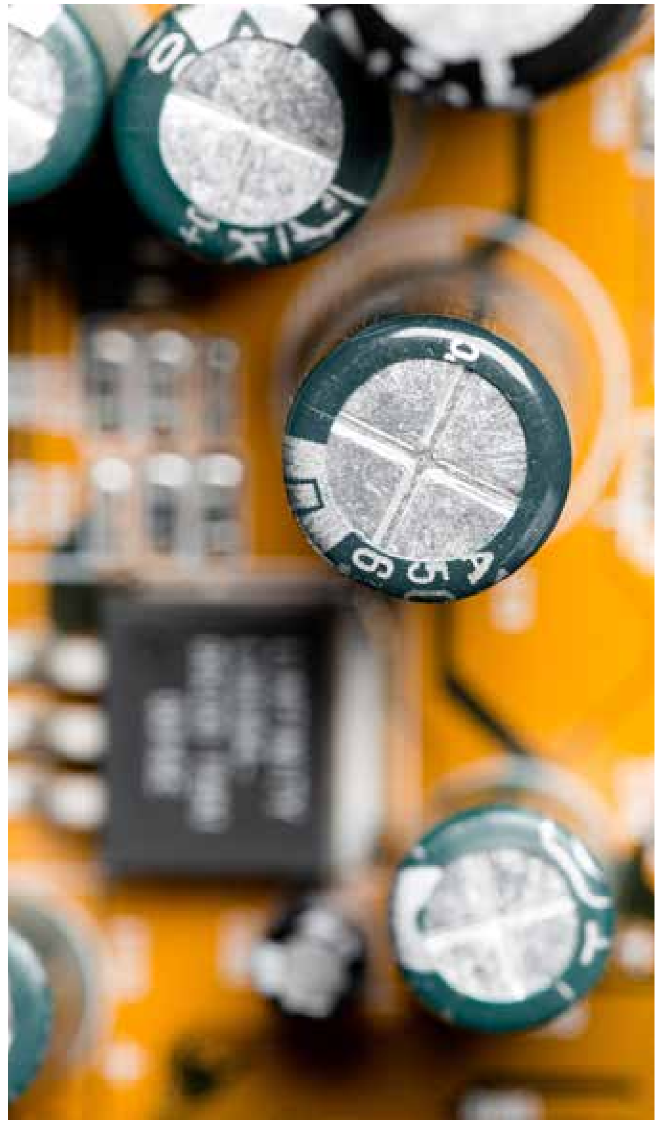


Table 9.7 Non-energy product emissions

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)

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 $c\text{-}C_4F_8$ $c\text{-}C_4F_8O$ 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). 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[67]. Current and expected application areas of HFCs and PFCs include[68]:

- Refrigeration and air conditioning
- Fire suppression and explosion protection
- Aerosols
- Solvent cleaning
- Foam blowing
- Other applications[69]

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

- Major industry that use fluorinated substitutes within the city boundaries
- 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.

67. The Montreal Protocol on Substances that Deplete the Ozone Layer (a protocol to the Vienna Convention for the Protection of the Ozone Layer) is an international treaty designed to protect the ozone layer. It requires the reduction of production and consumption of substances that are responsible for ozone depletion.

68. IPPC.IPCC/TEAP special report on safeguarding the ozone layer and the global climate system: issues related to hydrofluorocarbons and perfluorocarbons. Intergovernmental Panel on Climate Change, 2005. http://www.ipcc.ch/publications_and_data/_safeguarding_the_ozone_layer.html.

69. 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 (CF_4) PFC-116 (C_2F_6) PFC-218 (C_3F_8) PFC-31-10 (C_4F_{10}) PFC-51-144 (C_6F_{14})	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 Calculating emissions from product use using a consumption-based approach

Product use emissions may also be calculated according to consumption activities within the city boundary. This approach estimates emissions based on where the products are purchased and/or used, rather than where they are produced.

Cities can apply both a bottom-up and top-down approach to estimate the consumption-based emissions from product use.

A bottom-up approach would involve identifying products purchased within the city boundary, the quantity and average lifetime of each product, as well as the average rate of emissions during use. A top-down approach, on the other hand, would take regional or national-level activity or emissions data and adjust to the inventory boundary using an appropriate scaling factor.

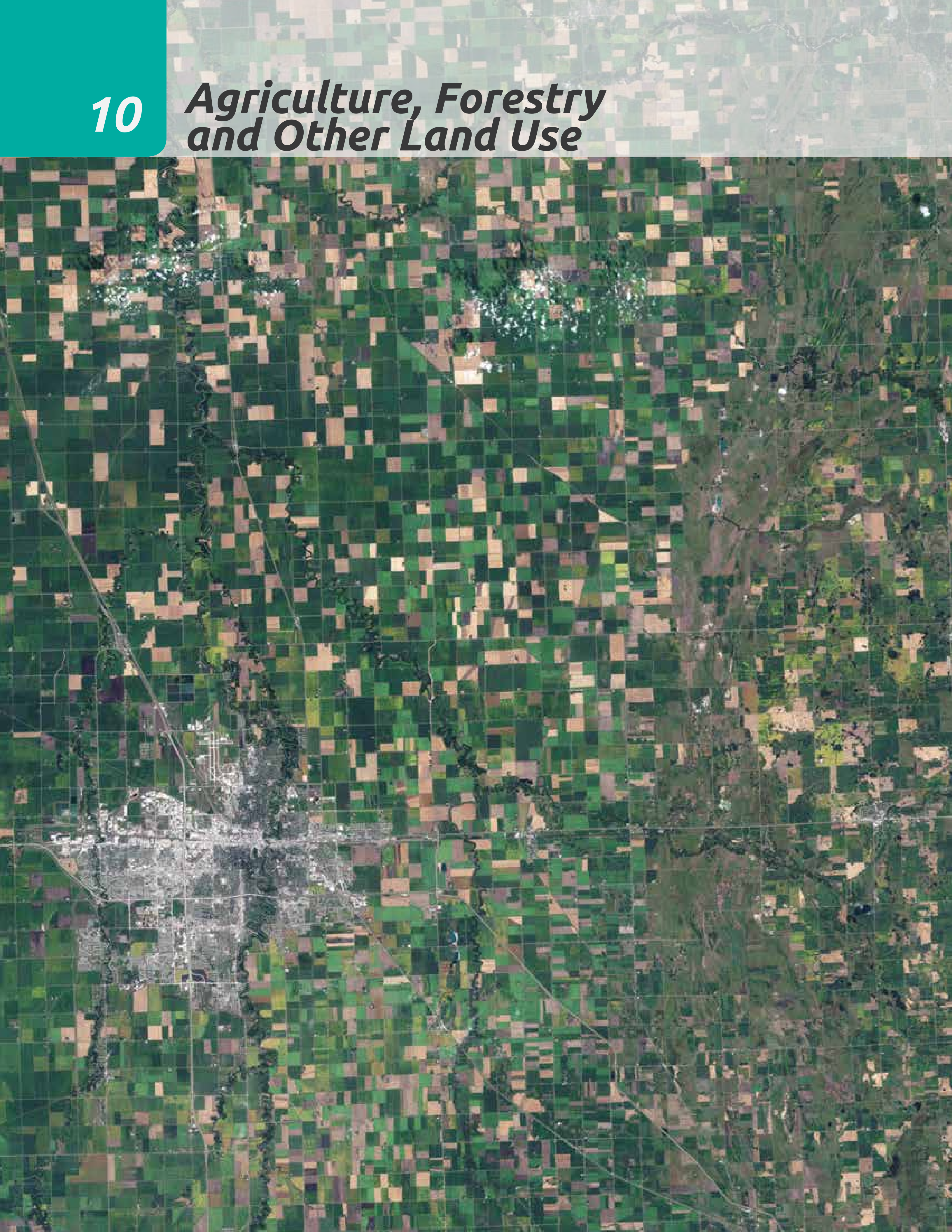
Case Study

Gibraltar used the consumption-based approach to calculate emissions from product use. With no industrial processes taking place within the city boundary and limited data on product use, Gibraltar used data from National Atmospheric Emissions Inventory for the United Kingdom—which compiles estimates of emissions from UK sources, including crown dependencies and overseas territories, for submission to the UNFCCC—to calculate emissions from product use. Emissions were apportioned to the inventory boundary using a range of appropriate scaling factors:

Product use	Scaling factor
Aerosols	Population
Commercial refrigeration	GDP
Mobile air conditioning	Number of vehicles

Source: Ricardo-AEA (2014) A City-level Greenhouse Gas Inventory for Gibraltar.

10 Agriculture, Forestry and Other Land Use



The Agriculture, Forestry and Other Land Use (*AFOLU*) sector produces GHG emissions through a variety of pathways, including land-use changes that alter the composition of the soil, methane produced in the digestive processes of livestock, and nutrient management for agricultural purposes.

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 Categorizing *AFOLU* emissions by scope

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

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* allocates these emissions to *IPPU*.

Scope 2: Not applicable

Emissions from use of grid-supplied energy in buildings and vehicles in farms or other agricultural areas shall be reported in *Stationary Energy* and *Transportation*, respectively.

Scope 3: Other out-of-boundary emissions

Emissions from land-use activities outside the city (e.g., agricultural products imported for consumption within the city boundary) are not covered in the GPC under BASIC/ BASIC+ but may be reported as *Other Scope 3*.

10.2 Defining AFOLU activities

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 sources of *AFOLU* emissions. Other cities may have significant agricultural activities and managed lands. Notation keys shall be used to indicate where sources do not occur, or where data gaps exist. *IPCC Guidelines* divides *AFOLU* activities into three categories:

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

These emission sources and their scope categorization are summarized in Table 10.1.

