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How to prepare a greenhouse gas emission inventory

Covenant of Mayors Guidebook | Complementary document 1

Covenant of Mayors for Climate & Energy EUROPE

Joint Research Centre

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European Commission, Joint Research Centre, 2025

CONTENTS

Abstract

The Covenant of Mayors for Climate and Energy – Europe (CoM EU) is the largest European initiative for local climate and energy action. Through the Covenant of Mayors for Climate and Energy (CoM) framework, cities voluntarily commit to tackling climate change, and thus pursuing and advancing the commitments of national governments at the local scale.

To ensure sound and effective climate action planning, implementation and monitoring, the CoM guidebook provides cities with relevant context, objectives, methodological principles, procedures, data sources and examples to develop a Sustainable Energy and Climate Action Plan (SECAP). This document is part of the CoM guidebook, and it provides detailed guidance on how to prepare greenhouse gas (GHG) emission inventories under the CoM framework, which are a key part of a SECAP.

The CoM GHG accounting framework draws on the main CoM principles of promoting the quality, consistency, transparency and comparability of data, while ensuring flexibility to meet local and regional circumstances and needs. In brief, GHG emission inventories within the CoM are prepared with activity data collected and processed covering a range of sectors, mainly on energy use, which is then combined with emission factors to estimate GHG emissions. GHG emission inventories are key for informing climate change mitigation action but also for monitoring and showcasing cities' progress and achievements. Transparent planning, monitoring and communication of results is key in multilevel governance and increases the understanding, credibility and uptake of climate change mitigation action across all key stakeholders, including the general public, national governments and industry and business communities, among others.

This document first describes the CoM general approach to preparing GHG inventories, including key concepts, scope and boundary selection, and methodological choices. Then, it details the main steps of preparing a GHG emission inventory under the CoM framework, and it provides technical guidance on activity data collection and treatment, including potential data sources and methodological alternatives, and on calculations used to estimate the associated GHG emissions.

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This document builds on the guidebook '*How to develop a Sustainable Energy and Climate Action Plan (SECAP)*' published in 2018, in particular on the work done on Part 2 by Andreea Iancu, Albana Kona, Suvi Monni, Marilena Muntean, Paolo Bertoldi, Oliver Lah and Silvia Rivas.

1 Introduction

The Covenant of Mayors for Climate and Energy – Europe (CoM EU) initiative brings together about 12 000 municipalities, fostering the design and implementation of effective climate policies and strategies at the urban level. Under the Covenant of Mayors for Climate and Energy (CoM) framework, signatories voluntarily commit to developing and implementing a Sustainable Energy and Climate Action Plan (SECAP), which includes the compilation of greenhouse gas (GHG) emission inventories. A CoM emission inventory quantifies the potential GHG emissions associated with a municipality. In brief, activity data (mostly on energy use) is collected and/or calculated for a set of key sectors, and emission factors (EFs) are then applied to estimate the GHG emissions associated with urban activities in each sector.

To support local and regional authorities in designing and implementing robust climate change mitigation action, this document provides guidelines, advice and recommendations for preparing a GHG emission inventory in the context of the CoM. It is part of the CoM guidebook collection, and it complements the main document: *How to prepare a Sustainable Energy and Climate Action Plan (SECAP)* (Davide et al., 2025). The guidance provided here applies both to the development of a baseline emission inventory (BEI), a key part of the SECAP, and to the successive monitoring emission inventories (MEI). In the CoM, the BEI is used as a starting point reference – that is, it sets out where the municipality is at the start, in its baseline year – and the subsequent MEIs show the progress achieved towards the target. This document also notes specific considerations for maintaining consistency between inventories across SECAP implementation.

Accounting for GHG emissions is of critical importance to support climate change mitigation action, and CoM inventories enable the municipality to plan, monitor and measure the impacts of its SECAP and to adapt or adjust the action plan over time. Moreover, GHG emission inventories are key to transparent processes and communication, potentially increasing the motivation of and uptake by all stakeholders and parties who can contribute to the municipality's climate and energy objectives.

Definitions, methodological guidelines and recommendations are specifically provided for the development of GHG emission inventories within the CoM EU context. They build on well-established standards and frameworks to ensure high levels of quality, relevance and comparability, while remaining flexible and adjustable to municipalities' needs and capacities. In particular, the CoM GHG accounting framework is aligned with the Global Covenant of Mayors (GCoM) common reporting framework.[1]

The CoM's main principles, key concepts and methodological options for preparing a GHG emission inventory are presented in Section 2, followed by the general methodology and calculation steps for estimating GHG emissions in Section 3. Section 4 provides recommendations and tips on data collection and potential data sources, and Section 5 provides information on EFs and associated calculations. Section 6 provides brief considerations regarding the documentation and reporting of GHG emissions within the CoM, and Section 7 presents the final considerations.

[1] https://www.globalcovenantofmayors.org/our-initiatives/data4cities/common-global-reporting-framework

Box 1. Main changes from the last CoM guidebook edition

In the previous edition of the CoM guidebook, guidance on GHG emission inventories was provided in Part 2A (Iancu et al., 2018). The present document builds on and updates that guidance. Particularly significant updates were introduced in relation to the following points:

— recommendations on the scope and boundaries of GHG inventories, namely: (i) the recommendation to account for and tackle emissions in all four key activity sectors, and in the waste and wastewater management sector and (ii) the recommendation to account for three reference GHGs – carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O);

— recommendations regarding the selection, calculation and use of GHG emission factors (EFs), in particular considering the evolution of the grid-supplied electricity mix and its associated GHG emissions;

— the inclusion and improvement of methodological guidance and data sources to account for GHG emissions associated with the waste and wastewater management sector;

— clarifications in the guidance on the introduction of sectors such as buildings and road transport into the revised EU Emissions Trading System Directive (ETS) (Directive (EU) 2023/959), known as the ETS2.

General guidance and materials were revised, involving clarifications, updates and minor changes across the document.

The CoM GHG accounting framework and the related SECAP guidance include requirements, recommendations and optional choices or alternatives:

— the term ‘shall’ is used to indicate what is required (indicated as ‘mandatory’);

— the term ‘should’ is used to indicate a recommendation (indicated as ‘recommended’);

— the term ‘may’ is used to indicate an option that is permissible or allowable and that municipalities may choose to follow (indicated as ‘optional’).

Providing the motivation and reasoning behind and supporting all choices and options (‘recommended’ and ‘optional’) is recommended, as it can improve the soundness and transparency of a SECAP.

2 The CoM greenhouse gas accounting framework

In the CoM, climate change mitigation actions to reduce final energy use in the local territory – and its associated GHG emissions – are prioritised. Climate change mitigation is intrinsically connected to the clean energy transition, where energy efficiency, electrification and local renewable energy sources are promoted to ensure more sustainable development. As such, the CoM framework puts the 'energy efficiency first' principle at the centre of climate change mitigation. This principle, established by the Energy Efficiency Directive (Directive (EU) 2023/1791), prioritises the reduction of energy demand. Energy efficiency should then be combined with electrification and the promotion of local renewable energy sources to effectively mitigate GHG emissions associated with energy use and ultimately enable the transition to clean and sustainable energy, as highlighted in the Renewable Energy Directive (Directive (EU) 2023/2413).

The CoM GHG emission reduction targets are aligned with the EU's established commitments and targets, namely the European Climate Law (Regulation (EU) 2021/1119), which aims for a 55% reduction in GHG emissions by 2030, a 90% reduction by 2040 and climate neutrality by 2050. To achieve these climate targets, EU cities need to be more ambitious in their climate change mitigation strategy. In the CoM, increased ambition is reflected in (i) higher GHG emission reduction targets and (ii) a more comprehensive scope of GHG mitigation actions. Regarding the scope of GHG mitigation action, the CoM framework has increased attention paid to, guidance on and support for tackling and accounting for GHG emissions in a more comprehensive manner, including, for example, non-energy-related GHG emissions, such as those from waste and wastewater treatment.

CoM inventories shall inform and support climate change mitigation action at the city level, enable progress monitoring and ease the communication and benchmarking of results and achievements. They provide detailed information on urban activities (e.g., on final energy use and waste generation) and the associated GHG emissions across all relevant sectors and sources for a reference year. This section provides key concepts, guiding principles and descriptions of the main components, elements and methodological issues associated with the preparation of a GHG emission inventory under the CoM framework.

2.1 Key concepts

In the CoM framework, the key concepts that are relevant to the compilation of GHG emission inventories include the following:

— **Emission inventory.** CoM emission inventories quantify annual GHG emissions associated with the local territory for a reference year by activity sector. Generally, GHG emission inventories are compiled by collecting activity data on each relevant activity sector (e.g., on final energy use by energy source/carrier) and multiplying the activity data point(s) by the corresponding GHG emission factors (EFs).

— **Local territory.** The local territory corresponds to the geographical jurisdiction or administrative territory of the municipality.

— **Macro-sectors.** CoM macro-sectors are the first-level categories that group activity sectors. Macro-sectors and activity sectors are used to structure CoM inventories.

- **Activity sectors.** Activity sectors are the second-level categories (inside macro-sectors) used to structure GHG emission inventories. They include key and optional sectors (see Section 2.3).
- **Key activity sectors.** Key activity sectors are particularly relevant sectors at the city level that shall be included in CoM emission inventories (see Sections 2.3 and 2.4).
- **Activity data.** Activity data essentially quantifies human activities occurring in the local territory in the reference year. Most activity data in the CoM key activity sectors (see Section 3) is related to *final energy consumption*, typically expressed in megawatt-hours (MWh). Non-energy-related activity sectors, such as waste and wastewater management, use mass or volume units (e.g., tonnes of solid waste and/or cubic metres of wastewater treated).
- **Energy source/carrier.** This refers to the form of energy input used in energy-related activities. Energy carriers typically used in cities include, for example, electricity, fossil fuels, biofuels and heat. In addition to these, renewable energy sources, such as solar and wind power, may be considered. The main energy sources/carriers in the CoM framework are described in Section 4 'Activity data collection'.
- **Final energy use.** Final energy use (or consumption) refers to the energy supplied for and used by the end user. In CoM inventories, it is disaggregated by activity sector and energy source/carrier.
- **Emission factor (EF).** EFs express GHG emissions per unit of activity, for example GHG emissions per megawatt-hour of energy used for a given energy source/carrier, or GHG emissions per tonne of solid waste treated (see Sections 3 and 5).
- **Baseline year.** The baseline year is the year against which the emission reduction target shall be compared (see Section 2.5).
- **Baseline emission inventory (BEI).** The BEI quantifies GHG emissions by activity sector in the baseline year. It should describe GHG emissions from all relevant anthropogenic sources, providing information on the sectors' relative contributions, to support the design and prioritisation of GHG mitigation actions.
- **Monitoring emission inventory (MEI).** During SECAP implementation (after the initial submission of the SECAP, which includes a BEI), MEIs shall be compiled regularly to monitor progress towards GHG reduction targets. MEIs shall be consistent and follow the same methods and principles as the BEI (see Section 2.5).

2.2 Guiding principles

The SECAP[2] should be prepared based on a sound knowledge of the local context, in particular in relation to energy use and the associated GHG emissions. In the CoM, GHG emission inventories:

— focus on activity sectors under the direct influence of the local administration;

— cover the geographical jurisdiction of the local administration;

— structure GHG emissions by sector and source;

— build on the bottom-up collection and processing of data.

In this way, CoM inventories can inform the design, development and implementation of GHG mitigation actions, and they enable the monitoring and reporting of progress toward the GHG emission reduction target.

The CoM GHG accounting framework is guided by the following principles:

— **Ambition.** Activity and GHG accounting data should support ambitious climate change mitigation action, while considering the local context and needs, encouraging municipalities to pursue comprehensive and integrated strategies.

— **Relevance.** Activity and GHG accounting data should be relevant to the specific context and situation of the municipality, so that GHG inventories effectively support local climate action. Municipalities are encouraged to use context-specific data over national or European estimates – whenever relevant and available – as these may better reflect the status quo and the local actions pursued to reach GHG emission reduction targets.

— **Flexibility.** The CoM framework aims for the simplicity of use and application, while remaining flexible to suit various regional and local situations and to accommodate the needs and resources of different municipalities, reflecting their specific characteristics and taking into account their policymaking priorities, capacity and regulatory context.

— **Completeness.** CoM inventories are not meant to be exhaustive or comprehensive, but they should cover all relevant activity sectors[3] and associated GHG emissions to provide relevant data and insights, and adequately support the SECAP's strategy. Complete and meaningful GHG emission inventories are key for supporting the design, implementation and monitoring of ambitious climate change mitigation actions and for monitoring progress.

— **Accuracy.** GHG emission inventories should be as accurate as possible and represent a reasonable estimate of the real energy use, activities and GHG emissions. This requires, in particular, using reliable local activity data and robust methodologies, based on well-established standards, methods and data.

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[2] See the CoM guidebook main document, '*How to develop a Sustainable Energy and Climate Action Plan (SECAP)*' (Davide et al., 2025).

[3] 'Relevant activity sectors' in the context of GHG mitigation in the CoM framework refers to sectors including activities (i) that have significant relative contributions to the GHG emissions associated with the local territory and/or (ii) whose GHG emissions can be reduced or affected by the SECAP.

— **Consistency.** CoM inventories should be complementary to and consistent with national GHG accounting systems, tools and methodologies. Moreover, the scope, methodology and data should be in line with CoM specifications and consistent over time. Consistency in methodological aspects, choices and assumptions across inventories is particularly important.

— **Transparency.** The data collection process, data sources and methodology for calculating CoM inventories should be transparent and well documented in the SECAP. The methodology, data, assumptions and choices behind the main results of the GHG emission inventories reported should be described in detail in the SECAP documentation.

— **Availability.** Municipalities should be able to regularly compile consistent GHG emission inventories until the target year. Thus, the data sources selected should be available in the future. It is important to identify from the beginning all data sources, including departments and external stakeholders that will be able to provide data over time.

These principles build on the Global Covenant of Mayors (GCoM) common reporting framework principles. [4]

Box 2. Increasing GHG mitigation ambition in the CoM

This document updates and improves on the previous guidance on GHG accounting under the CoM framework. While it provides specific recommendations to improve GHG accounting, going beyond common or basic practices – such as accounting for GHG emissions associated with waste and wastewater management or the use of life-cycle (LC)-based emission factors (EFs) that include energy supply chain emissions – it remains primarily focused on current typical practices. Nonetheless, increased ambition is strongly supported and encouraged.

Increased ambition in GHG mitigation under the CoM can be achieved through one or the combination of:

— more ambitious reduction targets (larger energy savings and GHG emission reductions);

— a more recent baseline year;

— more comprehensive coverage and scope of GHG accounting (e.g., including more activity sectors and emission sources, accounting for indirect emissions).