Multiple methodologies can be used to quantify *AFOLU* emissions. Guidance provided in this chapter is consistent with IPCC Tier 1 methodologies, unless otherwise specified. Tier 1 methodologies involve using default IPCC data, while Tier 2 methodologies involve using country-specific data. Country-specific data should be used if readily available, and if not, 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).*

10.3 Calculating livestock emissions

Livestock production emits CH_4 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.

10.3.1 Enteric fermentation

The amount of CH_4 emitted by enteric fermentation is driven primarily by the number of animals, type of digestive system, and 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).

Activity data on livestock can be obtained from various sources, including 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.[70]

10.3.2 Manure management

CH_4 is produced by the decomposition of manure under anaerobic conditions, during storage and treatment, whilst

Table 10.1 AFOLU Summary Table

GHG Emission Source	Scope 1	Scope 2	Scope 3
Agriculture, Forestry and Other Land Use	Emissions from agricultural, other land-use and land-use-change		
Livestock	V.1		
Land	V.2		
Aggregate sources and non-CO_2 emission sources on land	V.3		

Sources required for BASIC+ reporting

Sources included in Other Scope 3

Non-applicable emissions

70. See *2006 IPCC Guidelines*, Volume 4, Chapter 10 "Emissions from Livestock and Manure Management.". Available at: www.ipcc-nggip.iges.or.jp/public/2006gl/vol4www.ipcc-nggip.iges.or.jp/public/2006gl/vol4

Figure 10.1 Overview of AFOLU emission sources

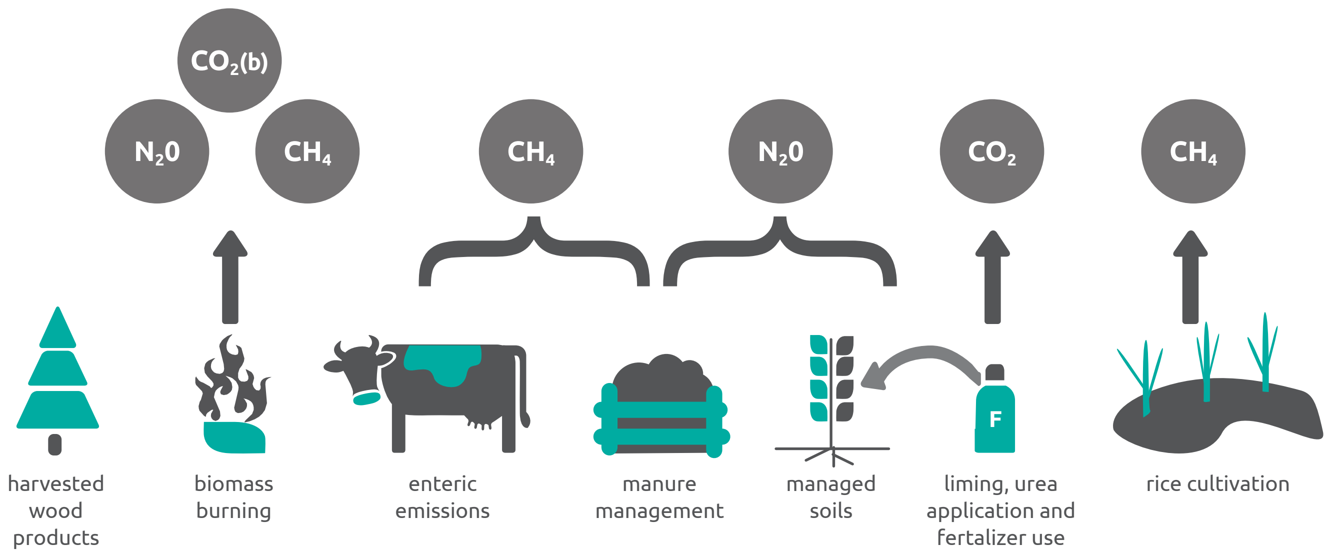


Table 10.2 Livestock emission sources and corresponding IPCC references

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

Equation 10.1 CH_4 emissions from enteric fermentation

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

Description			**Value**
CH_4	=	CH_4 emissions in tonnes	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 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

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).

Livestock numbers and categorization should be consistent with the method listed in Section 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.[71]

N_2O emissions from manure management

Manure management takes place during the storage and treatment of manure before it is applied to land or otherwise used for feed, fuel, or construction purposes. To estimate N_2O emissions from manure management systems 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

Equation 10.2 CH_4 emissions from manure management

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

Description			Value
CH_4	=	CH_4 emissions in tonnes	Computed
T	=	Species / Livestock category	User input
$N_{(T)}$	=	Number of animals for each livestock category	User input
$EF_{(T)}$	=	Emission factor for manure management (kg of CH_4 per head per year)	User input or default values

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

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

Emissions are then summed over all manure management systems. Country-specific data may be obtained from the national inventory, agricultural industry and scientific literature. 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.[72]

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), or under *Waste* (Chapter 8) if burned without energy recovery.

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.

Equation 10.3 N_2O emissions from manure management

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

N_2O	=	N_2O emissions in tonnes
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

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

$Nex_{(T)}$	=	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

72. 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

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

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

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

10.4 Calculating land use and land-use change emissions

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.

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.

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

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

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

GHG	=	GHG emissions in tonnes CO_2
Area	=	Surface area of city by land-use category, hectare
Flux	=	Net annual rate of change in carbon stocks per hectare, tonnes C per hectare per year
LU	=	Land-use category

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.[73] If the land-use change took place less than 20 years prior to undertaking the assessment, that 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 emissions 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.

Average annual carbon stock change data per hectare 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 (see Equation 10.6). Default data on annual carbon 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[74]. Alternatively, annual carbon stock changes can be determined for different land-use categories by subtracting estimated carbon stocks in a previous year from estimated carbon stocks in the inventory year, divided by the total area of land in the inventory year. Default data on annual carbon stock changes can be obtained from the above listed sources. Finally, all changes in carbon stock are summed across all categories (see Equation 10.5) and multiplied by 44/12 to covert to CO_2 emissions.

73. The use of 20 years as a threshold is consistent with the defaults contained in *IPCC Guidelines*. It reflects the time period assumed for carbon stocks to come to equilibrium.

74. For example: Watson, R.T., Noble, I.R., Bolin, B., Ravindranath, N.H., Verardo, D.J., and Dokken, D.J. (2000) Land Use, Land Use Change and Forestry (IPCC Special Report): Chapter 4. Web published

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

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 Calculating emissions from 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 cultivation, fertilizer use, liming, and urea application, which can make up a significant portion of a city's AFOLU emissions. Rice cultivation is treated separately from other crops because it releases CH_4 emissions.

10.5.1 GHG emissions from biomass burning

Where biomass is burned for energy, the resulting non-CO_2 emissions shall be reported under scope 1 for *Stationary Energy* (see Chapter 6), while the CO_2 emissions are reported separately as biogenic CO_2. 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 under *AFOLU*.

Country-specific factors should be used where available.; alternatively, default IPCC values may be used for M_B, CF and EF.[75]

75. These are listed in 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

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

Category	Emission sources	*2006 IPCC Guidelines* 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 cultivation	Volume 4; Chapter 5; Section 5.5
	Harvested wood products	Volume 4; Chapter 12

Equation 10.7 GHG emissions from biomass burning

$$GHG = A \times M_B \times CF \times EF \times 10^{-3}$$

GHG	=	GHG emissions in tonnes 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

Equation 10.8 CO_2 emissions from liming

$$CO_2 = ((M_{Limestone} \times EF_{Limestone}) + (M_{Dolomite} \times EF_{Dolomite})) \times 44/12$$

CO_2	=	CO_2 emissions in tonnes
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

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

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.

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

Equation 10.9 CO_2 emissions from urea fertilization

$$CO_2 = M \times EF \times 44/12$$

CO_2	=	CO_2 emissions in tonnes
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

Equation 10.10 Direct N_2O from managed soils

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

N_2O_{Direct}	=	Direct N_2O emissions produced from managed soils, in tonnes
$N_2O\text{-}N_{N\ inputs}$	=	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

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.

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

Equation 10.11 Direct N_2O-N from managed soils

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

$N_2O\text{-}N_{N\ inputs}$	=	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

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

$N_2O\text{-}N_{OS}$	=	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

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

$N_2O\text{-}N_{PRP}$	=	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

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.[76]

Sections (a)–(f) below show how to source and calculate activity data identified in the previous equations.

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

Equation 10.14 N from organic N additions applied to soils

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

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

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.

76. 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

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

Equation 10.15 N from animal manure applied to soils

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

FAN	=	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
$Frac_{FUEL}$	=	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

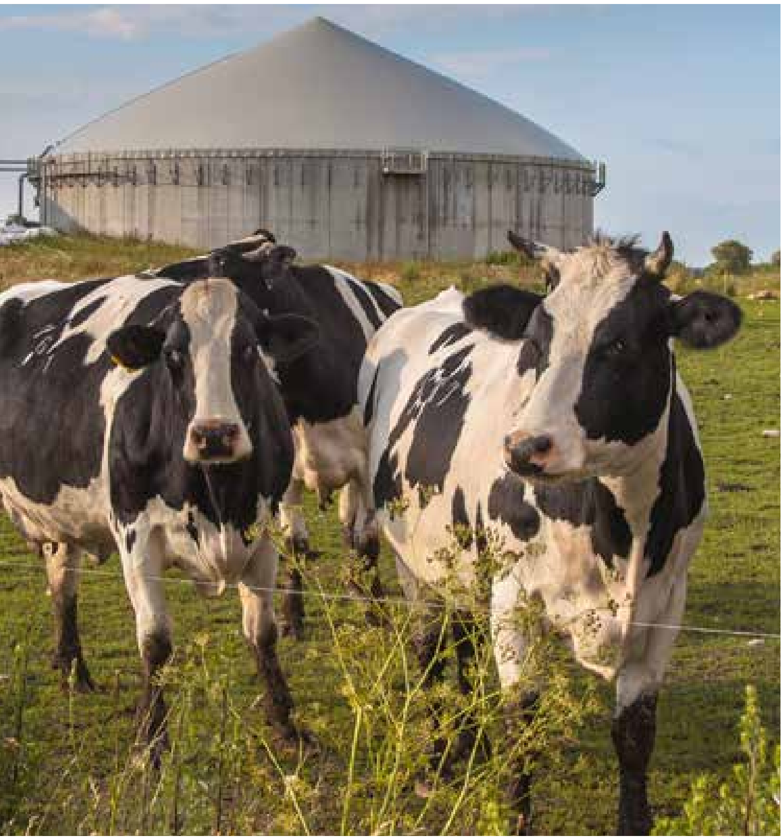
(c) Urine and dung from grazing animals (F_{PRP})

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

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

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

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

F_{CR}	=	Amount of N in crop residue returned to soils, kg N per year
$Crop_{(T)}$	=	Harvested dry matter yield for crop T, kg d.m. per hectare
$Area_{(T)}$	=	Total harvested area of crop T, hectare per year
$Area\ burnt_{(T)}$	=	Area of crop burnt, hectare 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. $R_{AG(T)} = AG_{DM(T)}) \times 1000 / Crop_{(T)}$
$N_{AG(T)}$	=	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

(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

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

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

N_2O emissions 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

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

$N_2O_{(ATD)}$	=	Amount of N_2O produced from atmospheric deposition of N volatilized from managed soils in tonnes
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 NO_x, 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 NH_3 and NO_x, 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 NH_3-N and NO_x-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

Activity data used in the above two equations is the same as the data 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.

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

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

$N_2O_{(L)}$	=	Amount of N_2O produced from leaching and runoff of N additions to managed soils in regions where leaching / runoff occurs, in tonnes
$Frac_{LEACH-(H)}$	=	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

Default emission, volatilization and leaching factors should be used in the absence of country-specific data.[77]

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 NO_x. 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.[78]

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

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

N_2O	=	Indirect N_2O emissions due to volatilization of N from manure management in tonnes
$N_{volatilization-MMS}$	=	Amount of manure nitrogen that is lost due to volatilization of NH_3 and NO_x, 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 NO_x-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

77. 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

78. 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 + NO_x-N volatilized)$^{-1}$ may be used for EF_4.

Equation 10.22 N losses due to volatilization from manure management

$$N_{volatilization\text{-}MMS} = \Sigma_S [\Sigma_T [(N_{(T)} \times Nex_{(T)} \times MS_{(T,S)}) \times (Frac_{GasMS} \times 10^{-2})_{(T,S)}]]$$

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

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).

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 10.23 CH_4 emissions from rice cultivation

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

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 CH_4 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 CH_4 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

Equation 10.24 Adjusted daily emission factors

$$EF_i = EF_c \times SF_w \times SF_p \times SF_o$$

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**

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

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 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.[79]

10.5.8 Harvested wood products (HWP)

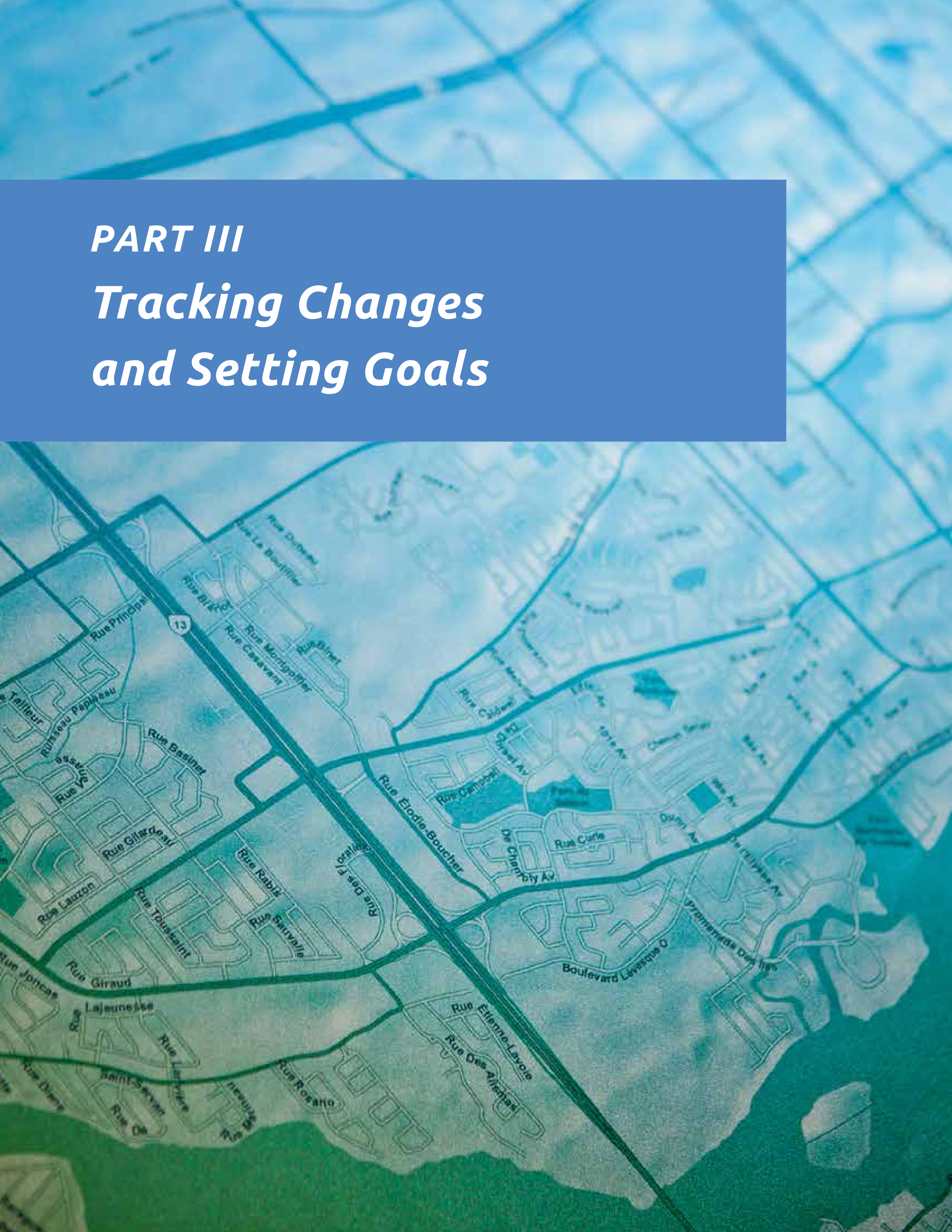
Harvested wood products (HWP) include all wood material that leaves harvest sites and constitutes a carbon reservoir (the time carbon is held in products will vary depending on the product and its uses). Fuel wood, for example, may be burned in the year of harvest, and many types of paper are likely 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.

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 *2006 IPCC Guidelines* should be followed.

79. 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 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 Goal Standard*,[80] which has been designed for national and sub-national entities, as well as cities.

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 (see Box 11.1 for an example of NYC's goal setting and performance tracking).

The type of goal provides the basis against which emissions and emissions reductions are tracked and reported. Users with a multi-year goal shall report whether the goal is an average, annual, or cumulative multi-year goal. In general, there are four goal types:

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

80. See www.ghgprotocol.org/mitigation-goal-standard

Box 11.1 Setting goals and tracking progress— New York City

New York City aims to reduce GHG emissions by 30% below 2005 levels by 2030, and 80% by 2050.[81] 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

Base year emissions goals represent a reduction in emissions relative to an emissions level in a historical base year. They are framed in terms of a percent reduction of emissions compared to a base year emissions level, and therefore correspond to an absolute reduction in emissions.

Fixed level 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 tonnes) 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 level goals do not include a reference to an emissions level in a baseline scenario or historical base year.