[4] https://www.globalcovenantofmayors.org/our-initiatives/data4cities/common-global-reporting-framework/

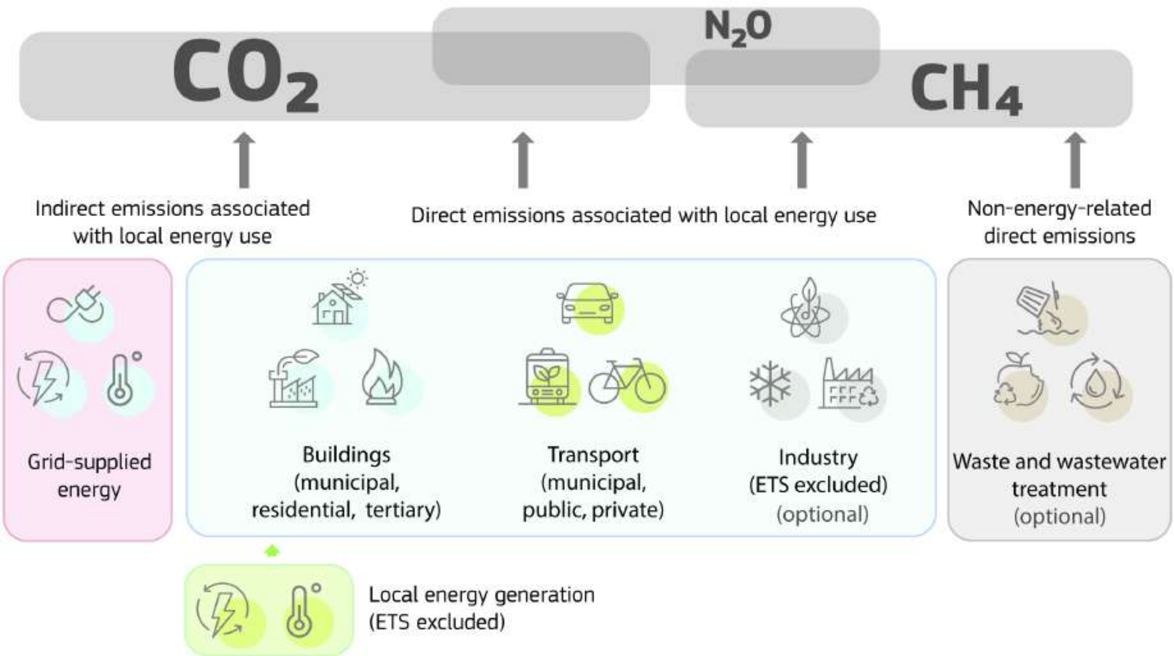
2.3 Scope, boundaries and activity sectors

In the CoM, municipalities shall tackle citywide GHG emissions. The CoM GHG accounting framework builds on the Intergovernmental Panel on Climate Change (IPCC) guidelines to establish specific guidance for cities. The scope, boundaries and methodology of the CoM framework follow the principles of the IPCC used in the reporting of the national-level GHG emission inventories to the United Nations Framework Convention on Climate Change (UNFCCC). For example, municipal buildings, facilities and equipment are considered together in CoM inventories as an activity sector, for which energy use and GHG emissions should be provided separately to promote transparency and the exemplary role of the local administration.

Figure 1 provides an overview of the scope and boundaries of GHG emission inventories under the CoM framework. The framework follows a territorial-based approach in GHG accounting – that is, the scope and boundaries of the inventories (i.e., the GHG emissions that are accounted for) depend on the geographical place where activities, energy use and emissions occur. GHG emissions in CoM inventories are related to activities taking place in the 'local territory'. The emissions may occur within the municipality (local territory) or, in some cases, they may occur elsewhere.

The geographical boundaries of the local territory are generally the administrative boundaries of the entity (e.g., municipality, region) governed by the local administration. These often correspond to the local administrative units (LAU) of the Nomenclature of Units for Territorial Statistics (NUTS),[5] which may ease data collection, harmonisation and processing.

Figure 1. GHG inventories' scope and boundaries overview



Source: Joint Research Centre (JRC) analysis.

5 http://ec.europa.eu/eurostat/web/nuts/

In brief, GHG emissions in CoM inventories include the following:

- **Direct emissions associated with local use of energy.** Direct emissions occur in the place and at the time of the activity. The local use of energy (from renewable and non-renewable energy sources/carriers) and its direct GHG emissions should be included in CoM inventories, under the relevant activity sectors.
- **Indirect emissions associated with local use of grid-supplied energy (electricity, heat and cold).** Indirect emissions occur in a different place and/or at a different time from the activity. Emissions from the generation and supply of energy (grid-supplied energy including electricity, heat and cold) that is used in the local territory may occur in the territory or beyond its geographical boundaries. The local use of grid-supplied energy and the GHG emissions associated with its generation should be included in CoM inventories, under the relevant activity sectors.
- **Non-energy-related direct emissions.** GHG emissions associated with waste and wastewater treatment should also be included in CoM inventories. Other non-energy-related activity sectors and sources should be included if the SECAP includes actions to reduce their associated GHG emissions; otherwise, those may be excluded from CoM inventories.

In GHG accounting, direct emissions (associated with energy use and non-energy-related activities) occurring in the local territory are typically referred to as ‘scope 1’ emissions, whereas indirect emissions related to grid-supplied energy generation and supply, which typically occur outside the local territory, are referred to as ‘scope 2’ emissions. Other GHG emissions associated with activities taking place in the local territory but occurring elsewhere (e.g., upstream supply chain emissions associated with final product consumption) are referred to as ‘scope 3’.

A more ambitious approach can be adopted in the CoM framework to pursue comprehensive climate change mitigation actions and inventories by including other relevant GHG emissions associated with urban activities, such as upstream and downstream emissions. In particular, the CoM GHG accounting framework includes a life-cycle (LC)-based approach, in which GHG emissions associated with the supply chain of energy sources/carriers are included (see Section 5).

CoM inventories are structured, at the first level, by macro-sectors and, at the second level, by activity sectors, as summarised in Table 1. SECAPs and their GHG emission inventories should cover at least the four CoM key activity sectors, which are:

- Municipal buildings, equipment and facilities;
- Tertiary (non-municipal) buildings, equipment and facilities;
- Residential buildings;
- Transport.[6]

[6] Transport is both a macro-sector and a key activity sector, while the other key activity sectors fall under the buildings macro-sector.

These activity sectors focus on energy-related activities and GHG emissions. As mentioned, it is also recommended to include waste and wastewater management and any other activity sectors that the municipality may address through climate change mitigation actions, so that the results of those actions can be adequately evaluated and monitored. CoM inventories typically exclude the 'Agriculture, forestry and other land use' (AFOLU) sector, for example, which is often of low relevance in an urban context. Nonetheless, any sectors and activities may be included if they are significant and/or if the municipality envisages climate change mitigation actions addressing them.

More detailed descriptions of and guidance on the CoM activity sectors, activities and emission sources that should be considered in CoM inventories are provided in Section 3.

Table 1. Summary of the macro-sectors and activity sectors structuring CoM inventories

CoM macro-sectors	**CoM activity sectors**
Buildings, equipment, facilities and industries (also referred to as the 'buildings macro-sector')	Municipal buildings, equipment and facilities (*)
	Tertiary (non-municipal) buildings, equipment and facilities (*)
	Residential buildings (*)
	Industry
	Agriculture, forestry and fisheries
	Other (including fugitive emissions)
Transport	Transport (*)
Other non-energy-related sectors	Waste and wastewater management

(*) CoM key activity sector.

Source: JRC analysis.

Box 3. The path to climate neutrality

The European Green Deal set the goal of achieving climate neutrality by 2050. The definition of climate neutrality - and the associated net-zero GHG emission balance - draws on the underlying principle that a maximum reduction of GHG emissions should be pursued. Any remaining emissions that cannot be mitigated, namely residual emissions, should be balanced with carbon sequestration and compensation.

In alignment with the EU commitments and goals, the CoM has set the goal of achieving net-zero GHG emissions by 2050. In the near future, specific guidance on a climate neutrality definition and associated GHG accounting recommendations should be developed, including criteria for and guidelines on addressing residual emissions.

With that perspective in mind, it is also essential to increase the scope, coverage and completeness of CoM inventories (i.e., not excluding any relevant sectors, activities or emission sources). While emissions associated with the 'Agriculture, forestry and other land use' (AFOLU) and 'Industrial Processes and Products Use' (IPPU) sectors are seldom included in CoM inventories, these are included in other sound GHG accounting frameworks. Cities therefore have the option to consider them in CoM inventories, including their GHG emissions and their potential removals (e.g., carbon sinks).

2.4 Main methodological choices

Drawing on the key principle of flexibility, the CoM encourages municipalities to develop a SECAP, including a climate change mitigation strategy, '*in a way that suits their own circumstances, permitting those already engaged in energy and climate action to come on board of the Covenant of Mayors, while continuing to follow the approaches they have used before with as little adjustments as possible*' (Bertoldi et al., 2010). With this in mind and to improve the comparability, consistency and aggregation of GHG emission inventories, the CoM has developed methodological guidelines on GHG accounting that build on existing standards and well-established frameworks. The guidelines include several alternative options that municipalities may consider based on their specific context, needs and preferences.

The main methodological choices described in this section are related to (i) the emission accounting approach (which includes the selection of GHGs and the relevant EFs), (ii) the baseline year, (iii) the emission reduction target and (iv) the sectors and activities that should be included in CoM inventories. It is worth highlighting that some of these choices are interdependent.

2.4.1 Emission accounting approach

In CoM inventories, GHG emissions are calculated by multiplying activity data points by GHG EFs. In energy-related sectors, the final energy use for each energy source/carrier (see Section 4) is multiplied by the corresponding GHG EF (see Section 5). Two approaches can be adopted under the CoM framework to calculate GHG emissions: the activity-based approach and the life-cycle (LC-) based approach.

— The **activity-based approach** focuses on GHG emissions that occur during energy conversion (e.g., emissions from local fuel use in an internal combustion vehicle or emissions occurring in electricity generation). These GHG emissions may be directly estimated based on the carbon content of the fuel. This is the approach used for national reporting in the context of the UNFCCC, and it is generally aligned or compatible with EU legislation on climate and energy.

— The **LC-based approach** expands the scope of GHG emission accounting towards a life-cycle perspective. In the CoM, this approach adds GHG emissions associated with the energy supply chain to those emissions accounted for in the activity-based approach. These can be particularly significant for renewable energy sources and carriers, such as photovoltaic electricity generation (see Section 5).

In both approaches, GHG emissions due to energy use within the municipality, either direct (e.g., fuel combustion) or indirect (e.g., use of grid-supplied electricity and heat/cold), are included. The decision to adopt either the activity-based approach or the LC-based approach draws on a balance between the (i) increased comprehensiveness and completeness of data and (ii) availability of representative data.

The activity-based approach includes emissions occurring during fuel combustion, and it is based on the use of default IPCC EFs that are readily available and commonly used. The LC-based approach includes both emissions from fuel combustion and those occurring in the supply chain (e.g., including the extraction of raw materials and production and transport processes), which can be particularly difficult to ascertain and are subject to higher uncertainties (Cerutti et al., 2013).

The CoM data collection[7] provides data (EFs) for calculating activity- and LC-based GHG emissions representative of the EU context, which are readily available and regularly updated. However, it is important to carefully consider whether these EFs are representative of the local context.

2.4.1.1 Greenhouse gases to be included

Three reference, long-lived GHGs should be considered in CoM inventories: CO_2, CH_4 and N_2O. For aggregation, emissions of the three GHGs are converted into carbon dioxide equivalent (CO_2-eq) using their corresponding global warming potential (GWP) values (see also Section 5) and summed in CoM inventories as tonnes of CO_2 equivalent (t CO_2-eq).

Drawing on the principles of ambition, relevance and completeness, it is recommended that all three GHGs be included. Nonetheless, most GHG emissions associated with energy-related activities are CO_2 emissions and, within the activity-based approach, the municipality may decide to include only CO_2 in the emission inventory. However, if the municipality includes waste and/or wastewater treatment in the inventory, CH_4 and N_2O emissions shall be included.

While CH_4 and N_2O typically account for lower relative emissions, in particular from combustion processes in the residential and transport sectors, these GHGs often have relevant contributions in terms of shares of waste and wastewater treatment emissions (see Section 5.4).

2.4.1.2 Emission factors (EF)

In relation to EFs, signatories can use either context-specific data or default EFs, such as those provided by the IPCC (2006) or by the JRC in the CoM data collection. The CoM data collection provides EFs, calculated for the activity-based approach (for CO_2 only and for the three reference GHGs) and for the LC-based approach. CoM EFs are readily available for municipalities to use, cover the most commonly used energy sources/carriers and are regularly updated.

GHG EFs should be relevant to the specific context of the municipality (see Section 2.2 'Guiding principles'). If signatories prefer to use context-specific EFs from national, regional or local sources or to develop their own EFs based on detailed context-specific data on their activities, energy use or supply chains, for example, they are welcome to do so, as long as such EFs are reliable and transparently documented. It is always recommended that EFs follow consistent guidelines for accounting GHG emissions, in particular the IPCC guidelines for accounting GHG emissions associated with energy and waste (IPCC, 2006, Volumes 2 and 5).

When adopting a LC-based approach, it is recommended that municipalities consider the applicability of the CoM default EFs provided by the JRC before using them and obtain case-specific data where appropriate. It is worth noting that obtaining information on the emissions upstream in the energy supply chain may appear challenging and that significant differences may occur even for the same type of fuel.

[7] CoM data collection: https://data.jrc.ec.europa.eu/collection/id-00172

New knowledge and technologies can lead to significant changes in the EFs. Depending on the motivations behind these changes, different EFs may be applied across inventories (e.g., between the BEI and a MEI) or the same EFs may be applied (potentially requiring the recalculation of previous inventories, if there is a change in the EF).

- Changes associated with new knowledge or data that may result in updated EFs and calculations but are not associated with a 'real life' change in GHG emissions over time should be applied to all inventories. For example, if new EFs are selected for a MEI with updated GWPs, the same should also be applied in previous inventories (including the BEI) to ensure consistency.
- EF updates that result from actual GHG emission changes, such as a reduction of GHG emissions associated with grid-supplied electricity due to the evolution of the electricity generation mix, may be applied across inventories (e.g., the BEI and MEI may use different EFs for grid-supplied electricity). This also applies to changes in the fuel used (e.g., a change in fuel properties or use of another fuel within the same category); in these cases, EFs can vary between inventories.

2.4.2 Baseline and reference years

The baseline year is the reference year against which the GHG emission reduction will be compared. A baseline emission inventory (BEI) shall be included in the SECAP, detailing activity data and GHG emissions by sector and energy source/carrier for the baseline year.