81. New York City Mayor's Office of Long-Term Planning and Sustainability (2014). "Inventory of New York City Greenhouse Gas Emissions." 2014. http://www.nyc.gov/html/planyc/downloads/pdf/NYC_GHG_Inventory_2014.pdf

Figure 11.1 Example of a base year emissions goal

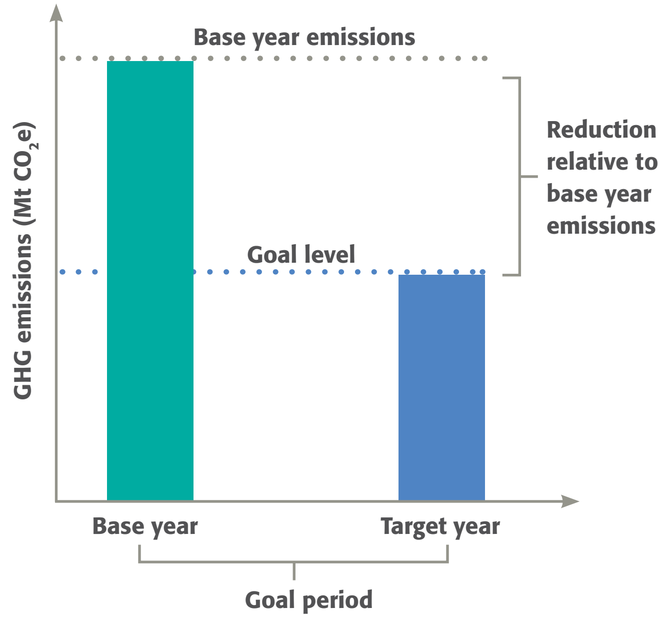
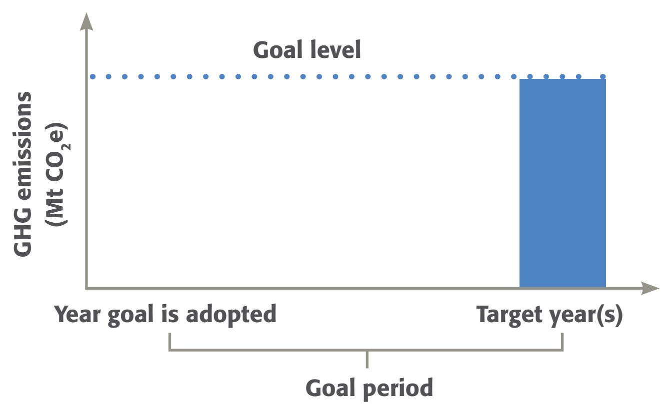
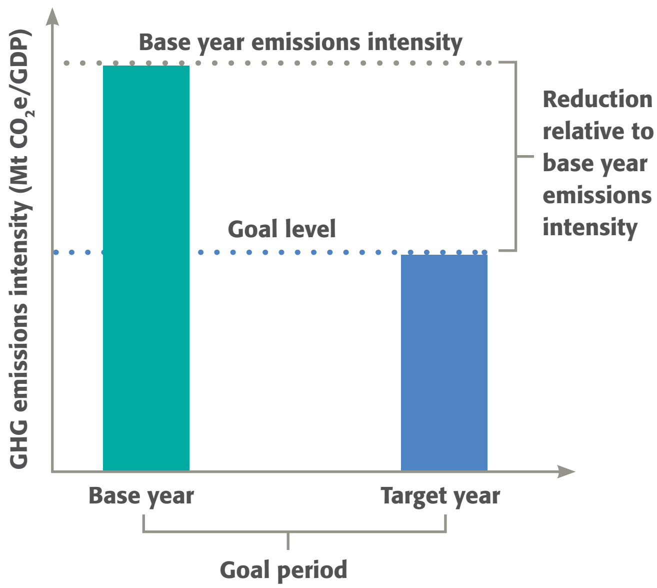


Figure 11.2 Example of a fixed-level goal



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 framed in terms of a percent reduction of emissions intensity compared to a base year emissions intensity, and therefore correspond to an absolute reduction in emissions intensity.

Figure 11.3 Example of a base year intensity goal



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 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 (i.e. business-as-usual).

All goal types, except for fixed level goals, require a base year GHG inventory and a GHG inventory in the target year for evaluation of results. To estimate the business-as-usual (BAU) baseline, additional historical data series may be used, including GDP, population, sectoral energy intensity, among others. Although GPC does not provide guidance on how to estimate the BAU baseline, it is advisable to have historical city inventories for a cross-check analysis. Table 11.1 gives examples of different goal types and minimum inventory need.

Figure 11.4 Example of a baseline scenario goal

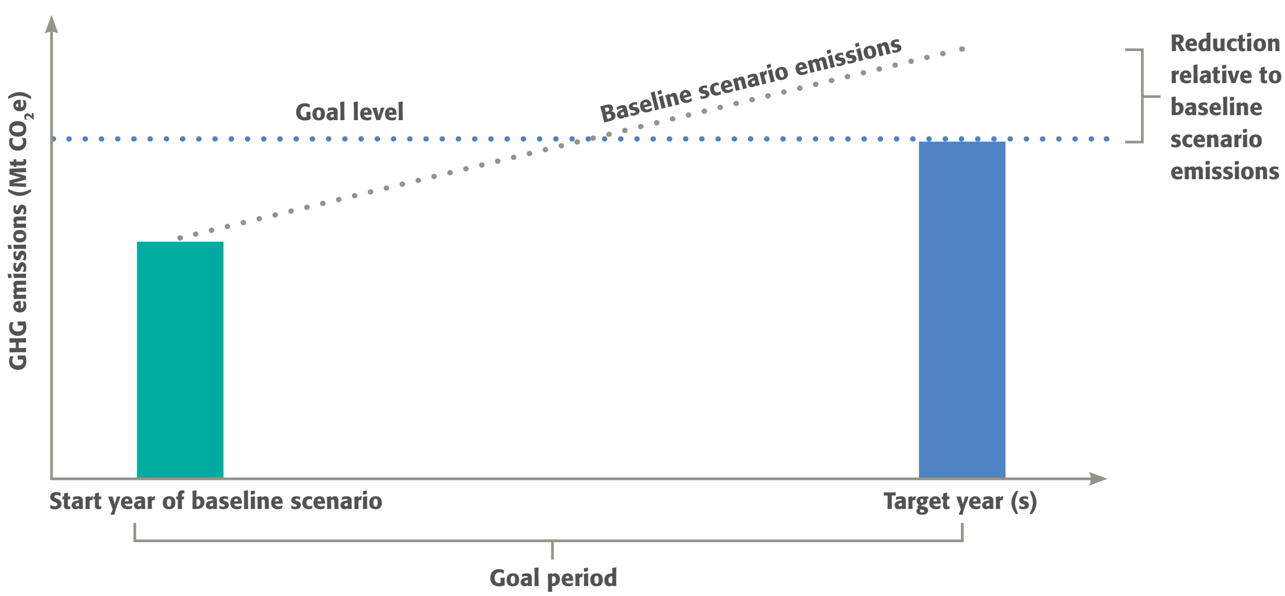


Table 11.1 Examples of city goal types and inventory need

Goal type		Example	Minimum inventory need
Base year emissions 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.	Inventory for 2020. In the case of Melbourne, current inventory required to determine quantity of offsets necessary to cover remainder of emissions, as well as GHG inventory in 2020.
Base year 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 boundary

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 boundary (Chapter 3). 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 inventory boundary are included or excluded in the goal. 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%. Cities may also include additional operations such as city-owned waste facilities or city-owned energy generation facilities that are located outside the inventory boundary.

Cities may follow the *GHG Protocol Mitigation Goals Standard* to set goals separately for each scope, in order to minimize double counting the same emissions in the same goal. If cities choose to set a combined scope 1 and 2 goal, then cities should use the BASIC/BASIC+ framework, or include an adjusted scope 2 total reflecting energy consumption net of energy production occurring in the city.

To avoid double counting scope 1 and scope 2 emissions in a GHG goal, cities can set separate goals for scope 1 and scope 2. If cities seek to set a target that combines scope 1 and scope 2, they may set a target based on BASIC or BASIC+ total. Alternatively, they can have a separate target for scope 2 emissions "net" of energy produced within the city. For this, cities may perform adjustments to scope 2 activity data and regional emission factors (following the location-based method) and report this total separately. These procedures are elaborated upon in Box 11.2.

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 shall document any sold GHG offsets from projects located within the inventory boundary as well as any credits purchased from projects located outside of the city boundary for the purpose of goal attainment. These shall be reported separately (see Section 4.4).

11.3 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 city-wide emissions. 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 real changes in emissions or removals as well as the pattern of methodological refinements.

If cities set an emissions goal, they should identify a base year for that goal. To clarify how emissions will be tracked over time, cities should report base year emissions. Cities should also identify a base year recalculation policy, including the significance threshold for recalculating base year emissions. For example, a city may identify a 5% threshold to determine if the applicable changes to base year emissions warrant recalculation.

Cities may undergo significant changes, which will alter a city's historical emissions profile and make 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 should recalculate base year emissions if they encounter significant changes such as:

Box 11.2 Adjustments to identify energy consumption emissions net of energy production

To determine emissions from grid-supplied energy consumption net of in-city energy production, cities may subtract energy generated in the city from total scope 2 emissions and/or adjust regional emission factors to subtract energy generated in the city.

To adjust the activity data to identify grid-supplied energy consumption net of in-city energy production, a city may follow the equation below.

Grid-supplied energy consumption of net in-city prodution (MWh) =
Grid-supplied energy consumption (MWh) - In-city grid-supplied energy production (MWh)

If a city generates and delivers to the grid more energy than it uses from the grid (e.g. the city is a net generator compared with consumption), it should report zero net energy consumption emissions (shall not be negative emission). If a city uses more grid-supplied energy than it produces, then it would deduct the MWh hours of generation from its MWhs of production, and multiply the remaining MWhs by a location-based emission factor. If all emissions from electricity generation are accounted for, any residual consumption will be served by electricity generated outside of the city boundaries.

Even with an adjustment of activity data, there may be further double counting in the form of the location-based emission factors (applied to any consumption net of production). Because these factors represent an average of all energy generation in the region, and will therefore inherently include emissions from any energy generation located in the city. Cities may attempt to address this by also adjusting the emission factor, which would require the city to identify the total emissions and total generation (in MWh) represented in the regional grid average emission factor as shown below:

$$\textbf{Adjusted emission factor} = \frac{\text{Total regional emissions (tonnes } CO_2e) - \text{emissions from city generation (tonnes } CO_2e)}{\text{Total generation (MWh)} - \text{city generation (MWh)}}$$

From there, a city may deduct the emissions and generation produced in-boundary.

- **Structural changes in the inventory 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 (known as "organic growth").
- **Changes in calculation methodology or improvements in data accuracy**. A city may 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 be reasonably applied to all past years, or new data points may not be available for past years. The city may then have to back cast these data points, or the change in data source may simply be acknowledged without recalculation. This acknowledgement should be made in the report every 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.

Cities should *not* recalculate base year emissions for organic growth (e.g., changes in the level or type of city activities). Cities should also note that emission factors for electricity and GWP are specific to every year, and their changes do not count as methodology changes. To isolate the role of changing activities compared with changing emission factors, cities may track activity data separately—for instance, tracking energy use separately to see the impact of energy efficiency policies.

These recalculation triggers are summarized in Table 11.2.

Whether recalculation is needed depends on the significance of the changes. Determining 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% 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.

Table 11.2 Example of recalculation triggers

Goal type	Example	Recalculation needed (if significant)	No recalculation needed
Changes in inventory 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 Methane Commitment Approach to the First Order Decay Method	X	
	Adoption of more accurate activity data instead of a scaled-down national figure	X	
	Change in global warming potential factors used		X
	Change in electricity emission factor due to energy efficiency improvement and growth of renewable energy utilization		X
Discovery of significant errors	Discovery of significant mistake in units conversion in formula used	X	

12 Managing Inventory Quality and Verification

The GPC does not require that cities verify their inventory results, but recommends that cities choose the level and type of verification that meets their needs and capacity. This chapter outlines how cities can establish inventory management plans to ensure data quality improvements over time and preparation for verification procedures.

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. The GPC 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. Cities 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 city 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. Cities 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 12.1 for an outline of procedures for ensuring QA/QC.

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 reporting requirements have been met, estimates are correct and data sourced is reliable.

To enable verification, the accounting and reporting principles set out in Chapter 2 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.

Table 12.1 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

12.3 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 criteria for a GHG emissions inventory should include the following:

- Inventory 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 inventory boundary and technology-specific to the activity being measured
- Data are sourced from reliable and robust sources and referenced appropriately
- All assumptions are documented

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.[82]

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.

82. 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.

Appendices

Appendix A
Overview of GHG standards and programs

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

National GHG inventory methods

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 similar 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 transboundary 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.

Corporate GHG inventory methods

The *GHG Protocol Corporate Standard*[83] established 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 has been adapted in the GPC to fit the geographic inventory boundaries of cities. Table A.1 shows the application of scopes terminology for corporate and city-level inventories.

83. See *GHG Protocol Corporate Standard*, 2004.

Table A.1 Scope definitions for corporate and city inventories

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

Some standards use frameworks or requirements that differ from the GPC, including:

- **IEAP** requires two levels of reporting: city-wide 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 2 and 3, with some overlap in scope 1. Activities are recognized as those processes which can be managed for emissions reductions regardless of where the emissions occur. 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. These recognize cities as both consumers and producers of goods services. The direct plus supply chain (DPSC) methodology captures territorial GHG emissions and those associated with the largest supply chains serving cities and is consistent with the GPC. The consumption-based (CB) methodology uses input-output modeling to estimate direct and life cycle GHG emissions for all goods and services consumed by residents of a city.

Some other important features, including primary audience, use of the "scopes" framework, inclusion of transboundary emissions and emission sources categories are also compared and summarized below.

Primary audience

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 to track their progress to achieve their SEAP goal. The U.S. Community Protocol was designed as a management framework to guide U.S. local governments to account for and report their GHG emissions associated with the communities they represent, with an emphasis on sources and activities over which U.S. local governments have the authority to influence.

Adoption of "scopes" framework and inclusion of transboundary 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 processes that take place within the community boundary which result in transboundary emissions. All standards cover both in-boundary and transboundary 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 four 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 emission 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 production 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. PAS 2070 provides a detailed case study of how London, United Kingdom, used its methodologies. Other standards only provide general requirements on accounting and reporting of GHG emissions.

Calculation tools

No specific tool is required to be used in order to achieve conformance with the GPC. WRI developed an Excel-based tool to help Chinese cities calculate emissions. 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. 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.

Guidance on setting reduction targets

Only the *GHG Protocol 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
Global Protocol for Community-Scale GHG Emissions Inventories (GPC)	C40 ICLEI WRI (2014)	Communities worldwide	Yes	Yes	Yes
1996/2006 IPCC Guidelines for National Greenhouse Gas Inventories	IPCC (1996/2006)	National governments	NA	Yes[84]	Yes
International Local Government GHG Emissions Analysis Protocol (Version 1.0)	ICLEI (2009)	Local governments and communities	Yes[85]	Yes	Yes
International Standard for Determining Greenhouse Gas Emissions for Cities (Version 2.1)	UNEP UN-HABITAT World Bank (2010)	Communities	Yes	Yes	Yes
Baseline Emissions Inventory/ Monitoring Emissions Inventory Methodology	The Covenant of Mayors Initiative[87] (2010)	Cities in the EU	Yes/No[88]	Yes	Yes
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[89]	No	Yes
PAS 2070: 2013	BSI (2013)	Cities	Yes	Yes	Yes
Bilan Carbone	ADEME[90] (since 2001)	Companies, local authorities, and regions, in France	No		
Manual of Planning against Global Warming for Local Governments	Ministry of Environment, Japan (2009)	Sub-national governments	Yes[91]	Yes	Yes

84. IPCC emission sources categories include all in-boundary emissions and international aviation and water-borne related out-of-boundary emissions

85. Sub-category (government) not consistent with IPCC categorization

86. Upstream embedded GHG emissions

87. The Joint Research Centre (JRC) of the European Commission

Out-of-boundary emissions	Gases	Detailed guidance on calculation methodologies	Guidance on setting reduction targets	Other information
Yes	Seven gases	No	Yes	• Divides in-boundary and transboundary emissions into scopes 1,2,and 3 • Provides BASIC, BASIC+ reporting levels • Pilot tested by 35 pilot cities
Yes	Six gases	Yes	No	• Provides detailed guidance on emission/removal categories, calculation formula, data collection, default emission factors, and uncertainty management

Yes	Six gases	Yes	No	• Requires two levels of reporting:
				  • local government operations (LGO)
				  • community-wide

Yes[86]	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
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 CO2 emissions due to final energy consumption • Considers interactions with other policies such as EU ETS
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

Yes	Six gases	Yes	No	• Provides two methodologies to assess city GHG emissions:
				  • Direct plus supply chain methodology, which is consistent with GPC
				  • Consumption-based methodology
				• Worked case study of the application of PAS 2070 provided for London, United Kingdom

	Six gases		Yes	
Yes	Six gases	Yes	Yes	

88. Does not include industry energy, air transport, water-borne sources, and includes waste but not agriculture, forestry and industrial processes

89. Basic emission generating activities—no carbon sinks

90. Managed by the Association Bilan Carbone (ABC) since 2011

91. 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 transportation
1A3c	Railways	II.2	Railways
1A3d	Water-borne navigation	II.3	Water transport
1A3a	Civil aviation	II.4	Aviation
1A3e	Other transportation	II.5	Off-road transportation
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-CO_2 emissions sources on land Other	V.3	Other agriculture

Appendix B
Inventories for local government operations

Introduction

Local government operations (LGO) and their 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, presenting an opportunity to measure and manage emissions, and demonstrate to tax payers a responsible and efficient use of resources by city leadership.

To guide local governments on calculating 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 LGOs, tailoring general guidance on 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 GPC 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.[92]

Other standards and guidelines have also provided similar guidance on a local or national level, including the U.S.-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.

Purpose of an LGO inventory

An LGO inventory accounts for GHGs from operations, activities and facilities that governments own or operate, including those from 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 city-wide emissions, though rare exceptions can occur. One such exception is 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 3–7% of total city-wide emissions. Although this is a relatively small fraction of the city's emissions, it clearly shows that 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 city-wide emissions.

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 an LGO inventory

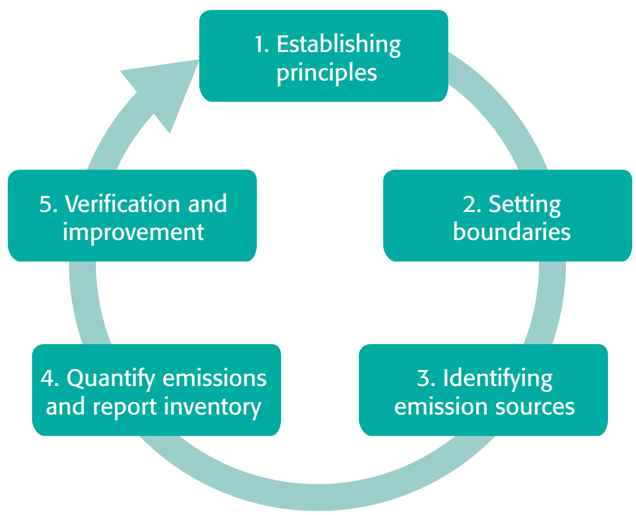
Overall, an LGO inventory follows the five steps described in Figure 1. This appendix only illustrates the special requirements for LGO emissions inventory in steps 1, 2 and 3.