Signatories shall choose a baseline year from 1990 onwards for which comprehensive, reliable and meaningful inventory data can be obtained. The year of 1990 is often adopted as the baseline in UNFCCC and EU contexts. It is currently used for the EU's 2030 and 2050 emission reduction targets established by the European Climate Law (Regulation (EU) 2021/1119), in line with the European Green Deal climate neutrality goal.

Other common choices among CoM EU signatories for the baseline year are 2005 and 2010 (Rivas et al., 2018; Kona et al., 2017). The year of 2005 is also used as the baseline reference in the 2030 national targets that apply to domestic transport, buildings, agriculture, small industry and waste, set by the Effort Sharing Regulation (Regulation (EU) 2023/857).

Municipalities that submitted SECAPs in the past, for example with a commitment for 2020, may continue using the same baseline year for subsequent targets, such as 2030 and 2050, renewing their commitments as a continuation of their efforts.

If the BEI is more than 4 years old at the time of SECAP submission and implementation, an inventory for a more recent reference year should be included in the SECAP to account for changes in GHG emissions since the baseline year. This is important for providing an accurate picture of the GHG emission levels at the moment of implementation of SECAP mitigation actions.

Any inventories after the BEI are generally referred to as monitoring emission inventories (MEIs) in the CoM. In this case, the GHG emission reduction achieved by the SECAP actions should be compared with a recent emission inventory (also referred to as a MEI) as a reference, as described in the illustrative examples below.

Illustrative example

Baseline year as a reference for GHG emission reduction

Consider a city with:

— GHG emissions in the baseline year (e.g., 2005): 100 000 t CO_2-eq

— GHG emissions in 2030: 40 000 t CO_2-eq

It would have a GHG emission reduction in 2030 of 60%:

$$100\,000 \text{ t } CO_2\text{-eq} - 40\,000 \text{ t } CO_2\text{-eq} = 60\,000 \text{ t } CO_2\text{-eq}$$

Illustrative example

Baseline year and subsequent reference year for GHG emission reduction

Consider a city implementing the SECAP from 2022, with 2005 as baseline year, with:

— GHG emissions in the baseline year (e.g., 2005): 100 000 t CO_2-eq

— GHG emissions in the reference year (e.g., 2020): 60 000 t CO_2-eq

— GHG emissions in 2030: 40 000 t CO_2-eq

It would have a GHG emission reduction in 2030 of 60%:

$$100\,000 \text{ t } CO_2\text{-eq} - 40\,000 \text{ t } CO_2\text{-eq} = 60\,000 \text{ t } CO_2\text{-eq}$$

Of that:

— 40 000 t CO_2-eq would be achieved before the SECAP, by the reference year (e.g., 2020);

— 20 000 t CO_2-eq would be achieved during SECAP implementation, until 2030.

2.4.3 Emission reduction target

The emission reduction target is the overall GHG emission reduction (as a percentage) that the municipality commits to achieve in annual GHG emissions by the target year (e.g., 2030, 2050). The reduction target is always calculated in relation to the baseline year. In line with the EU targets, the GHG emission reduction target currently proposed by the CoM is at least a 55% reduction by 2030, in comparison with 1990 levels (Davide et al., 2025). A larger percentage reduction or the selection of a more recent year as a baseline may reflect higher ambition, which is encouraged.

The long-term EU target is to become climate neutral by 2050. In this context, CoM municipalities shall achieve net-zero GHG emissions by cutting GHG emissions to the maximum extent possible. GHG emissions that are unavoidable due to technological, financial or other limitations, referred to as 'residual emissions', shall be balanced, for example through carbon removal or sequestration.

A reduction target can be established on an 'absolute' or 'per capita' basis. Generally, absolute reduction targets are adequate if no significant changes in population are observed or expected between the baseline and target years. However, if significant changes in population are observed in this period, an absolute reduction target is likely to be inadequate:

- in the event of a large population increase, the reduction target might be unrealistic (i.e., not achievable or underestimating the effort needed in the SECAP);
- in the event of a sharp population decrease, the reduction target might not adequately reflect the municipality's efforts and achievements (i.e., with GHG emissions decreasing mostly as a result of the population decrease).

If reliable population data or projections are available and show a significant change in population, the CoM framework recommends the use of a 'per capita' target. If no significant population changes are expected between the baseline and target years in the local territory, the absolute reduction target approach should be used, to avoid adding a source of uncertainty (e.g., on the future population trend). The illustrative example below provides reduction targets calculated on an 'absolute' basis and a 'per capita' basis, in instances where there is no population change, or there is a significant population increase or decrease.

Regardless of the type of reduction target, GHG emissions in CoM inventories and estimated GHG emission reductions associated with SECAP actions are always expressed as absolute annual GHG emissions. Particular attention should be paid when calculating the absolute GHG emission reduction needed in order to account for the changes in emissions that would take place due to the change in population, as illustrated in the example below.

Illustrative example

Comparison of 'absolute' and 'per capita' emission targets

The following is an example of a city of 50 000 inhabitants emitting 500 000 t CO_2-eq in the baseline year, considering the following scenarios:

(a) no population change;

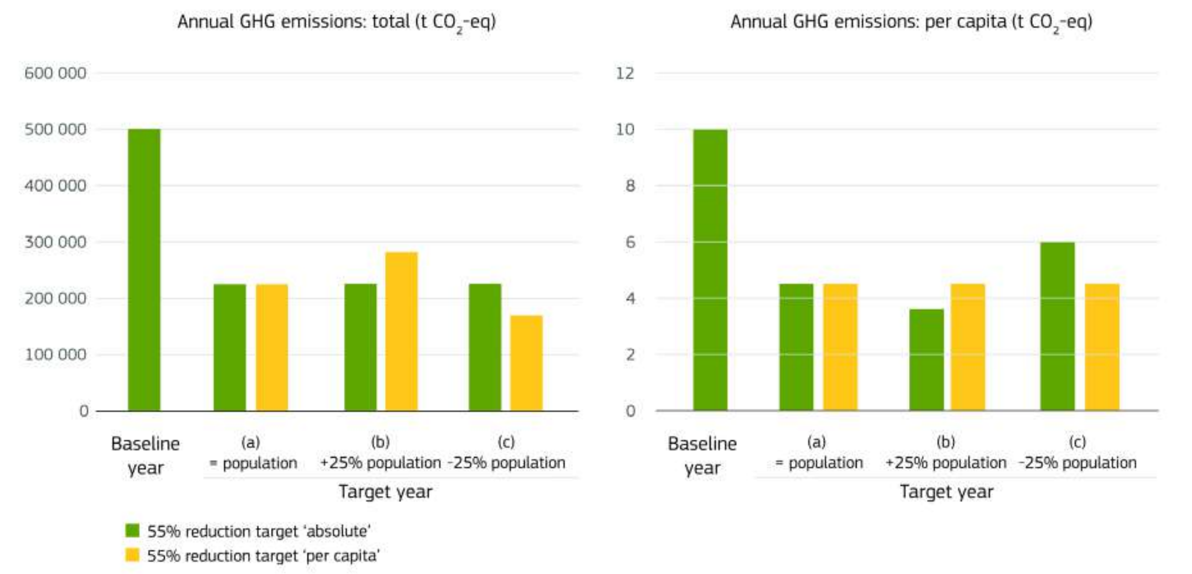
(b) a 25% increase in population to 62 500 by the target year;

(c) a 25% decrease in population to 37 500 by the target year.

Annual GHG emissions for the baseline year and for the target year considering a 55% emission target were calculated on 'absolute' (total emissions) and 'per capita' terms. Calculations where the 55% reduction was applied to calculate annual GHG emissions are indicated with the linking yellow arrow.

	Baseline year	Target year					
		(a) = population		(b) +25% population		(c) -25% population	
Reduction target		**absolute**	**per capita**	**absolute**	**per capita**	**absolute**	**per capita**
Population	50 000	50 000		62 500		37 500	
Annual GHG emissions total	500 000 -55%	225 000	225 000	225 000	281 250	225 000	168 750
Annual GHG emissions per capita	10 -55%	4.5	4.5	3.6	4.5	6	4.5

Annual emissions are shown for the baseline year (the left-most bar) and for the target year considering a stable, increasing and decreasing population. The 55% reduction target is given in 'absolute' terms in green and 'per capita' in yellow.



2.4.4 Activity sectors and activities to be included

CoM inventories include activity data and GHG emissions by activity sector for a reference year. This section introduces the structure and disaggregation of activity sectors and emission sources in CoM inventories, and it describes the typical activities and GHG emissions that should or may be included. CoM inventories cover commonly used energy sources/carriers in these activity sectors and activities across the EU, including electricity, district heating and cooling and a wide range of fossil fuels and renewable energy sources.

As mentioned, CoM inventories are structured into three macro-sectors, which are disaggregated into activity sectors based on the nature and jurisdiction of the different activities and main actors (municipal/public and private). Local energy generation and supply is also considered and described here; however, it is included in CoM inventories through local energy emission factors (LEEFs) for energy production (see Section 3.3). Further clarification regarding the inclusion or exclusion of sectors, activities and GHG emission sources covered by the EU emissions trading system (ETS) is provided in Box 4.

Table 2. Summary of recommendations on activity sectors and sources and related guidance sections

<table>
<tr><th>Macro-sector</th><th>Recommendation</th><th>Activity sectors and sources</th><th>Section</th></tr>
<tr><td rowspan="3">Buildings, equipment, facilities and industries</td><td>Shall be accounted for and shall include</td><td>• Residential
• Commercial
• Municipal/institutional buildings, equipment and facilities</td><td rowspan="3">3.1</td></tr>
<tr><td>May also include</td><td>• Manufacturing and construction industries</td></tr>
<tr><td>Should not include</td><td>• Industries covered by ‘cap and trade’ schemes</td></tr>
<tr><td>Transport</td><td>Shall be accounted for and shall include</td><td>• Municipal fleet
• Public transport
• Private and commercial transport
• Other (if relevant)</td><td>3.2</td></tr>
<tr><td rowspan="2">Other non-energy-related sectors</td><td>Should be accounted for and should include</td><td>• Waste treatment
• Wastewater treatment</td><td rowspan="2">3.4</td></tr>
<tr><td>May also include</td><td>• Other non-energy-related activities (e.g., AFOLU, IPPU), if relevant</td></tr>
<tr><td>Local energy generation and supply (*)</td><td>Should be considered through LEEFs and may include</td><td>• Electricity-only units
• Combined heat and power units
• Heat/cold production plants</td><td>3.3</td></tr>
</table>

(*) ‘Local energy generation and supply’ is not a macro-sector, but it is detailed in CoM inventories in a corresponding section.

NB: AFOLU, Agriculture, forestry and other land use; IPPU, Industrial processes and products use; LEEF, Local energy emission factor.

Source: JRC analysis.

Box 4. How to address sectors and emission sources covered by the EU ETS Directive

The EU emissions trading system (EU ETS), launched in 2005, regulates emissions from sectors and entities with particularly significant GHG emissions in the EU and associated countries based on a 'cap and trade' principle. Under the EU ETS, companies shall monitor and report their GHG emissions and the overall yearly emissions of covered sectors shall stay under a defined cap. [8] CoM inventories may include or exclude activity sectors, activities and GHG emissions that are currently covered by the EU ETS Directive (Directive 2003/87/EC):

— GHG emissions associated with local energy generation and supply shall be accounted for (indirectly) through local energy emission factors (LEEFs), excluding energy generation plants in the local territory covered by the EU ETS Directive (unless the SECAP includes actions affecting them);

— GHG emissions associated with the generation of energy outside the local territory for final consumption in the municipality (e.g., national grid electricity) typically include energy generation emissions covered by the EU ETS Directive, and these are included in CoM inventories;

— any other industry-related GHG emissions covered by the EU ETS Directive should be excluded (unless the SECAP includes actions affecting them);

— other sectors and activities included in and/or recently added to the revision of the directive, in particular those introduced by the ETS2 in 2023 (e.g., transport, buildings and municipal waste incineration) will continue to be included in CoM inventories.

While the EU ETS has focused on energy generation, large industry and aviation – which are emission sources with potentially limited significance in an urban context and which local administrations are likely to have limited power to influence - the ETS2 covers key emission sources in urban areas, namely building heating, road transport and small industry. These sources account for a large share of GHG emissions in EU cities, and they are among the main targets of local climate action.

All sources of GHG emissions covered by the EU ETS in the local territory should be identified in the SECAP, even if they are excluded from CoM inventories.

Sectors and activities to be excluded

The CoM focuses primarily on sectors and activities that can be influenced by the municipality. As such, activities and sectors other than the ones described, on which the municipality does not have influence, may be excluded. In addition, some specific sectors and activities in the local territory should be excluded from CoM inventories to ensure the overall consistency of the GHG accounting framework and to avoid double counting. These sectors and activities include:

— industrial activities covered by 'cap and trade' schemes (e.g., the EU ETS);

— carbon capture and storage (CCS) technologies;

— nuclear energy generation;

— GHG emission credits purchased or sold on the carbon market.

8 https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets/

2.5 Monitoring progress

This section provides insights on specific aspects related to monitoring emission inventories (MEIs) such as the recommended frequency, the importance of ensuring consistency through time and cases when recalculations are necessary.

In order to monitor energy use and GHG emission data effectively, signatories are encouraged to compile MEIs on a yearly basis. The advantages of regular and consistent progress monitoring are:

- a detailed continuous understanding of the various factors that influence the GHG emissions in the territory;
- an annual input to decision-making, allowing prompt reaction and, if needed, the prompt adjustment of the SECAP;
- transparent communication, promoting credibility, increased engagement and uptake;
- further development and consolidation of local expertise, knowledge and tools for accounting for and tackling GHG emissions.

In the event of limited resources, signatories may compile MEIs at 2- or 4-year intervals, for example, but regular monitoring is strongly recommended. A last MEI for the target year is particularly important to transparently communicate the SECAP's results and achievements.

2.5.1 Consistency over time

Consistency over time is essential to adequately monitor progress and evaluate the results and achievements within the CoM framework. Differences between BEI and MEIs should adequately describe and reflect changes in GHG emissions over time. As such, CoM inventories shall follow the same structure, scope and boundaries and use consistent data – that is, the inventory approach (activity- or LC-based), scope, sectors and activities should be the same across GHG inventories.

When municipalities that have already submitted a SECAP submit a new SECAP, new commitments, targets and achievements should build on the previous SECAP and results. GHG inventories should, in principle, also be consistent over time and between SECAPs, and the same baseline year should be used. In exceptional cases of significant changes, for example in methodological choices or in the scope of SECAP actions to reflect higher ambition, these may be changed.

2.5.1.1 Recalculations

In general, there is no need to change an emission inventory compiled and/or reported in the past. However, there can be occasions where a recalculation of a previous inventory is necessary to be consistent over time and to adequately monitor and evaluate progress. For example, the recalculation of a submitted BEI or MEI may be needed when one or several of the following occur/arise during the SECAP's implementation:

- an industry relocation;

— the availability of new information on activity data, emissions and/or emission factors (EFs);[9]

— the addition or removal of sectors or activities, in accordance with changes in GHG mitigation actions;

— changes in territorial boundaries.

When recalculations are applicable, signatories shall recalculate all inventories (the initial BEI and all MEIs) accordingly to ensure consistency. In exceptional cases of the loss of, incomplete or inadequate information supporting previous inventories, which prevents municipalities from ensuring consistency across inventories, the replacement of previous inventories may also be needed. Some illustrative examples of recalculations are provided in Annex 1.

If changes in emissions, information or approach lead to significant changes in GHG inventories, actions and/or relative reduction targets (e.g., a shift in priority of the goals and/or in the activity sectors to be tackled), then the SECAP should be updated.

2.6 Summary of methodological options for GHG accounting

The main options, specifications and recommendations for building a GHG emission inventory, under the CoM framework, are summarised in Table 3. When defining the approach and different options, it is important to ensure relevance and consistency.

There are other reference frameworks available for practitioners preparing local GHG emission inventories, including, for example, the *Global Protocol for Community-scale Greenhouse Gas Inventories*.[10] Several internationally and nationally developed tools[11] are also available for reference, which can ease the preparation of GHG emission inventories. Municipalities may choose to use any such reliable tool or method available, provided it is in line with the CoM principles, guidelines and reporting requirements.[12]

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9 If real changes in the local EFs have occurred between the baseline year and a subsequent year – for instance, due to changes in fuel properties – then different EFs should be applied across inventories to adequately reflect the changed circumstances, and recalculation is not needed.

10 https://ghgprotocol.org/ghg-protocol-cities

11 https://www.globalcovenantofmayors.org/resource-library-search/#tools
https://dataportalforcities.org/

12 https://eu-mayors.ec.europa.eu/en/resources/reporting

Table 3. Main methodological options and recommendations of the CoM GHG accounting framework

Key elements		M	R	O/A	General comment	Specific recommendations and comments
GHG included	CO_2	-	-	(X)	CO_2 emissions are calculated in tonnes of CO_2.	Optional, if sectors and activities with other significant GHG emissions (e.g., waste treatment) are not included in the inventory. JRC EFs for CO_2 (only) are available for the activity-based approach.
	CO_2, CH_4, N_2O	-	X	-	GHG emissions are calculated in tonnes of CO_2-eq.	Recommended, particularly important if non-energy-related activity sectors (e.g., waste and wastewater treatment) are included in the inventory. Updated IPCC global warming potential (GWP) data shall be used to aggregate emissions of CO_2, CH_4 and N_2O into CO_2-eq. GWPs shall be the same across inventories (BEI and MEIs) – if needed, previous inventories should be recalculated. JRC EFs for CO_2, CH_4 and N_2O are available for activity- and LC-based approaches.
	CO_2, CH_4, N_2O, F-gases	-	-	(X)	GHG emissions are calculated in tonnes of CO_2-eq.	If data is available, municipalities may also account for emissions for six reference GHGs: CO_2, CH_4, N_2O, fluorinated gases (F-gases, including hydrofluorocarbons and perfluorocarbons), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3).
Inventory approach	Activity-based approach	-	X	-	GHG emissions from energy conversion.	Recommended. An activity-based approach accounts for relevant direct GHG emissions associated with energy conversion processes (e.g., GHG emissions from fuel combustion in vehicles and emissions from electricity and heat generation).
	LC-based approach	-	(X)	-	GHG emissions from energy conversion plus out-of-boundary emissions (e.g., upstream supply chain emissions).	Recommended, if available data is representative of the local context. Life-cycle data provides more comprehensive GHG accounting, including out-of-boundary emissions associated with, for example, the supply chain of energy sources/carriers. However, it can add uncertainty to inventories. It is thus important to ensure data is representative of the local context.
Emission factors (EF)	Country- or city-specific EFs	-	(X)	-	Municipalities are encouraged to use EFs that are representative of the local context.	Recommended, provided that specific representative data is available and reliable (e.g., from a reference organisation) and that regular updates are expected during the implementation period.
	CoM EFs [1]	-	(X)	-	Provided by the JRC for both activity- and LC-based approaches, for energy sources/carriers commonly used in the EU.	These are recommended if city-, regional- or country-specific EFs that may better represent the local context are not available. CoM activity-based EFs are IPCC-based and account for GHG emissions associated with energy conversion. They are primarily representative of stationary sources; they may be increased by up to 3% for fuel combustion in transport.

Table 3 (continuation)

Key elements		**M**	**R**	**O/A**	**General comment**	**Specific recommendations and comments**
Reduction target	Baseline year	min. 1990	-	-	A reference year for which reliable and complete data is available should be selected, no earlier than 1990.	The mandatory baseline year is 1990 or later. EU targets have been established in relation to 1990 levels. The EU Effort Sharing Regulation reference year is 2005, which is also commonly used as baseline year in the CoM. If the baseline year is more than four years before the year of SECAP preparation and submission, a more up-to-date inventory should be prepared and considered (as a MEI).
	Absolute target	-	X	-	Target is at least 55% by 2030.	This is recommended, except if a significant change in population is expected and reliable population projection data is available.
	Per capita target	-	(X)	-	Target is at least 55% by 2030.	This is recommended if a significant change in population is expected, based on reliable population projection data. If a per capita reduction target is set, GHG emissions and planned reductions (in tonnes of CO_2-eq) shall be provided in absolute values in CoM inventories (not per capita).
Emissions scope	Direct emissions from final energy use	X	-	-	Direct, energy-related emissions shall be included.	Relevant direct GHG emissions associated with the activity sectors included in the inventory shall be accounted for. It is important to avoid double counting of energy-related emissions.
	Indirect emissions from grid-supplied energy use	X	(X)	-	Indirect emissions from local use of grid-supplied energy shall be included.	In the case of energy generation at the national or regional level, where the municipality has no influence, emissions are typically calculated using default EFs (e.g., national EFs for electricity). If energy used in the territory includes local energy generation sources, a local energy emission factor (LEEF) shall be calculated, to account for local energy generation and supply (including local/distributed electricity, heat and cold generation sources), also referred to as local production of energy.
	Non-energy-related emissions	-	X	-	Direct emissions from waste and wastewater treatment should be included.	Direct GHG emissions from the treatment of waste and wastewater generated in the municipality should be accounted for in this sector, regardless of where emissions occur, except if the treatment is associated with energy recovery. Other non-energy-related activities may be included in CoM inventories, if relevant.

([1]) Available from the CoM data collection (https://data.jrc.ec.europa.eu/collection/id-00172).

NB: 'M', 'R', 'O/A' columns refer to 'Mandatory', 'Recommended', 'Optional/Alternative' requirements, respectively. X indicates an unconditional option or recommendation, while (X) indicates a conditional option or recommendation, typically related to context-specific aspects and availability of representative data.
Source: JRC analysis.

3 Setting up an emission inventory

To prepare a CoM inventory, GHG emissions are calculated for each activity sector by multiplying the activity data points by the corresponding emission factors:

$$GHG\ emissions = activity\ data \times emission\ factor$$

- activity data[13] expresses the magnitude of a human activity associated with emissions or removals taking place during a given period of time – for example, electricity use in megawatt-hours (MWh).
- an emission factor (EF) is a coefficient that expresses GHG emissions or removals per unit of activity[14] – for example, GHG emissions per MWh of electricity used, expressed in t CO_2/MWh or t CO_2-eq/MWh.

Municipalities shall compile activity data and EFs to calculate GHG emissions for all relevant sources by activity sector and by energy source/carrier (for energy-related sectors) or by waste stream (for waste and wastewater treatment). As mentioned, energy sources/carriers in CoM inventories cover a diverse range of commonly used energy sources/carriers in these activity sectors and activities across the EU, including electricity, district heating and cooling and a wide range of fossil fuels and renewable energy sources.

Data on final energy use and non-energy-related activities needs to be collected, and relevant EFs need to be selected from reference data sources or calculated using context-specific data. As such, data collection is an integral part of preparing a GHG emission inventory. This section provides guidance on how GHG emissions should be calculated for typically relevant sectors and activities. Methodological principles and guidance on activity data collection and on EFs are provided in Sections 4 and 5, respectively.

3.1 Buildings (stationary energy)

Final energy use and GHG emissions associated with fuel combustion and use of grid-supplied energy in stationary sources within the municipality's boundary shall be accounted for in the buildings macro-sector (including direct emissions from fuel combustion and indirect emissions associated with grid-supplied energy use).

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[13] According to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006).

The buildings macro-sector is particularly important, as it typically accounts for a significant part of final energy use and GHG emissions in cities and these can, to a large extent, be shaped by local action. It should be disaggregated into the following activity sectors (CoM key activity sectors marked in the list with an asterisk *):

— Municipal buildings, equipment and facilities,* which may be further disaggregated into:
    - Municipal buildings, equipment and facilities
    - Public lighting
— Residential buildings*
— Tertiary (non-municipal) buildings, equipment and facilities,* which may be further disaggregated into:
    - Institutional buildings
    - Other
— Industry, which may be further disaggregated into:
    - Non-ETS
    - ETS (not recommended)

Table 4 describes the activity sectors and GHG emission sources that are to be considered in this macro-sector. The term 'buildings, equipment and facilities' generally covers the energy-related GHG emissions from stationary sources (e.g., fuel combustion) and generation of the grid-supplied energy used within the local territory, and their associated fugitive emissions.

While the municipal sector has a low relative contribution to citywide GHG emissions (typically below 3%) (Melica et al., 2024), it is separated in CoM inventories for transparency purposes, to highlight the municipality's efforts and serve as an example to the private sector and general society. Actions implemented herein can have high replicability potential in other sectors.

Tertiary (non-municipal) buildings, equipment and facilities include commercial buildings and institutional buildings that are not owned by the municipality. While direct emissions from waste and wastewater treatment should be accounted for as non-energy-related emissions, the energy used in waste and wastewater management plants should be included in the 'buildings macro-sector'. If these plants are owned by the municipality, the energy and emissions should be included in the 'Municipal buildings, equipment and facilities' activity sector; otherwise, they should be included in 'Tertiary (non-municipal) buildings, equipment and facilities'.

Final energy use and GHG emissions associated with industrial buildings, equipment and facilities (e.g., the manufacturing or construction sectors) may also be accounted for as a separate activity sector in the 'buildings macro-sector' if they make a significant relative contribution to the city's overall GHG emissions and/or if the SECAP includes actions that may affect them.

Industrial GHG emission sources covered by 'cap and trade' schemes (typically large industrial plants with over 20 MW as thermal energy input) should be excluded; GHG emissions associated with energy generation in any buildings, industries or facilities, shall not be included in this macro-sector, to avoid double counting.

Table 4. Buildings macro-sector: activity sectors and emission sources to be included in CoM inventories

Activity sector	**Description**
Municipal buildings, equipment and facilities (*)	All final energy use and related GHG emissions occurring in buildings, equipment and facilities that are owned/operated by the municipality shall be accounted for in this activity sector (e.g., offices, schools, police stations, hospitals). This excludes social housing buildings. This sector includes final energy use and related GHG emissions associated with the operation of municipally owned buildings, equipment and facilities for public services (e.g., water supply, solid waste and wastewater treatment and disposal facilities). Energy generation from municipal facilities (e.g., photovoltaic generation, power and/or heat production from waste) should not be included in this activity sector; they shall be accounted for in the 'Local energy generation and supply' section. Electricity use in public lighting owned or operated by the municipality (e.g., street lighting and traffic lights) should be disaggregated, within this sector.
Tertiary buildings, equipment and facilities (*)	All final energy use and related GHG emissions associated with buildings, equipment and facilities of the tertiary sector (services) shall be accounted for in this activity sector (e.g., offices of private companies, banks, commercial and retail buildings, private schools, hospitals, institutional buildings not owned/operated by the municipality). This includes final energy use and related GHG emissions associated with the operation of privately owned buildings, equipment and facilities of public services.
Residential buildings (*)	All final energy use and related GHG emissions associated with buildings that are primarily used as residential buildings shall be accounted for in this activity sector. This includes energy for cooking, heating and cooling, lighting and appliances. Social housing buildings shall be included in this sector.
Industry	All final energy use and related GHG emissions occurring in manufacturing and construction industries not covered by the EU ETS (1) or similar schemes (typically with below or equal to 20 MW as thermal energy input) should be accounted for, particularly if GHG emission mitigation actions affecting them are included in the SECAP. Considering industries covered by the EU ETS or similar (over 20 MW as thermal energy input) in emission inventories is not recommended under the CoM framework. Exceptionally, these may be included if they were accounted for in previous energy or climate change mitigation action plans, or in previous emission inventories, to maintain consistency. Energy generation industries and activities should not be accounted for in this subsector but in the 'Local energy generation and supply' section.
Agriculture, forestry and fishing	Final energy use and related GHG emissions occurring in buildings, facilities and machinery of the primary sector (agriculture, forestry and fisheries), such as livestock facilities, irrigation systems and farm machinery, may be accounted for under this activity sector.
Other	Fugitive GHG emissions occurring in the local territory should be accounted for. Any other activities and related GHG emissions may be accounted for if relevant to the SECAP action planning and monitoring.

(*) CoM key activity sector.

(1) Signatories with a baseline year before 2005 (the start year for the EU ETS) should not include industrial plants that are currently covered by the EU ETS in the BEI.

Source: JRC analysis.

3.2 Transport

Transport is a CoM key activity sector. Final energy use and GHG emissions associated with transport within the municipality boundaries shall be accounted for (including direct emissions from fuel combustion and indirect emissions associated with grid-supplied electricity). Energy use and GHG emissions should be disaggregated by the following:

- Municipal fleet
- Public transport
- Private and commercial transport
- Other

For each of these categories, transport should be further disaggregated by mode (on-road, rail, waterborne navigation, aviation and off-road transport) and energy source/carrier, based on the modes and vehicle fleets that are used in the local context. A summary of the activities and GHG emission sources to be included, for modes that are typically used in an EU urban context, is presented in Table 5.