92. Available online at: http://www.iclei.org/details/article/international-local-government-greenhouse-gas-emissions-analysis-protocol-ieap.html

Accounting and reporting principles

An LGO inventory draws on the same accounting and reporting principles as a city-wide 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 governments typically fall within a city's geographical boundary (see GPC Chapter 3 on inventory boundaries). In some cases, such as electricity use and waste disposal, emissions can occur outside the geographic 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. Where such disaggregated activity data is not available, or not applicable due to the nature of the facilities, local governments should account for 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 the GPC for city-wide 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 prevents 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. Local governments should note that the scopes definition for categorizing LGO activities will differ from the scopes definition used for city-wide inventories. The categorization of GHG emissions according to scope for local government operations in IEAP is based on the degree of control, whereas a city-wide inventory 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)

Local government GHG inventories help inform city governments in their decision-making process. When local governments aggregate emissions from different sources, it may aggregate the energy emissions from the operation of waste management facilities (GPC's *Stationary Energy* sector) with emissions from the biodegradation of waste during treatment and disposal (GPC's *Waste* sector), but this aggregation result should not be directly used for reporting under 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 Scope 3* sector recognizes the diversity of local government functions and allows for consideration of any sources of emissions not included elsewhere.

A local government's influence over city activity might change through time as well. One emission sources within a local government operation might not be included in the government operation the next year. Ensure inventories contain the same emission source coverage when conducting LGO inventory comparisons.

Appendix C
Methodology reference

This table serves as a brief summary of the methodologies outlined in Part II of the GPC, and includes a general overview of activity data and emission factors used.

Please note that this table is not exhaustive. Cites may use alternative methodologies, activity data and emission factors as appropriate. Methods used to calculate emissions shall be justified and disclosed.

Table C.1 Methodology reference

Sectors	Emission sources	Scope	GPC recommended approaches	Recommended activity data	Recommended emission factors
Stationary Energy	Fuel combustion within the city boundary	1	Fuel consumption	Amount of fuel consumption	Mass GHG emissions per unit of fuel
	Consumption of grid-supplied energy consumed within the city boundary	2	Grid-energy consumption	Amount of grid-supplied energy consumption	Mass GHG emissions per unit of grid-supplied energy (grid specific emission factor)
	Transmission and distribution losses from grid-supplied energy	3	Loss rate based approach	Amount of energy transmitted and average loss rate of the grid	Mass GHG emissions per unit of grid-supplied energy
	Fugitive emissions from fossil fuels extraction and processing	1	Direct Measurement	Direct measurement of GHG emissions	
			Production-based estimation	Quantity of production in fuel extraction and processing	Mass GHG emissions per unit of fossil fuel production
Transportation	Fuel combustion for in-boundary transportation	1	ASIF model (Activity, Share, Intensity, Fuel)	Distance traveled by type of vehicle using type of fuel	Mass GHG emissions per unit distance traveled by type of vehicle using type of fuel
			Fuel sold method	Amount of fuel sold	Mass GHG emissions per unit of sold fuel
	Consumption of grid-supplied energy for in-boundary transportation	2	Grid-energy consumption model	Amount of electricity consumed	Mass GHG emissions per unit of grid-supplied energy (grid specific emission factor)
	Emissions from transboundary transportation	3	ASIF model (Activity, Share, Intensity, Fuel)	Distance traveled or fuel consumed by type of vehicle using type of fuel	Mass GHG per unit distance traveled or fuel consumed by type of vehicle using type of fuel
	Transmission and distribution losses from grid-supplied energy	3	Loss rate based approach	Amount of energy transmitted and average loss rate of the grid	Mass GHG emissions per unit of grid-supplied energy

Table C.1 Methodology reference (continued)

Sectors	Emission sources	Scope	GPC recommended approaches	Recommended activity data	Recommended emission factors
Waste	Solid waste disposal	1 and 3	First Order of Decay method (GPC recommended)	Amount of waste received at landfill site and its composition for all historical years	Methane generation potential of the waste
			Methane Commitment method	Amount of waste disposed in inventory year and its composition	Methane generation potential of the waste
	Biological treatment of waste	1 and 3	Waste composition based approach	Mass of organic waste treated by treatment type	Mass GHG emission per unit of organic waste treated, by treatment type
	Incineration and open burning	1 and 3	Waste composition based approach	Mass of waste incinerated and its fossil carbon fraction	Oxidation factor, by type of treatment
	Wastewater	1 and 3	Organic content based approach	Organic content of wastewater per each treatment type	Emission generation potential of such treatment type
IPPU	Industrial processes occurring in the city boundary	1	Input or output based approach	Mass of material input or product output	Emission generation potential per unit of input/output
			Direct Measurement	Direct measurement of GHG emissions	
	Product use occurring within the city boundary	1	Input or output based approach	Mass of material input or product output	Emission generation potential per unit of input/output
			Direct Measurement	Direct measurement of GHG emissions	
AFOLU	Livestock emission sources	1	Livestock based approach	Number of animals by livestock category and manure management system	Emission factor per head and nitrogen excretion per manure management system
	Land uses emission sources	1	Land area based approach	Surface area of different land use categories	Net annual rate of change in carbon stocks per hectare of land
	Aggregate sources and non-CO_2 emission sources on land	1	See details in corresponding chapters		

Abbreviations

AFOLU	Agriculture, forestry and other land use
BOD	Biochemical oxygen demand
C40	C40 Cities Climate Leadership Group
cCR	carbon*n* 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	Emission 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 Emission 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

Glossary

Activity data	A quantitative measure of a level of activity that results in GHG emissions. Activity data is multiplied by an emission 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.
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))	Emissions 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 GHG, 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.
Double counting	Two or more reporting entities claiming the same emissions or reductions in the same scope, or a single entity reporting the same emissions in multiple scopes.
Emission factor(s)	A factor that converts activity data into GHG emissions data (e.g., kg CO_2e emitted per liter of fuel consumed, kg CO_2e emitted per kilometer traveled, etc.).
Emission	The release of GHGs 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 Gases (GHG)	For the purposes of the GPC, 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).
Greenhouse gas inventory	A quantified list of a city's GHG emissions and sources.

In-boundary	Occurring within the established geographic boundary.
Inventory boundary	The inventory boundary of a GHG inventory identifies the gases, emission sources, geographic area, and time span covered by the GHG inventory.
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	GHG emissions from sources located within the city boundary.
Scope 2 emissions	GHG emissions occurring as a consequence of the use of grid-supplied electricity, heat, steam 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 taking places within the city boundary.
Transboundary emissions	Emissions from sources that cross the geographic boundary.

References

BSI. "Application of PAS 2070 – London, United Kingdom: An assessment of greenhouse gas emissions of a city." 2014. http://shop.bsigroup.com/upload/PAS2070_case_study_bookmarked.pdf.

The Climate Collaborative. "Discussion Paper: Community GHG Inventory and Forecast for Waterloo Region." May 2012. http://www.regionofwaterloo.ca/en/aboutTheEnvironment/resources/CommunityGHGInventoryForecastforWaterlooRegion_DiscussionPaper_May2012.pdf.

The Council for Scientific and Industrial Research. "Guidelines for Human Settlement Planning and Design." 2000: Chapter 5.5. Online at www.csir.co.za/Built_environment/RedBook.

GIZ. Dünnebeil, F. e. "Balancing Transport Greenhouse Gas Emissions in Cities – A Review of Practices in Germany." Beijing Transportation Research Center, 2012.

ICLEI – Africa. "Local Renewables: South-south cooperation between cities in India, Indonesia and South Africa." 2013.http://carbonn.org/uploads/tx_carbonndata/LocalRenewables_EMM_Energy%20Urban%20Profile_Final%20Draft_5April2013_stdPDF_09.pdf.

ICLEI. "Local government operations protocol for the quantification and reporting of greenhouse gas emissions inventories." version 1.1. 2010. http://www.arb.ca.gov/cc/protocols/localgov/pubs/lgo_protocol_v1_1_2010-05-03.pdf

IPCC. "Anthropogenic and Natural Radiative Forcing." In *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA., 2013. http://www.climatechange2013.org/.

IPCC. Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). *Guidelines for National Greenhouse Gas Inventories,* Prepared by the National Greenhouse Gas Inventories Programme, Published: IGES, Japan, 2006. http://www.ipcc-nggip.iges.or.jp/public/2006gl/.

IPCC. Houghton J.T., Meira Filho L.G., Lim B., Tréanton K., Mamaty I., Bonduki Y., Griggs D.J. and Callander B.A. (Eds). *Revised 1996 IPCC Guidelines for National Greenhouse Inventories*. IPCC/OECD/IEA, Paris, France,1997. http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.html.

IPCC. Penman J., Kruger D., Galbally I., Hiraishi T., Nyenzi B., Emmanuel S., Buendia L., Hoppaus R., Martinsen T., Meijer J., Miwa K., and Tanabe K. (Eds). *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*. IPCC/OECD/IEA/IGES,Hayama, Japan, 2000. http://www.ipcc-nggip.iges.or.jp/public/gp/english/.

IPCC. Penman J., Gytarsky M., Hiraishi T., Krug, T., Kruger D., Pipatti R., Buendia L., Miwa K., Ngara T., Tanabe K., Wagner F., *Good Practice Guidance for Land Use, land-Use Change and Forestry* IPCC/IGES, Hayama, Japan, 2003. http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf.html.

IPPC. *IPCC/TEAP special report on safeguarding the ozone layer and the global climate system: issues related to hydrofluorocarbons and perfluorocarbons*. Intergovernmental Panel on Climate Change, 2005. http://www.ipcc.ch/publications_and_data/_safeguarding_the_ozone_layer.html.

Kennedy, C. "Getting to Carbon Neutral: A Guide for Canadian Municipalities. Toronto and Region Conservation Authority." 2010.