Table 5. Transport sector: categories and emission sources to be considered in CoM inventories

Category	Mode	Description
Municipal fleet	Road transportation	All final energy use and related GHG emissions (*) for road transportation under the services and competence of the municipality shall be included.
Public transport	Road transportation	All final energy use and related GHG emissions (*) for public transport trips by road within the local territory shall be included. Public transport serving a larger area may be included (e.g., for transboundary trips starting or ending within the local territory).
	Rail transportation	All final energy use and related GHG emissions (*) for public transport trips by rail (e.g., metro, tram, local train) within the local territory shall be included. Public transport serving a larger area may be included, namely for transboundary trips (e.g., trips using regional trains starting or ending within the local territory).
	Waterborne navigation	All final energy use and related GHG emissions (*) for public transport trips by waterborne navigation (e.g., local ferries, boat trips) within the local territory shall be included. Public transport serving a larger area may be included for transboundary trips (starting or ending within the local territory).
Private and commercial transport	Road transportation	All final energy use and related GHG emissions (*) for private or commercial transport trips by road within the local territory shall be included. If there is a significant volume of crossing trips and accurate figures to estimate their associated energy and GHG emissions, these may be excluded.
	Rail transportation	Final energy use and related GHG emissions (*) for private and/or commercial transport trips by rail within the local territory may be included. Long-distance, regional, intercity and cargo rail transportation should be included if GHG mitigation actions may affect them.
	Waterborne navigation	Final energy use and related GHG emissions (*) for private and/or commercial transport trips by waterborne navigation (e.g., local ferries) within the local territory should be included. Private or commercial transboundary transport trips may be included (starting or ending within the local territory).
Other	Off-road transport	All final energy use and related GHG emissions (*) for off-road vehicles or mobile machinery in any economic sector (including agriculture, forestry and construction) should be included if GHG mitigation actions may affect them.

(*) Indicates emissions including fuel combustion and use of grid-supplied electricity.
Source: JRC analysis.

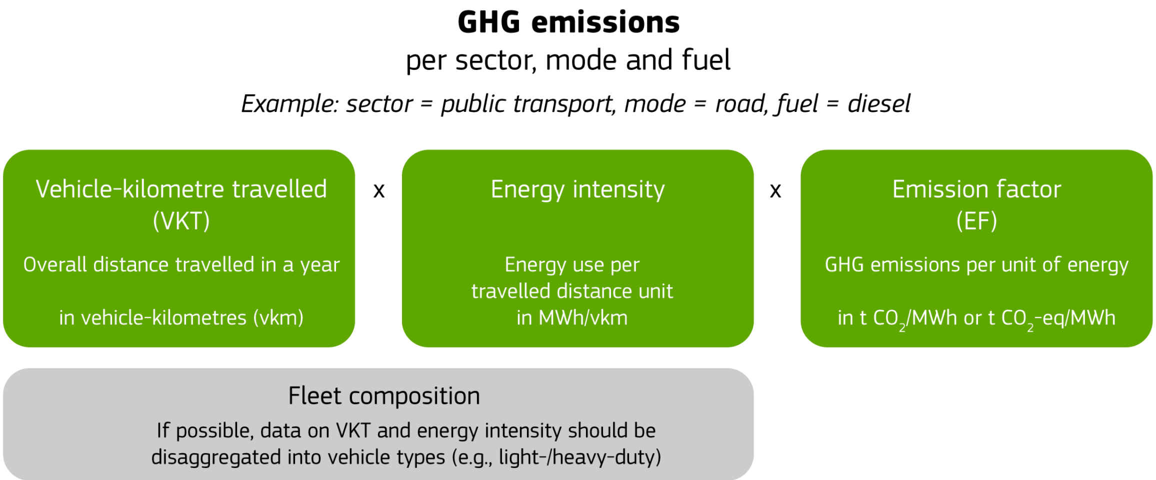
Waterborne navigation, aviation and off-road transport are unlikely to occur or be significant in most EU cities. If they are significant GHG emission sources and/or the municipality envisages actions that may affect their emissions, their final energy use and GHG emissions should be included.

Under the CoM framework, GHG emissions for each type of transport and energy source/carrier (fuel) should be calculated as:

$$GHG\ emissions = VKT \times energy\ intensity \times emission\ factor$$

where VKT is the total vehicle-kilometres travelled by the fleet (for a type of transport, vehicle and fuel), energy intensity is the energy use per vehicle-kilometre (in MWh/vkm) and the EF expresses GHG emissions per energy unit (in t CO_2/MWh or t CO_2-eq/MWh). Preferably, data and calculations (for VKT and energy intensity) should be collected by mode and type (e.g., for road transportation, passenger and freight transport, light-duty and heavy-duty vehicles) in accordance with the fleet composition and then combined to provide energy use by mode and fuel, which should be multiplied by the respective emission factor. This type of data may be modelled based on road traffic counts.

Figure 2. Transport sector: GHG emission accounting approach



Source: JRC analysis, based on Sims et al., 2014.

— VKT as a measure of traffic flows throughout the municipality comprises the overall distance travelled by a vehicle fleet in vehicle-kilometres (vkm). It can be calculated by multiplying the number of vehicles by the average distance travelled by vehicle (e.g., the number of trips multiplied by the length of the trips). In some cases, such as public transport, data can be collected in person-kilometres (1 person-kilometre (1 pkm) is equivalent to 1 person transported over a distance of 1 km) and divided by an average vehicle occupancy (e.g., 20 passengers per bus) to obtain an average distance travelled by a vehicle.

— Energy intensity as a measure of the energy use (e.g., fuel consumption) per distance unit can be calculated by multiplying the average fuel consumption of a vehicle (in l/km) and the net calorific value (NCV) of the fuel (in Wh/l).

— Fleet composition may be important, as energy intensity (fuel consumption) can vary considerably within a sector, based on mode, type of vehicle and fuel. For example, for public transport by road using diesel, the relative share of light- and heavy-duty passenger vehicles and related travel distances can strongly affect overall energy use and GHG emissions.

— EFs express GHG emissions per unit of energy use. In the case of transportation, EFs for direct emissions from fuel combustion can be used (which draw on the energy content of fuels and can be based on IPCC data) or EFs for indirect emissions from grid-supplied electricity.

Two challenges have been typically associated with GHG emission accounting for urban transport: one is the transboundary nature of urban trips, such as commuting trips going into or out of the municipality, and the other is the limited data availability. For municipalities with high shares of commuting travel, it can be relevant to account for these trips, either considering the share of the trips within local territory or accounting for half of all trips (starting or ending in the local territory).

In urban areas, the type of transportation with the most significant GHG emissions is usually road passenger transport. It is thus particularly important to collect high-quality data with adequate disaggregation for this type of transport, including the type of vehicles in use and related EFs. Alternative methodologies that can be adopted, depending on data availability, are provided in Section 4.3 and Annex 2.

It is important to ensure that energy use for the transport sector is not double counted in the buildings macro-sector. For example, when considering data on energy use in the local territory, both buildings and electric mobility use electricity. Municipal electric mobility may have its energy supply and data associated with municipal buildings, equipment and infrastructure as well as industry off-road energy use and emissions, such as those from construction. These should also be separated from other industry-related activities.

3.3 Non-energy-related sectors

Non-energy-related sectors include, for example, primary industry activities, such as agriculture, forestry and fishery, and waste and wastewater treatment activities. Accounting for non-energy-related GHG emissions is not mandatory under the CoM framework; however, direct GHG emissions associated with waste and wastewater treatment should be included. These can account for a relatively significant share of urban GHG emissions, and waste and wastewater prevention and management activities are often under the authority or direct influence of municipalities.

GHG emissions associated with other non-energy-related sectors and activities, such as the agriculture, forestry and other land use (AFOLU) and the industrial processes and products use (IPPU) sectors, may be accounted for, if they contribute a significant share of the overall GHG emissions and/or if the SECAP includes actions or measures that may affect these emissions.

If reliable data is available and SECAP actions or measures are anticipated to affect non-energy-related fugitive GHG emissions, these should also be included here.

3.3.1 Waste and wastewater management

Data on the disposal and treatment of waste and wastewater generated within the local territory, as well as the associated GHG emissions, should be included in CoM inventories, regardless of where emissions occur. GHG emissions associated with waste treatment should be disaggregated by the type of waste (e.g., municipal solid waste (MSW)) and treatment (e.g., waste incineration). If waste or wastewater treatment is associated with energy recovery/generation, GHG emissions should not be accounted for here, to avoid double counting.

GHG emissions associated with the disposal and treatment of waste and wastewater should be calculated by multiplying the activity data points in terms of volume or mass of waste/wastewater generated (i.e., annual generation of waste and wastewater in tonnes (t) and cubic metres (m^3), respectively) by the GHG EFs in tonnes CO_2-eq per unit of waste/wastewater generated (i.e., t CO_2-eq per t of solid waste or per m^3 of wastewater treated).

Waste and wastewater are generated in cities by virtually all activity sectors, including offices, residential buildings, restaurants, markets, public institutions and industry. These sectors generate different types of waste, with important differences in waste composition, and are often associated with different waste management systems (from waste collection to treatment, including recovery and/or disposal).

GHG emissions associated with waste and wastewater treatment should be structured in CoM inventories based on the different types of waste and wastewater generated in the municipality and the relevant management stream. Figure 3 summarises the waste management activities and types of waste and wastewater treatment that may typically be considered in the EU context.

Figure 3. Waste and wastewater GHG inventory structure: typical types of waste and waste treatments

Waste and wastewater management

Waste and wastewater generated within the municipality (e.g., in t or m^3)

Types of waste and wastewater
- Municipal solid waste (MSW)
- Sludge
- Industrial waste
- Construction and demolition waste
- Other

Types of waste treatment
- Solid waste disposal
- Biological treatment of solid waste
- Waste incineration
- Wastewater treatment and discharge
- Other

Source: JRC analysis.

GHG emissions associated with waste and wastewater treatment may vary significantly depending on the type and composition of waste and on the type of treatment. Important considerations that should be taken into account regarding the activities and GHG emissions and that should be included in CoM inventories for waste and wastewater management are as follows.

- If the waste or wastewater generated within the local territory involves *energy or material recovery*, activity data (i.e., on waste/wastewater generation) should be collected and documented; this a relevant indicator for the municipality, and the overall generation should be monitored and reduced. However, the associated GHG emissions shall not be included in this activity sector.
- If there is waste treatment with energy recovery for local energy supply and use, GHG emissions should be considered in the local energy generation and supply section. If waste and/or wastewater is exported for any other use (e.g., material or energy recovery) and/or beyond the municipality's influence, the associated GHG emissions should be excluded.
- GHG emissions associated with the disposal or treatment of waste from outside the municipality that is treated within the local territory may be included if the municipality has control/influence over these activities and the SECAP envisages actions to tackle these emissions. If possible, these activities should be separated from the disposal and treatment of waste and wastewater generated within the municipality in SECAP documentation.
- Grid-supplied energy (e.g., electricity) use in waste and wastewater treatment facilities and associated GHG emissions should be excluded from this activity sector. If these facilities are within the municipality, they shall be accounted for in the buildings macro-sector.

SECAP documentation should include a clear and detailed description of the relevant types of waste and wastewater generated and their sources, streams, composition and treatments for their specific context/situation. It should also provide clear motivations or criteria for the exclusion of any emission sources associated with waste/wastewater treatment.

Types of waste and wastewater

- **Municipal solid waste (MSW)** includes general urban waste collected by municipal services (or equivalent). MSW has a wide range of sources, such as households and offices, and it includes a large and complex mix of materials (e.g., food waste, paper and cardboard, textiles, metal, glass, plastic, rubber, textiles, electronic waste). As such, the composition of MSW may vary significantly among cities.
- **Sludge** is generally a semi-fluid slurry residual waste resulting from the treatment of wastewater/sewage.
- **Industrial waste** generation and composition depend on the sector and type of industry.
- **Construction and demolition (C&D) waste** accounts for a large share of solid waste generation in cities and it should be considered separately. However, it may be included in MSW or industrial waste. While signatories might have limited control/influence over the treatment activities for this type of waste, they are often able to influence C&D activities (e.g., through actions tackling buildings and/or circular economy actions).
- Other potentially relevant types of waste include clinical and/or hazardous waste due to the associated environmental and public health risks.

GHG emissions from waste and wastewater treatment

To estimate GHG emissions associated with waste and wastewater treatment, municipalities need to know the annual volume of waste and wastewater generated and how it is treated. It is important to have detailed data disaggregated by waste and treatment type (i.e., waste stream). Then, appropriate EFs should be selected or calculated, representative of the specific local context.

As mentioned, GHG emissions associated with waste and wastewater treatment are strongly dependent on waste composition, which varies significantly among cities and among waste streams. If context-specific data is unavailable, IPCC (2006, 2019) and other sources provide default values for waste composition, guidance on how to perform waste composition analyses and guidance on how to calculate GHG emissions. Further details on data collection and EFs for waste and wastewater management are provided in Sections 4.4 and 5.4, respectively.

3.4 Local energy generation and supply

Data on local energy generation and supply and the associated GHG emissions shall be considered in CoM inventories. This includes local/distributed electricity, heat and cold generation sources.

Under the CoM framework, data on local energy generation and supply and the associated GHG emissions is not accounted for (or summed) in the GHG inventory, unlike other reference GHG accounting frameworks at the city level (e.g., under an 'energy systems' sector). Instead, it is considered through local energy emission factors (LEEFs), which are applied to calculate GHG emissions associated with the final energy use reported across all activity sectors (for electricity, heat and cold).

Energy and GHG emissions from local energy generation and supply include generation within the local territory and generation of grid-supplied energy by facilities owned (fully or partially) by the municipality outside the local territory. Data should be collected and/or calculated and structured by the following:

— Local electricity generation, disaggregated into:
    - renewable energy sources (RES)
    - combined heat and power (CHP) units
    - electricity-only units (with a capacity limit of 20 MW of thermal input)

— Local heat/cold generation, disaggregated into:
    - combined heat and power (CHP) units
    - district heating (DH) only

The rules for including or excluding local energy generation and supply, and the associated GHG emissions in CoM inventories are summarised next, and further details are provided in Section 4.4.

This section refers to any plant, unit or installation generating and supplying electricity, heat and/or cold, from renewable and/or non-renewable energy sources, as defined below. Typically, cases of particular interest include energy recovery from municipal waste treatment or CHP generation associated with the municipal district heating network.

It is important that the selection of local energy generation units remains consistent across GHG emission inventories (BEI and MEIs) to ensure that local changes in EFs reflect real changes in local electricity generation. For example, for units running on RES, all units reported in the MEI(s) that are not in the BEI should be new installations – that is, installed after the baseline year.

! This LEEF guidance applies to signatories committing to targets for 2030 and/or later. Signatories going from a 2020 commitment to a 2030 commitment, for example, should apply this guidance and include generation units accordingly. If needed, previous BEIs/MEIs may be recalculated.

! When preparing MEI(s), consistency in the selection of generation units is required to ensure that changes in LEEFs reflect real changes in local energy generation and supply.