King County and SEI. "Greenhouse Gas Emissions in King County: An updated Geographic-plus inventory, a Consumption-based Inventory, and an Ongoing Tracking Framework." 2012. http://your.kingcounty.gov/dnrp/library/dnrp-directors-office/climate/2008-emissions-inventory/ghg-inventory-summary.pdf.

Makerere University. *Greenhouse Gas Emissions Inventory for Kampala City and Metropolitan Region,* 2013. http://mirror.unhabitat.org/downloads/docs/12220_1_595178.pdf.

New York City Mayor's Office of Long-Term Planning and Sustainability. "Inventory of New York City Greenhouse Gas Emissions." 2014. http://www.nyc.gov/html/planyc/downloads/pdf/NYC_GHG_Inventory_2014.pdf.

North American Reliability Corporation. "Understanding the Grid." Accessed November 25, 2014. http://www.nerc.com/page.php?cid=1|15.

Schipper, L., Fabian, H., & Leather, J.. "Transport and carbon dioxide emissions: Forecasts, options analysis, and evaluation." Asian Development Bank, Manila, 2009. http://www.indiaenvironmentportal.org.in/files/Transport-CO2-Emissions.pdf.

Schipper, L., Marie-Lilliu, C., & Gorham, R. Flexing the Link between Transport and Greenhouse Gas Emissions: A Path for the World Bank. International Energy Agency, Paris, 2000. http://www-wds.worldbank.org/servlet/WDSContentServer/WDSP/IB/2000/02/09/000094946_00012505400755/Rendered/PDF/multi_page.pdf.

United Nations. "Household surveys in developing and transition countries." New York, 2005. http://unstats.un.org/unsd/HHsurveys/.

The World Bank. "Electric power transmission and distribution losses (% of output)." World Development Indicators (WDI). Accessed November 25, 2014. http://data.worldbank.org/indicator/EG.ELC.LOSS.ZS.

WRI/WBCSD GHG Protocol. "Allocation of GHG Emissions from a Combined Heat and Power (CHP) Plant: Guide to calculation worksheets (September 2006) v1.0." 2006. http://www.ghgprotocol.org/files/ghgp/tools/CHP_guidance_v1.0.pdf.

WRI/WBCSD GHG Protocol. *The Greenhouse Gas Protocol: a corporate accounting and reporting standard (revised edition)*, 2004. http://www.ghgprotocol.org/standards/corporate-standard.

WRI/WBCSD GHG Protocol. *The Greenhouse Gas Protocol Mitigation Goal Standard.* 2014. http://www.ghgprotocol.org/mitigation-goal-standard

WRI/WBCSD GHG Protocol. *The Greenhouse Gas Protocol Scope 2 Guidance.* 2014. http://ghgprotocol.org/scope_2_guidance.

Recognitions

Pilot Testing Cities

Adelaide, Australia	Lorraine Irwin
	Marnie Hope
Arendal, Norway	Ragnhild Hammer
Ballynagran Energy Plus Com.,	Christoph Walter
Wicklow, Ireland	Susan Byrne
Belo Horizonte, Brazil	Sônia Mara Knauer
Buenos Aires, Argentina	Ines Lockhart
	Josefina Ujit den Bogaard
Cornwall, UK	Ben Simpson
Doha, Qatar	Svein Tveitdal
Durban (eThekwini municipality),	Magash Naidoo
South Africa	
Georgetown, Malaysia	Bikash Kumar Sinha
Goiania, Brazil	Matheus Lage Alves de Brito
Hennepin County, Minnesota, USA	Tony Hainault
Iskandar Malaysia, Malaysia	Boyd Dionysius Joeman
Kampala, Uganda	Shuaib Lwasa
Kaohshiung, Taiwan, China	Cathy Teng
	Vincent Lin
Kyoto, Japan	Saki Aoshima
La Paz, Bolivia	Miguel Rodríguez
Lagos, Nigeria	Maximus Ugwuoke
Lahti, Finland	Marko Nurminen
Lima, Peru	Mariela Rodriguez
London, UK	Michael Doust
	Leah Davis
Los Altos Hills, USA	Steve Schmidt
Melbourne, Australia	Beth McLachlan
	Kim LeCerf
Mexico City, Mexico	Saira Mendoza Pelcastre
	Victor Hugo Paramo
Morbach, Germany	Mona Dellbrügge
	Pascal Thome
Moreland, Australia	Judy Bush
	Matthew Sullivan
Nonthaburi and Phitsanulok,	Shom Teoh
Thailand	Simon Gilby
Northamptonshire, UK	Aiman Somoudi
	Chiara Cervigni
	Darren Perry
Palmerston North, New Zealand	William van Ausdal

Rio de Janeiro, Brazil	Flávia Carloni
	Nelson Franco
Saskatoon, Canada	Matthew Regier
Seraing, Belgium	Alexis Versele
	Christelle Degard
	Leen Trappers
	Sabien Windels
Stockholm, Sweden	Emma Hedberg
Tokyo, Japan	Yuuko Nishida
Wellington, New Zealand	Catherine Leining
	Maurice Marquardt
	Zach Rissel

Other stakeholders and contributors

Pravakar Pradhan	Asian Institute of Technology and Management (AITM), Thailand; Center for Climate Change, Energy and Environment; Khumaltar, Lalitpur, Nepal
Sri Indah Wibi Nastiti	Asosiasi Pemerintah Kota Seluruh Indonesia (APEKSI), Indonesia
Paula Ellinger	Avina Foundation, Brazil
Emiliano Graziano	BASF, Brazil
Alaoui Amine	BHCP, France
Rohit Aggarwala	Bloomberg Associates
Amrita Sinha	C40
Cristiana Fragola	C40
Gunjan Parik	C40
Hasting Chikoko	C40
Zoe Sprigings	C40
Ali Cambrau	CDKN
Pauline Martin	CDP
Ambesh Singh	CDP India
Damandeep Singh	CDP India
Andreia Bahne	CDP Brasil
Todd Jones	Center for Resource Solutions, U.S./Green-e
Minal Pathak	Centre for Environmental Planning and Technology University (CEPT), India
Leonardo Lara	City Betiim, Brazil
Haileselassie Hailu	City of Addis Ababa, Ethiopia
Aleka Meliadou	City of Athens, Greece
Dessy Fitrianitha	City of Balikpapan, Indonesia
Nursyamsiami	City of Balikpapan, Indonesia
Ayu Sukenjah	City of Bandung, Indonesia
Deti Yulianti	City of Bandung, Indonesia
Jürg Hofer	City of Basel, Switzerland
Elly Tartati Ratni	City of Blitar, Indonesia
Djodi G.	City of Bogor, Indonesia
Fredi Kurniawan	City of Bogor, Indonesia
Inolasari Baharuddin Ikram	City of Bogor, Indonesia

Lorina Darmastuti	City of Bogor, Indonesia
Rakhmawati	City of Bogor, Indonesia
Syahlan Rashidi	City of Bogor, Indonesia
Fakhrie Wahyudin	City of Bontang, Indonesia
Heru Triatmojo	City of Bontang, Indonesia
Muji Esti Wahudi	City of Bontang, Indonesia
Pak Juni	City of Bontang, Indonesia
Srie Maryatini	City of Bontang, Indonesia
Sarah Ward	City of Cape Town, South Africa
Mula Febianto	City of Cimahi, Indonesia
Untung Undiyannto	City of Cimahi, Indonesia
Claus Bjørn Billehøj	City of Copenhagen, Denmark
Maja Møllnitz Lange	City of Copenhagen, Denmark
Gusti Agung Putri Yadnyawati	City of Depensar, Indonesia
Gary Woloshyniuk	City of Edmonton, Canada
Janice Monteiro	City of Fortaleza, Brazil
Mandy Zademachez	City of Hamburg, Germany
Tiaan Ehlers	City of Johannesburg, South Africa
Sikhumbuzo Hlongwane	City of KwaDukuza, South Africa
Javier Castaño Caro,	City of Madrid, Spain
Marcos Vieira	City of Maracanaú, Brazil
Marta Papetti	City of Milan, Itala
Barreh John Koyier	City of Nairobi, Kenya
Joram Mkosana	City of Nelson Mandela Bay, South Africa
Budi Krisyanto	City of Probolinggo, Indonesia
Dwi Agustin Pudji Rahaju	City of Probolinggo, Indonesia
Nazeema Duarte	City of Saldanha Bay, South Africa
André Fraga	City of Salvador, Brazil
Purnomi Dwi Sasongko	City of Semarang, Indonesia
Safrinal Sofaniadi	City of Semarang, Indonesia
Carolina Barisson M. O. Sodré	City of Sorocaba, Brazil
Sibongile Mtshweni	City of Steve Tshwete, South Africa
Gustaf Landahl	City of Stockholm, Sweden
Kamalesh Yagnik	City of Surat, India
Magesh Dighe	City of Surat, India
Tukarama Jagtap	City of Surat, India
Vikas Desai	City of Surat, India
Akhmad Satriansyah	City of Tarakan, Indonesia
Edhy Pujianto	City of Tarakan, Indonesia
Lemao Dorah Nteo	City of Tshwane, South Africa
Brenda Stachan	City of uMhlathuze, South Africa
Riaz Jogiat	City of uMungundlovu, South Africa
Simone Tola	City of Venice, Italy
Kacpura Katarzyna	City of Warsaw, Poland
Marcin Wróblewski	City of Warsaw, Poland
Ade B. Kurniawan	Conservation International, Indonesia