3.4.1 Local generation and supply of electricity

This section provides methodological guidelines for defining and calculating a local energy emission factor for electricity ($LEEF_{EL}$) under the CoM framework (detailed calculation steps are provided in Section 5 'Emission factors'). Through the $LEEF_{EL}$, the local generation and supply of electricity is integrated into the EF that will be applied to calculate GHG emissions associated with electricity use in the different activity sectors.

Electricity generation plants, units or installations (hereafter 'units') that should be considered in the $LEEF_{EL}$ depend on the:

1. geographical location of electricity generation units;
2. source, type and/or size of electricity generation units.

1. Geographical location of an electricity generation unit

All electricity generated and supplied by generation units within the municipality's territory should be included, provided that they comply with one of the conditions described in point 2.

If a generation unit is outside the local territory, it may be included (optionally) if it is under the direct control or influence of the municipality. In other words, any generation unit under the direct control or influence of the municipality (i.e., operated and/or at least partly owned by the municipality) can be accounted for in the calculation of the $LEEF_{EL}$, provided that it complies with one of the conditions described in point 2.

If a unit has more than one owner and/or generates and supplies energy for other territories, local electricity generation should be accounted for in accordance with the responsibility, share of ownership and relative electricity use of all partners and end users (including municipalities or commercial partners).

2. Source, type and size of an electricity generation unit

For generation units compliant with the geographical location criteria, data on energy generation and the associated GHG emissions is compiled for local/distributed electricity generation from the following:

- renewable energy sources (RES);
- combined heat and power (CHP) units;
- electricity-only units.

RES such as wind power, solar power, geothermal energy, hydropower and combustible biofuels (including bioliquids, biogas, solid-wood-based biomass and organic waste) shall be included. Any electricity from RES with guarantees of origin (as defined by the Renewable Energy Directive (EU) 2023/2413) transferred to a third party outside the local territory shall be deducted (see also Section 5.2).

CHP units shall be included. Any energy produced from high-efficiency cogeneration, with guarantees of origin (per the Renewable Energy Directive) transferred to a third party outside the local territory shall be deducted.

Electricity-only units shall be included if they are not part of the EU ETS (if their size/capacity is less than or equal to 20 MW of thermal energy input).

The criteria above are based on the assumption that small plants/units primarily serve mostly local communities, and that the municipality tends to have more control or influence over these, whereas large power plants primarily produce electricity for the national grid and are regulated through the ETS 'cap and trade' scheme. For small-scale RES and CHP units, in order to avoid overlaps and the double counting of benefits, certified electricity (e.g., through guarantees of origin) that is sold to third parties outside the local territory shall always be excluded.

3.4.2 Local generation and supply of heat and cold

This section provides guidelines to consider when defining and calculating a local energy emission factor for heat or cold ($LEEF_H$ and $LEEF_C$ respectively) under the CoM framework. Through these LEEFs, local generation and supply of heat and/or cold is considered in the EF that will be applied to calculate GHG emissions associated with thermal energy use in the territory, across different activity sectors.

The municipality shall account for all heat and/or cold supplied to end users within the local territory, regardless of the generation units' geographical location and ownership. In order to estimate the indirect emissions due to the generation and supply of heat and cold, it is necessary to identify all units providing heat and cold to (and used in) the local territory and exclude any heat and cold that is generated in the local territory and exported/used elsewhere (see also Section 5.3).

3.4.3 Summary of sources and emissions to be included

Table 6 summarises the types of local energy generation and supply units, activities and emissions that should be considered in CoM inventories.

Table 6. Local energy generation and supply: local energy sources and related GHG emissions

Type of energy		Description
Local generation and supply of electricity	Renewable energy sources (RES)	Local electricity generation from renewable energy sources (including wind power, hydropower, photovoltaics, geothermal, biofuels) and its associated GHG emissions should be included, regardless of the technology and capacity of generation units. Electricity sold to third parties outside the local territory, under disclosed attributes such as guarantees of origin (GO) and other tracking instruments shall be excluded.
	Combined heat and power units	Local electricity generation from combined heat and power (CHP) units and the associated GHG emissions should be included, regardless of the capacity of generation units (see Section 4.4.1). Energy and emissions associated with heat generation should be excluded (a method for allocating GHG emissions to electricity and heat from CHP is proposed in Annex 3).
	Electricity-only units	Local electricity generation from electricity-only power plants that are not covered by the EU ETS (with a capacity limit of 20 MW) and its associated GHG emissions, should be included.
Local generation and supply of heat/cold	Combined heat and power units	Local heat/cold generation from distributed CHP units and supplied through district networks for use within the local territory, and its associated GHG emissions, should be included, regardless of the capacity or location of generation units. Energy and emissions associated with electricity generation should be excluded (a method for allocating GHG emissions to electricity and heat from CHP is proposed in Annex 3).
	District heating	Any other local heat/cold generation distributed and supplied through district networks for use within the local territory, and the associated GHG emissions, should be included, regardless of the capacity or location of generation units. Energy and emissions should be for heat/cold only and should exclude any co-products.

Source: JRC analysis.

4 Activity data collection

Local activity and GHG emission data shall be collected, adjusted or estimated based on reliable data sources. Several approaches and data sources may be combined to prepare CoM inventories. This section provides recommendations on and tips for data collection for preparing a GHG emission inventory for CoM key activity sectors in the buildings and transport macro-sectors – namely, Municipal buildings, Residential buildings, Tertiary sector buildings and Transport – and for Waste and wastewater treatment.

Exceptionally, if energy use data for buildings and transport cannot be disaggregated among individual activity sectors, the data may be provided at the macro-sector level. In this case, it is important to clearly specify which sectors, activities and emission sources have been included in the relevant macro-sector. Energy sources and carriers commonly used in these sectors are described in Box 6.

Most reference organisations across the EU use the NUTS standard as a reference to collect, structure and organise data in relation to geographical areas or units. Generally, NUTS boundaries correspond with the geographical borders of national, regional and local administrations, which aids data collection and processing in the context of the CoM.

All data collection, calculations and assumptions (e.g., on the scope and coverage of the subsectors and aggregation or disaggregation of data) shall be detailed and documented in the SECAP in a clear manner to ensure transparency, and to enable the adequate interpretation, use and consistency of GHG inventories.

Box 5. ETS2: increased data availability for buildings and transport

The 2023 revisions of the EU ETS Directive are expected to provide an important data source for CoM inventories, particularly for buildings and road transportation.

The ETS2 requires fuel suppliers to monitor and report 'the release for consumption' of fuels used in the following:

— commercial/institutional buildings;

— residential buildings;

— manufacturing industries and construction;

— road transportation.

Box 6. CoM energy sources and carriers

For energy-related sectors, data on final energy use (consumption) within the local territory should be disaggregated by energy source/carrier. Essentially, the annual amount of energy (e.g., fuels, electricity, heat) used in each of the activity sectors included in the CoM inventory should be quantified in terms of final energy use (usually expressed in MWh) for all relevant activities and energy sources/carriers.

Relevant energy sources/carriers may be grouped into four categories:

— **Electricity.** This includes all electricity supplied to and used at end-use points (final consumers, end-use buildings, facilities and/or vehicles) within the municipality, regardless of its origin (e.g., national grid or local generation sources). If electricity use in the territory includes electricity directly supplied by local sources (e.g., photovoltaic generation), it is included in the total electricity consumption. Then, the amount that is locally generated will also be considered in the 'Local energy generation and supply' section of the inventory (see Section 3.3) and in the GHG emissions associated with electricity use, through a local energy emission factor (LEEF).

— **Heat/cold.** This includes all heat/cold that is supplied as a commodity and used at end-use points (final consumers, end-use buildings, facilities and/or vehicles) within the municipality (e.g., from district heating/cooling, CHP generation or waste heat recovery). This may include heat/cold from local generation, which should also be considered in the 'Local energy generation and supply' section of the inventory (see Section 3.3) and in the GHG emissions associated with electricity use though a local LEEF. Note that building heating that is not supplied as a commodity but generated in buildings through small-scale systems shall not be included here (e.g., natural gas boilers in buildings); this is included in the 'Buildings' macro-sector.

— **Fossil fuels.** This includes all fossil fuels supplied to and used at end-use points (final consumers, end-use buildings/facilities/vehicles) in the territory. For example, in buildings, fossil fuels may be used for cooking, or space and/or sanitary water heating; for transportation, they are commonly used in internal combustion vehicles. Fossil fuels are also often used as input in combustion processes in the industrial and primary sectors and, thus, if the relevant sectors are included, this final energy use should be included. Fossil fuel data under the CoM framework are typically provided for the following types of fuels: 'Natural gas', 'Liquid gas', 'Heating oil', 'Diesel', 'Gasoline' (or petrol), Lignite', 'Coal' and 'Other fossil fuels'. The last category may include any fuels that are not specifically covered by any other type (e.g., peat or non-organic waste).[14]

— **Renewable energy sources/carriers.** This includes all energy from renewable sources/carriers that are supplied to and used at end-use points (final consumers, end-use buildings, facilities and/or vehicles) in the local territory, include any biofuels (liquid, gaseous or solid fuel produced from biomass) and solar thermal and geothermal energy. Biofuels include (and should be disaggregated by) several sources/carriers: liquid and gaseous biofuels, such as biogasoline, biodiesel and biogas; and solid biomass, such as organic municipal solid waste, wood and wood waste.

Final energy use may be associated with a 'mix of fuels' – for example, petrol/gasoline in the EU typically includes a share of biogasoline, and waste-to-energy generation may include organic and non-organic waste fractions. In such cases, energy sources/carriers may be disaggregated (recommended), or they may be considered under 'Fossil fuels'. Moreover, several biofuels may be considered and aggregated under the CoM categories 'Biofuel', 'Plant oil' and 'Other biomass'.

[14] Although peat is not strictly speaking a fossil fuel, its GHG emission characteristics have been shown in life-cycle studies to be comparable to those of fossil fuels and may be included in CoM inventories under 'fossil fuels'.

The energy sources/carriers and categories described here are commonly used in the EU context. However, it is important to ensure that the SECAP and its inventories adequately reflect the local context/situation, so that the resulting GHG emissions are accurate and consistent. In cases where a category includes different energy sources/carriers, corresponding EFs for the category should be calculated/adjusted accordingly (e.g., with weighted average EFs). Details (e.g., in terms of amount, sources or carriers) should be transparently detailed in SECAP documentation.

Final energy units and conversion

Fuel use data is often available on a mass or volume basis. For example, transportation fuels may be in litres and wood-based biomass in tonnes. All final energy use should be provided in the same unit, usually MWh, and thus unit conversion is often needed. An adequate conversion is essential to ensure accurate GHG emission estimates. Conversion factors and tools are available from multiple online sources.[15]

Typically, EFs are available per unit of energy. Thus, fuel use data shall be converted using net calorific values (NCV),[16] which express the energy content of fuels per unit of mass or volume (e.g., in MWh/t, MJ/l). Default NCV values for different types of fuels are provided by the IPCC (2006), and country-specific values may also be available.

4.1 Data collection and sources: Buildings

As a first step, the CoM framework recommends that signatories investigate if there are already national, regional or local mechanisms for energy (or GHG) monitoring in place, which may provide relevant data for GHG accounting for the Buildings macro-sector. This section is structured in the following subsections:

4.1.1. Municipal buildings, equipment and facilities

4.1.2. National and regional data sources

4.1.3. Data from market operators

4.1.4. Data from surveys

15 https://www.iea.org/data-and-statistics/data-tools/unit-converter

16 A net calorific value (e.g., in MWh/t, MJ/l) is used to convert a fuel quantity between natural units (mass or volume) into energy units (energy content).

17 https://unstats.un.org/unsd/energystats/pubs/yearbook/

4.1.1 Municipal buildings, equipment and facilities

Many municipalities monitor energy use in their own buildings, equipment and facilities (including municipal and institutional buildings, hereafter 'municipal buildings'); thus, they should be able to collect accurate and comprehensive final energy use data for the reference year. For municipalities that do not have a monitoring system in place or for those whose systems do not cover all municipal buildings, energy data collection could draw on the following steps:

1) identify all buildings, equipment and/or facilities owned/managed by the municipality;
2) identify all energy supply points and types of energy used (e.g., electricity, natural gas, heat from heating district networks, fuel oil tanks);
3) identify the person(s) / department(s) receiving energy data (e.g., billing invoices);
4) organise a centralised and structured system to collect, store and manage the data.

Implementing a robust and reliable energy monitoring system in municipal buildings is important not only for estimating and reporting energy and GHG emissions within the CoM, but also for improving the energy management of these buildings. It allows for the identification of buildings and/or processes associated with high energy consumption (hotspots), for example, which may be targeted or prioritised in energy efficiency actions. Real-time or regular daily, weekly or monthly monitoring can also help identify irregular energy wastage and take immediate corrective action. It is thus important that data are collected and reported regularly. Automatic monitoring/measurement systems can aid the process of data collection and management.

Regarding fuels (e.g., heating oil) delivered in bulk, the CoM framework recommends the use of a measurement device (e.g., gauge) to help monitor and quantify fuel use during a given period. Otherwise, it can be assumed that the fuel purchased each year is equal to fuel use. This assumption may be adequate if fuel is supplied at the same period each year or if many deliveries occur in a year.

All final energy use should be accounted for in the CoM inventory, including electricity, heat and cold from local RES and/or certified origin (e.g., building-installed photovoltaics, or electricity with 'guarantee of origin'). The potential benefits of these energy sources are included in CoM inventories through local energy emission factors (LEEFs), in the 'Local energy generation and supply' section.

It is important that non-final use of energy (i.e., energy inputs for energy generation or transformation) is excluded from the 'final energy use' section in the GHG inventory to avoid double counting. Fuel used for local energy generation (e.g., electricity and district heating) should nonetheless be tracked and documented separately.

A relevant component within the municipal buildings sector is public lighting, which may be disaggregated within the 'Municipal buildings' section in CoM inventories. In principle, municipalities should be able to collect and provide energy data on public lighting. If this is not the case, data collection follows the same steps and principles described for municipal buildings. Note that any non-municipal lighting of public spaces should be included under the 'Tertiary (non-municipal) buildings, equipment and facilities' sector.

If the data collected for buildings (e.g., electricity use in buildings) does not distinguish municipal buildings, it should be calculated separately and subtracted (if needed) from other data, to avoid double counting.

4.1.2 National and regional data sources

Energy data have been made increasingly available with high granularity, including at the regional and city levels. In the EU, for example, several directives include recommendations for EU Member States to encourage and facilitate the implementation of SECAPs at the local level, which has motivated the development of tools and databases supporting municipalities' efforts. As such, it is important to check what is already available from national and regional energy sources, such as statistical, energy, environmental or economic ministries, organisations, agencies and regulatory authorities.