Charu Gupta	Deloitte, India
Steven Vanholme	EKOenergy, Finland
Délcio Rodrigues	Elkos Brasil/Geoklock, Brazil
Juliette Hsu	Environmental Science Technology Consultants Corporation (ESTC)
Aditya Bhardwaj	Ernst & Young, India
Anindya Bhattacharya	Ernst & Young, India
Carolina Dubeux	Federal University of Rio de Janeiro, Brazil
Flavia Azevedo Carloni	Federal University of Rio de Janeiro, Brazil
Guilherme Raucci	Federal University of Rio de Janeiro, Brazil
A. Izzul Waro	GIZ Indonesia
Pricilla Rowswell	ICLEI Africa
Steven Bland	ICLEI Africa
Siegfried Zöllner	ICLEI Europe
Gina Karina	ICLEI Indonesia
Irvan Pulungan	ICLEI Indonesia
Steve Gawler	ICLEI Indonesia
Teresa Putri Sari	ICLEI Indonesia
Igor Albuquerque	ICLEI South America
Emani Kumar	ICLEI South Asia
Keshav Jha	ICLEI South Asia
Soumya Chaturvedula	ICLEI South Asia
Soumya Chaturvedula	ICLEI South Asia
Irvan Pulungan	ICLEI Southeast Asia
Michael Steinhoff	ICLEI USA
Garrett Fitzgerald	ICLEI US Community Protocol Steering Committee
Karen Talita Tanaka	IEE, Brazil
Mahesh Kashyap	Indian Institute of Sciences (IISc), India
Frank Dünnebeil	Institute for Energy and Environmental Research (IFEU), Germany
Sergio Zanin Teruel	Instituto Vale das Garças, Brazil
David Maleki	Inter-American Development Bank
Pedro Torres	ITDP, Brazil
Anggiat Jogi Simamora	Kementerian Badan Usaha Milik Negara (BUMN), Indonesia
Sengupta Baishakhi	KPMG, India
Sumedha Malviya	Leadership for Environment and Development (LEAD), India
Ucok W.R. Siagian	Low Emission Capacity Building Program (LECB), Indonesia
Anggri Hervani	Ministry of Agriculture, Litbang, Balingtan, Indonesia
Randy A. Sanjaya	Ministry of Agriculture, Litbang, Balingtan, Indonesia
Tze-Luen Alan Lin	National Taiwan University (NTU)
Stephen Kenihan	Net Energy Asia, Australia
Ida Bagus Badraka	Province of Bali, Indonesia
Aisa Tobing	Province of Jakarta, Indonesia
Rita Rahadiatin	Province of Jakarta, Indonesia
Susi Andriani	Province of Jakarta, Indonesia
Phindite Mangwana	Province of Western Cape, South Africa
Oswaldo Lucon	Sao Paulo State Secretariat for the Environment (SMA-SP), Brazil
Tanya Abrahamse	SAUBI, South Africa

Susan Carstairs	Scotland's Rural College, U.K.
Hukum Ogunbambi	State of Lagos, Nigeria
Melusile Ndlovu	Sustainable Energy Africa, South Africa
Keith Baker	The Initiative for Carbon Accounting (ICARB)
Susan Roaf	The Initiative for Carbon Accounting (ICARB)
Budhi Setiawan	The National Center of National Action Plan for Greenhouse Gas Reduction (Sekretariat RAN-GRK), Indonesia
Tri Sulistyo	The National Center of National Action Plan for Greenhouse Gas Reduction (Sekretariat RAN-GRK), Indonesia
Julianne Baker Gallegos	The World Bank
Matt Clouse	U.S. Environmental Protection Agency
Tom Frankiewicz	U.S. Environmental Protection Agency EPA / Global Methane Initiative
Klaus Radunsky	Umweltbundesamt, Germany
Marcus Mayr	UN-Habitat
Eugene Mohareb	University of Cambridge, U.K.
Tommy Wiedmann	University of New South Wales, Australia
Adriana Jacintho Berti	University of São Paulo, Brazil
Carlos Cerri	University of São Paulo, Brazil
Cindy Moreira	University of São Paulo, Brazil
Luana Ferreira Messena	University of São Paulo, Brazil
Sérgio Pacca	University of São Paulo, Brazil
Chris Kennedy	University of Toronto, Canada
Ghea Sakti M.	University Padjajaran, Indonesia
Ika Anisya	University Padjajaran, Indonesia
Rose Maria Laden Holdt	Viegand Maagoe Energy People
João Marcelo Mendes	Waycarbon, Brazil
Matheus Alves de Brito	Waycarbon, Brazil
Joe Phelan	WBCSD India
Andrea Leal	WRI
Angad Gadgil	WRI
Benoit Leferve	WRI
Charles Kent	WRI
David Rich	WRI
Erin Cooper	WRI
Laura Malaguzzi Valeri	WRI
Laura Valente de Macedo	WRI
Magdala Arioli	WRI
Nancy Harris	WRI
Rachel Biderman	WRI
Srikanth Shastry	WRI
Stacy Kotorac	WRI
Xiaoqian Jiang	WRI
Derek Fehrer	WSP Group
Valerie Moye	Yale School of Forestry & Environmental Studies, USA

Disclaimer

The GHG Protocol *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories* is designed to promote best practice GHG accounting and reporting, It has been developed through an inclusive multistakeholder process involving experts from nongovernmental organizations, governments, and others convened by WRI, C40, and ICLEI. While the authors encourage the use of the GPC by all relevant organizations, the preparation and publication of reports or program specifications based fully or partially on this standard is the full responsibility of those producing them. Neither the author organizations nor other individuals who contributed to this standard assume responsibility for any consequences or damages resulting directly or indirectly from its use in the preparation of reports or program specifications or the use of reported data based on the standard.

Other Acknowledgments

The standard development process was generously supported by The Caterpillar Foundation, The Stephen M. Ross Foundation, UN-Habitat, United Technologies Corporation, C40 Cities Climate Leadership Group, ICLEI - Local Governments for Sustainability, and the Urban-LEDS project.

The Urban-LEDS project is funded by the European Union. The views expressed in this document can in no way be taken to reflect the official opinion of the European Union.

A list of funders is available at www.ghgprotocol.org/city-accounting

World Resources Institute

WRI is a global research organization that works closely with leaders to turn big ideas into action to sustain a healthy environment— the foundation of economic opportunity and human well-being.

Our Challenge

Natural resources are at the foundation of economic opportunity and human well-being. But today, we are depleting Earth's resources at rates that are not sustainable, endangering economies and people's lives. People depend on clean water, fertile land, healthy forests, and a stable climate. Livable cities and clean energy are essential for a sustainable planet. We must address these urgent, global challenges this decade.

Our Vision

We envision an equitable and prosperous planet driven by the wise management of natural resources. We aspire to create a world where the actions of government, business, and communities combine to eliminate poverty and sustain the natural environment for all people.

C40 Cities Climate Leadership Group

C40 is a network of large and engaged cities from around the world committed to implementing meaningful and sustainable climate-related actions locally that will help address climate change globally. C40 was established in 2005 and expanded via a partnership in 2006 with President William J. Clinton's Climate Initiative (CCI). The current chair of the C40 is Rio de Janeiro Mayor Eduardo Paes; the three-term Mayor of New York City Michael R. Bloomberg serves as President of the Board.

C40 helps cities identify, develop, and implement local policies and programs that have collective global impact. Working across multiple sectors and initiative areas, C40 convenes networks of cities with common goals and challenges, providing a suite of services in support of their efforts: direct technical assistance; facilitation of peer-to-peer exchange; and research, knowledge management & communications. C40 is also positioning cities as a leading force for climate action around the world, defining and amplifying their call to national governments for greater support and autonomy in creating a sustainable future.

ICLEI-
Local Governments for Sustainability

ICLEI is the world's leading network of over 1,000 cities, towns and metropolises committed to building a sustainable future. By helping our members to make their cities sustainable, low-carbon, resilient, biodiverse, resource-efficient, healthy and happy, with a green economy and smart infrastructure, we impact over 20% of the global population.

ICLEI's Low Carbon City Agenda outlines a pathway to urban low-emission development. The focus in on the role and influence of local governments in shaping and guiding their local communities into becoming low-carbon, low-emission or even carbon-neutral communities, as signposts to sustainability and global climate change mitigation. Technical support is offered through ICLEI's carbonn Center (Bonn Center for Local Climate Action and Reporting).

MIX
Paper from responsible sources
FSC® C068100

PRINTED ON RECYCLED PAPER

PRINTED WITH SOY INK

Printed on Chorus Art Silk, an FSC-certified paper with 30% pcw recycled content and with inks that are of soy content.

Stock photography: Shutterstock.com

Pg. 26 Sean Munson; pg. 28, 116, NASA; pg. 40-41 Tambako The Jaguar; pg. 54 Doc Searls; pg.68-69 arbyreed; pg. 104 Peter Gorges; pg. 127 Chesapeake Bay Program, pg. 131, 132, Kate Evans, CIFOR; pg. 133 Tri Saputro, CIFOR; pg. 134 James Anderson, WRI; pg. 135 Kris Krüg; pg. 136 Duncan; pg. 144 Antony Tran, World Bank; pg. 149 Nico Kaiser; pg. 171 Benoit Colin, EMBARQ.

Design: Alston Taggart, Studio Red Design, with assistance from Elliott Beard and Alex Kovac.

ISBN: ???
Printed in USA

GREENHOUSE GAS PROTOCOL

The Greenhouse Gas Protocol provides the foundation for sustainable climate strategies. GHG Protocol standards are the most widely used accounting tools to measure, manage and report greenhouse gas emissions.

www.wri.org www.c40.org www.iclei.org www.ghgprotocol.org