Energy and GHG observatories (at the national and/or regional levels) may also provide relevant data for different regions, areas and sectors. These may include regional or local platforms based on collaboration models for data sharing.

4.1.3 Data from market operators

With the liberalisation of gas and electricity markets, the number of stakeholders related to energy supply has increased, and data from energy providers and operators have become increasingly protected and difficult to collect. Nonetheless, signatories may identify and ask for data from energy suppliers active in their local territory. Another alternative is to collect data from energy grid operators. It may be advisable to formalise agreements between the municipality and data providers (e.g., market operators) in order to facilitate cooperation and ensure data availability and consistency across SECAP implementation.

Ideally, energy data should be specific to the local territory (e.g., covering all postal codes in the municipality) and disaggregated by residential, tertiary and industry buildings for each energy source/carrier (e.g., electricity, heat, natural gas).

A higher level of disaggregation is not needed for preparing CoM inventories. However, it can significantly help designing, implementing and monitoring effective energy-saving and climate change mitigation actions. For example, energy data further disaggregated by subsectors, industry and neighbourhoods, among others, can inform targeted and effective actions. This disaggregation may use NACE (general industrial classification of economic activities within the EU)[18] or postal codes, for example. Particular attention may be needed for highly disaggregated data. For example, data on the energy consumption of industrial activities may cover facilities and offices of industrial companies in the local territory but also facilities and offices elsewhere. Some fine-tuning or questionnaires (and clear, detailed documentation) may be necessary to adequately inform SECAP actions and ensure consistent monitoring.

Under Directive 2023/1791 on energy efficiency, energy market operators that are designated by the state should provide on request aggregated statistical information on their final customers. Although the directive specifically acknowledges the CoM initiative and the role of urban areas in achieving energy efficiency objectives, it is not explicitly aimed at energy data sharing between

[18] See Regulation (EC) No 1893/2006 of the European Parliament and of the Council of 20 December 2006 establishing the statistical classification of economic activities NACE revision 2 and amending Council Regulation (EEC) No 3037/90 as well as certain EC regulations on specific statistical domains.

energy suppliers and local authorities. Nevertheless, there are cases where national laws have specifically introduced provisions that facilitate the access of municipalities to energy data.

4.1.4 Data from consumer surveys

When data from statistics, market operators or other organisations/entities is not available with adequate levels of quality, disaggregation and detail, it may be necessary to complement it with locally collected data, for example gathered through surveys. This is typically the case for energy sources/carriers that are not grid-supplied and can have many local suppliers, such as wood.

Several strategies for questionnaire-based surveys can be adopted:

- For sectors and energy carriers with a large number of small, distributed end users (e.g., the residential sector), the CoM framework recommends addressing a questionnaire to a representative sample of the population, spread over all areas, districts or neighbourhoods of the municipality. The questionnaire may be online, but it should be ensured that a representative and relevant sample of answers is collected (and that the online nature of the survey does not prevent some groups of customers from providing data, which would provide biased results).
- For sectors and energy carriers where the number of actors is limited, it may be worthwhile addressing the questionnaire to all energy consumers (this may be the case, for example, for the industrial sector).
- For sectors and energy carriers where there are many stakeholders (suppliers and/or end users) but a few large ones (e.g., the tertiary sector) are likely to account for the majority of energy use in the local territory, it is important to include at least all large players (e.g., supermarkets, hospitals, universities, housing companies, large office buildings). They can be identified through local knowledge, statistical or commercial data, or inquiries to the grid operator (asking who the main electricity/gas consumers in the local territory are), for example. Another option for identifying large electricity consumers is asking grid operators the identity of all consumers connected to the middle- and high-voltage distribution networks (or even to the transmission network, in some rare cases).

What to ask

Besides the type and quantity of energy used and the eventual local energy generation (e.g., solar photovoltaics, CHP), other indicators and data related to energy use (e.g., floor space (m^2) of a building, number of inhabitants or number of pupils in a school) may be useful for interpretation, comparison or extrapolation purposes.

- For industry or services, it might be relevant to identify the subsector/type of industry.
- For the residential sector, it may be particularly useful to ask questions that allow for the extrapolation of collected data. These questions depend on what kind of statistical information is available at the municipal level that can be combined with survey-based data. This could be, for example, household size (number of occupants), socioeconomic data, location (postal code and/or rural/urban area), dwelling type (detached house, semi-detached house or apartment), size of the dwelling (e.g., floor area in square metres) and the year the building was constructed.

What to do with the data

Data collected through surveys should enable the municipality to provide an overall picture of final energy use in the local territory, by activity sector and energy source/carrier. It should include all relevant data to support the design of effective and targeted SECAP actions. A few examples of possible applications include the following:

— Survey-based data can help disaggregate statistical data on final energy use into sectors or subsectors in order to design and target actions effectively across different sectors or groups and to monitor results. Fuel ratios can also be derived from survey-based data to disaggregate statistical data.

— Data on energy demand per square metre or per inhabitant in the household sector for different types of buildings and/or different zones or socioeconomic groups can be applied to disaggregate statistical data or to extrapolate energy use in the whole sector.

Ideally, the collection of data through surveys and the processing of statistical data should be done with the support of statisticians to make sure that the results are statistically meaningful and representative. In addition, checks should be carried out to make sure that the overall results are consistent with data available at a more aggregate level.

Box 7. Tips for building a questionnaire-based survey

— Plan in advance what to do with the data collected – that is, how it will be used and how to make sure that useful and necessary questions are asked to collect all relevant data. Do not hesitate to get the help of specialists (statisticians) to design your survey.

— Make sure that questions are clear and precise so that they will be understood and interpreted by all respondents in a similar manner. Generally, questionnaire-based surveys should be simple and short, in order to obtain a satisfactory rate and high-quality level of answers. Provide short instructions, if necessary.

— Inform respondents clearly of the purpose of the questionnaire (e.g., informing respondents that the questionnaire is to measure progress in reaching GHG emission reduction objectives of the municipality); this may motivate people to respond. It is best practice to communicate your aims (SECAP development) in advance through the local media, explaining the context and expected benefits for local communities.

— Make sure that the sample is representative of the population. Be aware that the response rate is generally low and that those who respond may be particularly educated and climate-aware, for example, and therefore there is a risk of biased data collection, even if the questionnaire is addressed to a representative sample of the population. It may be advisable to organise data collection through face-to-face or phone interviews. In-person surveys can significantly increase the response rates and quality of data collection.

4.2 Data collection and sources: Transport

Collecting, calculating and monitoring activity data and GHG emissions associated with transportation is not only crucial for supporting climate change mitigation actions, but it is also helpful for guiding wider transport policy and planning. This section provides practical guidelines for accounting for GHG emissions associated with the transport macro-sector, focusing on road and rail transportation. The different resources and capabilities of municipalities are taken into account and alternative options are provided.

As previously mentioned, activity data (energy use) for the transport sector and related GHG emissions should be provided for the municipal fleet, public transport and private and commercial transport, and it should be disaggregated by mode and type of energy source/carrier (e.g., petrol, diesel, electricity). This section focuses on data collection for road and rail transportation, which are typically the most common and relatively significant transport modes in EU cities.

4.2.1 Road transportation

It can be challenging to account for road transportation emissions in urban areas given the nature of road transportation; it includes numerous mobile emission sources (vehicles) of private and public property, moving within but also across boundaries of the local territory. Detailed information about transport activities, travel patterns and commuter behaviour is relevant for all types of local authorities in supporting GHG mitigation actions (and air pollution mitigation actions), whether for large, medium or small cities, towns or municipalities. However, resources and capacities for collecting, analysing and reporting data may vary significantly.

Depending on the inventory objectives, the availability of high-quality data and context-specific aspects, activity data on energy use in road transportation and associated GHG emissions can be accounted for in different ways. Common approaches include the fuel sales method, territorial method, residential method and city-induced activity method (a summary of these methods is provided in Annex 2). Under the CoM framework, the **'territorial method'** is recommended.[19] This bottom-up approach is fully aligned with the scope and principles of the CoM (see Section 2.3): it is based on the travel distance driven within the local territory and it can be relatively simple to apply, while allowing for the identification and quantification of GHG emissions with adequate detail to inform GHG mitigation actions.[20]

The top-down '**fuel sales method**' estimates on-road transportation emissions based on the total fuel sold: the fuel sold in a territory is used as a proxy for transportation activity within the territory. This may be relevant at the national level, but it provides very limited information for supporting local action (Kennedy et al., 2010). The use of fuel sales data can be adequate for areas where trips across borders are infrequent in comparison with the travel within the local territory (e.g., within greater metropolitan areas or within an island territory).

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[19] The CoM recommendation is to focus on (at least) 'urban road travel', as defined in Section 3.2.

[20] The more complex 'resident activity' and 'city-induced activity' bottom-up methods, which are of particular relevance for local planning related to transport (see Annex 2), should only be used in instances where cities have a large share of local travel and a small share of transit travel and/or where cities have an ongoing plan based on such approaches.

To identify levers for policy interventions and to adequately monitor GHG emissions associated with road transportation, it is important to go beyond the approximate and aggregated estimates of the 'fuel sales method' and to understand transport activities and travel patterns using a bottom-up approach.

The 'territorial method' has greater data requirements than the 'fuel sales method', but it can provide important and meaningful information for designing, implementing and monitoring local GHG mitigation actions in the transport sector. It is thus considered an adequate compromise in terms of the accuracy and resource requirements of high-quality data collection and analysis for estimating GHG emissions associated with urban road transportation.

The 'territorial method' contains a spectrum of approaches, ranging from relatively simple to more sophisticated, but it is generally based on the following parameters:

- **Modal split and vehicle fleet.** The modal split describes the distribution of road travel (trips) among different transport modes, and the vehicle fleet composition assigns shares of road travel by mode to different types of vehicles. In urban areas, the most significant is typically passenger transport, which should be disaggregated into public and private and into light-duty and heavy-duty, for example. In addition, within these modes, the vehicle fleet can be further divided considering other characteristics, for example, by whether they are diesel or petrol cars or by vehicle emission (Euro) standards.
- **Vehicle-kilometres travelled.** The vehicle-kilometres travelled (VKT) provide a quantifiable measure of road travel: it results from multiplying the number of vehicles by their individual travelled distances. Therefore, 10 vehicle-kilometres (vkm) is the result of five vehicles travelling over 2 km each, but also of two vehicles travelling over 5 km.
- **Energy intensity.** Energy intensity is a measure of energy use per unit of distance travel (in Wh/km) that considers the fuel consumption and the energy content of fuels. It is calculated as the product of fuel consumption (as actual consumption, or an average consumption per km can be considered) of a vehicle (in l/km) and the fuel's NCV (in Wh/l).
- **Fuel GHG intensity.** Fuel GHG intensity relates to the GHG emissions of the fuels (e.g., diesel, motor gasoline/petrol, electricity, hydrogen) and it is applied in the CoM through EFs, which express GHG emissions per unit of energy (e.g., in t CO_2-eq/MWh).

As mentioned in section 3.2, GHG emissions for urban road transport in the CoM should be calculated as:

$$GHG\ emissions = \sum_{modes}\sum_{fuels}[VKT \times energy\ intensity \times EF]$$

The subsections that follow provide guidance on data collection for each of the four parameters described above.

4.2.1.1 Modal split and vehicle fleet

As previously mentioned, the modal split describes the distribution of road travel (trips) among different transport modes, and the vehicle fleet composition allows shares of road travel by mode to be assigned to different types of vehicles. It provides insight on the shares of annual road travel of, for example, private and public transport, by bus, passenger car and motorbike, and each of these types should be further disaggregated by petrol, diesel, electricity or other types of fuel.

Municipalities may also provide other types of disaggregation such as by Euro emission standard classification. At minimum, the fleet distribution should distinguish between the following:

— private passenger cars and taxis;
— heavy-duty and light-duty vehicles;
— buses and other vehicles used for public transport;
— two-wheelers.

The fleet distribution can be estimated based on the following types/sources of data:

— traffic counts (from which travel distances/shares need to be derived);
— vehicles registered in the municipality;
— national statistics;
— Eurostat statistics at the regional (or national) level;
— commercial datasets.

The use of any of the above data sources should be accompanied with a consideration as to whether it represents an appropriate estimate of the distribution of annual road travel in the local territory.

Some available tools for preparing local GHG emission inventories include default fleet distributions for different regions, which can be used if they are considered appropriate by the municipality. The fleet distribution can be adjusted to better suit the local territory if needed. For instance, traffic counts may be used to adjust regional statistics, as urban travel composition might be significantly different from that of surrounding areas.

4.2.1.2 Vehicle-kilometres travelled

While acknowledging that collecting data on road travel (e.g., VKT) may be challenging for municipalities, it is important to prepare meaningful and accurate GHG emission inventories for the road transport sector. There are various options for estimating the VKT on the street network of a local territory, which can be based on information on traffic flows and the length of the street network. Municipalities can often access data from local sources, such as the municipal transport department or the local, state or national road management authorities.

In the case of the municipality's own fleet and public transportation, VKT can be estimated based on the vehicles' odometers. Alternatively, fuel consumption of the municipal and public transportations fleet can be estimated based on fuel supply. All travel (and the associated fuel use and GHG emissions) associated with the municipal fleet and/or services should be included, regardless of geographical boundaries (i.e., if a work trip to another municipality takes place, it should be included). In the case of contracted services for public transport or other local travel services, the information should be provided by transport operators.

Fuel sales data may be used by municipalities if VKT and/or fleet (type of vehicles) data is limited or unavailable and the number of vehicle trips over the city borders (transboundary and/or crossing trips) is small compared with the number of trips within the city. However, this proxy should always be completed with local traffic and/or fleet data or estimates, in order to better inform local GHG emission mitigation actions (see also Annex 2).

4.2.1.3 Energy intensity

As mentioned, energy intensity is a measure of energy use per unit of distance travel (in Wh/km) that considers fuel consumption and the energy content of fuels. It is calculated as the product of fuel consumption (actual consumption, or an average consumption per km can be considered) of a vehicle (in l/km) by the fuel's NCV (in Wh/l). Default NCVs for a wide range of fuels are available through the IPCC (2006).

The average fuel consumption of each vehicle category depends on the type of vehicle, its age and a number of other factors, such as the driving cycle. The CoM framework recommends that signatories estimate the average fuel consumption of vehicles driving on the urban street network based on polls, information from inspection agencies or information on vehicles registered in the municipality (or region). Automobile or car clubs and transport associations can also provide information. The use of the national average fuel consumption for each vehicle category may produce biased estimates, since fuel consumption is highly dependent on the type of travel (e.g., urban, inter-city, motorway, rural).

If the SECAP includes measures that affect the fleet, travel or fuel consumption of vehicles, for instance by promoting the use of electric or hybrid vehicles, it is particularly important to calculate accurate estimates with detailed local data and to account for hybrid and electric cars separately (Donati et al., 2015).

4.2.1.4 Fuel carbon intensity

Fuel carbon intensity essentially describes the amount of GHG emissions that are released during fuel combustion (e.g., in kg of CO_2-eq per ktoe or per l or per Wh). Default EFs are available for a wide range of fuels and energy sources. If EFs for fuel combustion in stationary sources are used, they may be increased by up to 3% for fuel combustion in transport.

In the cases of diesel and petrol, biofuel shares should be considered; national average shares of energy from renewable sources in transport can be taken from Eurostat statistics.[21] However, if

[21] https://ec.europa.eu/eurostat/web/products-datasets/-/nrg_ind_ren

there is a particular use or promotion of biofuels, produced in a sustainable manner, in the SECAP, it is important to estimate the share of biofuels in the fuel used in the local territory. This can be done, for instance, by implementing surveys among the most important fuel distributors in the area. In the case of biofuels being used in the municipal fleet (beyond the average use in the local territory), the municipality is likely to have access to data on the amount of biofuel consumed.

Table 7. Data and potential sources for estimating GHG emissions from road transportation

Type of data	Potential sources
Vehicle-kilometres travelled	
Vehicle flows and distance travel for transport planning purposes	Local transport department, public transport providers
Travel surveys including numbers of vehicles passing fixed points per unit of time (on traffic volume) Household transport surveys (on origin and destination)	Some surveys count vehicle numbers by type of vehicle
Average daily traffic volumes for the whole EU	Open Transport Map: http://opentransportmap.info/
Data on transport infrastructure and standardised indicators on transport, covering 35 European cities	Union Internationale des Transports Publics:: http://www.uitp.org/
'Big data' such as data from smartphones and other travel data loggers that can provide details of trips	Various web applications voluntarily share data
Vehicle fleet distribution	
Data on modal share for many European cities	Eurostat: https://ec.europa.eu/eurostat/data-browser/view/urb_ctran
Passenger travel modal share	Various national- or city-level surveys
Average fuel consumption per kilometre	
Fuel consumption per km and vehicle type	European Environment Agency's *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2023* (EEA, 2023)
Fuel efficiency and GHG emission data sources for vehicle types	National inventory data on vehicles
Local estimates of fuel economy for different vehicle types	Local vehicle registration data
Fuel net calorific values	
Default net calorific values (NCV)	IPCC's *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC, 2006)
All activity data at national level	
VKT, vehicle fleet, energy, GHG and air pollutant emission data for the EU-27	Copert: https://copert.emisia.com/copert-data/
GHG emissions	
GHG emissions associated with road transportation	Google Environmental Insights Explorer: https://insights.sustainability.google/

Source: JRC analysis.

Box 8. Example calculation of GHG emissions from urban road transportation

Input data

- Total distance travelled (VKT) = 4 500 million km
- Fleet type distribution (as a percentage of VKT)
- Average fuel composition, net calorific values and emission factors

Fleet distribution (% of VKT)

	Passenger cars	Light-duty vehicles	Heavy-duty vehicles	Buses	Two-wheelers	Total
Petrol	25	1	-	-	13	39
Diesel	37	14	2	3	-	56
Electric	5	-	-	-	-	5
Total	67	15	2	3	13	100

Average fuel consumption, NCV and EFs

	Passenger cars (l/km)	Light-duty vehicles (l/km)	Heavy-duty vehicles (l/km)	Buses (l/km)	Two wheelers (l/km)	NCV (Wh/l)	EF (t CO_2-eq/MWh)
Petrol	0.0768	0.130	-	-	0.040	9 200	0.25
Diesel	0.0658	0.098	0.298	0.292	-	10 000	0.27
Electricity	-	-	-	-	-	-	0.29

NB: In the case of electric vehicles, fuel consumption is typically provided in kWh/km, which expresses the energy intensity. In this example, electric passenger cars are considered to have an average consumption of 0.186 kWh/km (see Step 2).

Calculation of energy consumption and GHG emissions

Step 1. *VKT per fleet type (million km) = total VKT (million km) x fleet distribution (% of VKT)*

	Passenger cars	Light-duty vehicles	Heavy-duty vehicles	Buses	Two-wheelers	Total
Petrol	1 125	45	-	-	585	1 755
Diesel	1 665	630	90	135	-	2 520
Electricity	225	-	-	-	-	225

Step 2. *Energy intensity per fleet type (Wh/km) = average fuel consumption (l/km) x NCV (Wh/l)*

	Passenger cars	Light-duty vehicles	Heavy-duty vehicles	Buses	Two wheelers
Petrol	706.6	1 196	-	-	368
Diesel	658.0	980	2 980	2 920	-
Electricity	186.0	-	-	-	-

Step 3. *Final energy consumption per fleet type (MWh) = VKT (km) x Energy intensity (Wh/km)*

	Passenger cars	Light-duty vehicles	Heavy-duty vehicles	Buses	Two-wheelers	Total
Petrol	794 925	53 820	-	-	215 280	1 064 025
Diesel	1 095 570	617 400	268 200	394 200	-	2 375 370
Electricity	41 850	-	-	-	-	41 850
Total	1 932 345	671 220	268 200	394 200	215 280	3 481 245

Step 4: *GHG emissions per fleet type (t CO_2-eq) = final energy consumption (MWh) x EF (t CO_2-eq/MWh)*

	Passenger cars	Light-duty vehicles	Heavy-duty vehicles	Buses	Two-wheelers	Total
Petrol	198 731	13 455	-	-	53 820	266 006
Diesel	295 804	166 698	72 414	106 434	-	641 350
Electricity	12 137	-	-	-	-	12 137
Total	506 672	180 153	72 414	106 434	53 820	919 493

NB: If EFs for fuel combustion in stationary sources are used, they may be increased by up to 3% for transport.

4.2.2 Rail transportation

Rail transportation may be divided into the following:

- **Urban rail transportation, including trams, metro and local trains.** The inclusion of urban rail transportation in the 'public transport' activity sector in the GHG emission inventory is strongly recommended.

- **Other rail transportation.** This covers long-distance, intercity and regional rail transportation that occurs in the local territory. Other rail transportation may serve not only the local territory but also a larger area (transboundary travel); and it often includes freight transport. These emissions may be included in the GHG emission inventory if the municipality has included measures to reduce these emissions in the SECAP.

Generally, rail transportation uses electricity or diesel. Use of diesel in urban rail transportation is less common for local services, and the number of providers of rail transport in the local territory is usually low. The municipality may have access to annual electricity and fuel use data directly from service providers. If such data is not available, GHG emissions can be estimated based on distance travelled (in VKT) and average electricity or fuel consumption per vehicle-kilometre (vkm).

4.3 Data collection and sources: Local energy generation and supply

As previously mentioned, locally generated energy (electricity, heat and/or cold), primary energy inputs and the associated GHG emissions shall be accounted for in the calculation of local energy emission factors (LEEFs): namely, for electricity ($LEEF_{EL}$) and for heat/cold ($LEEF_{H}$/ $LEEF_{C}$). As such, detailed data on local energy generation and supply and on the related EF calculations, should be provided in the 'Local energy production' section of the CoM inventory.

GHG emissions from each individual plant, installation or unit (hereafter, 'unit') shall be estimated. In this context, the signatory shall identify all local energy generation units directly providing electricity, heat and/or cold to be used within the municipality, regardless of the units' geographical location and ownership. Detailed data on local energy generation and supply should be collected separately and for each unit/supplier on:

- energy (electricity, heat or cold) produced in the local territory, primary energy inputs and associated GHG emissions;

- energy (electricity, heat and/or cold) exported to be used outside the local territory;

- energy (electricity, heat and/or cold) imported to be used inside the local territory, primary energy inputs and associated GHG emissions.

When a generation unit in the local territory supplies energy to another territory (energy exports), the relevant energy production, primary energy inputs and GHG emissions should be excluded. In the case of imports – that is, if there is energy use from a unit located outside the local territory – the share of energy, primary energy inputs and GHG emissions associated with the energy used in the local territory should be included.

The list of the electricity, heat and/or cold generation units, together with the corresponding primary energy inputs, generated outputs and GHG emissions, must be updated and consistent across the implementation period to account for changes in local production processes and to avoid double counting among city inventories. If a municipality adds, during implementation, a unit that was not accounted for before or excludes one that was included, previous inventories (BEI or MEIs) should be revised and recalculated accordingly. Examples of recalculations are provided in Annex 1. In the case of CHP generation, primary energy inputs and corresponding GHG emissions need to be allocated to electricity and heat/cold generation, as explained in Annex 3.

If there is a number of small, distributed generation units for local use for which adequate data cannot be collected and SECAP measures do not affect them, the equivalent amount of energy generated by these units may be excluded from the inventory (i.e., excluded from both the energy generation and supply section and from the final electricity, heat and/or cold use).

4.3.1 Local generation of electricity

Information on local electricity generation is often available or can be provided by local electricity providers and/or unit operators. For large plants, data on the (distributed or centralised) local electricity generation can usually be obtained through direct contact with plant managers (e.g., a municipal power agency or private company) or with network operators. Otherwise, data may be obtained through surveys involving local producers/suppliers (e.g., energy communities), or it can be estimated based on statistical data (e.g., on permits or subsidies) related to the number of installations and power units. Energy market operators may also have data about other entities that provide electricity to the grid (e.g., associated with certified 'green' electricity).

4.3.2 Local generation and supply of heat and cold

Data on heat/cold generation and supply may be available from local energy providers. Otherwise, it should be obtained through direct contact (or questionnaires) with the plant managers, as heat/cold is typically generated in relatively large units.

Due to the localised nature of heat/cold generation and supply, the total amount of heat/cold production reported in the 'Energy supply' section should be equal (or very close) to the quantity of heat/cold used locally and reported in the 'final energy consumption' of 'Heat/cold'. Differences may occur due to:

— auto-consumption of heat/cold by the facility;

— transport and distribution losses of heat/cold.

It is worth highlighting that the local electricity and heat/cold produced (or converted) and consumed on-site by end users should be accounted for in the 'Final energy consumption' section for the corresponding activity sector (reporting fuel and/or renewable energy consumption), and in the related GHG emissions should be calculated. For example, solar energy or wood-based biomass directly supplying (converted) energy that is consumed locally by end users may be reported under 'Residential buildings'.

When heat/cold from a plant is partly used in the local territory and partly used elsewhere, CoM inventories should include only energy inputs and GHG emissions corresponding to the share of final energy (heat/cold) used in the local territory.

4.4 Data collection and sources: Waste and wastewater management

Activity data for calculating GHG emissions associated with waste and wastewater management predominantly consist of data describing the waste and wastewater generated in the local territory. The amount and composition of generated waste may vary significantly across cities, and context-specific data may be particularly important for estimating emissions associated with its treatment.

The quantity and composition should be estimated and characterised for different types of waste and treatments (waste streams). These can often be collected or estimated based on data from waste and wastewater collection and management facilities. These facilities may treat waste from other territories as well, in which case it is important to consider data on the treatment of the waste generated in the local territory alone.

If an adequate monitoring and reporting system is not in place to provide high-quality data on waste generation and composition, such data may be estimated using national or regional data and complemented with surveys. For example, surveys on waste generation can be distributed to a sample of households or segments of the industrial sector (e.g., buildings and civil construction). Waste data may also be collected and reported on a voluntary basis by industrial associations and companies to provide information to their sector and for sustainability reporting, for example.

Ideally, to inform GHG emission mitigation actions tackling waste generation at the city level, data on quantity waste should be complemented with details on the following points (van Ewik and Stegemann, 2023):

— **Types of waste.** Signatories should look at different streams of waste, in particular waste including materials that can be reused, recovered and/or recycled (e.g., paper, metal, construction and demolition (C&D) waste, the organic fraction of municipal solid waste (MSW), plastic).

— **Sources of waste.** Sources of waste (e.g., industries, households and construction sites) can be important for effectively shaping waste prevention and management measures. Identifying and characterising activities associated with large sources of waste (e.g., large-scale consumption of single-use or packaged products) can help inform targeted local actions.

— **Time.** Waste generation can vary with day and season (e.g., in cities with relevant seasonal tourism activities).

A waste audit can support the municipality in the development and improvement of waste prevention and management strategies. Typically, these audits can be done by organisations, including specialised companies or universities, for example. To provide insight into what types of waste and the quantities that are generated throughout a year, an audit might use several samples to infer annual waste generation data.

If local data availability is limited, default values may be considered from IPCC guidelines (IPCC, 2006, 2019). These default values include MSW generation per capita, composition values and treatment shares for eastern, northern, southern and western Europe (see Annex 4).

Industrial waste generation default figures for most EU Member States are also provided by the IPCC. Regarding sludge, data is collected for some Member States by Eurostat under 'Water statistics on national level'.[22] Lastly, IPCC guidelines also provide guidance on conducting waste composition analyses (IPCC, 2006).

[22] https://ec.europa.eu/eurostat/databrowser/product/page/ENV_WW_SPD.

5 Emission factors

GHG emission accounting strongly depends on the methodological approach and data selected, in particular in relation to GHG emission factors (EFs). Under the CoM framework, municipalities have several options available that may be determinant:

- Municipalities can choose between the **activity-based approach**, in line with IPCC principles (i.e., focusing on direct GHG emissions associated with energy conversion, such as fuel combustion) and the **life-cycle (LC)-based approach** (adding GHG emissions associated with the energy supply chain).
- Municipalities are recommended to account for three reference GHGs, namely carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). If the activity-based approach is selected and if the sectors and actions in the SECAP are limited to energy-related activities, they may choose to account for CO_2 only (see Section 2).

After selecting the GHG accounting approach, the municipality can select or calculate its EFs accordingly. Signatories may use default EFs (e.g., provided by the JRC or other reference organisations), or define GHG EFs that may better reflect their specific local context.

- In general, *default GHG EFs* should be used if reliable context-specific (e.g., local or regional) EFs are not available. It is important to ensure that, if default EFs are selected, these are appropriate and representative of the local context and activities (e.g., local fuel quality and composition). If municipalities prefer to select or calculate EFs that may better reflect the properties of the fuels used in their territory, they are welcome to do so.
- Activity-based EFs depend mostly on the carbon content of the fuels and therefore do not vary significantly from case to case. If the municipality would prefer to use its own EFs, it should ensure that they are in line with the guidelines and recommendations provided by the IPCC (2006, 2019).
- IPCC-based GWP values should be used – to convert and aggregate all GHGs accounted for into CO_2-eq – and they are expected to remain constant over the monitoring period (i.e., the same GWP values should be used for both the BEI and subsequent MEIs). GWP values from the most recent IPCC assessment report at the time of reporting should be used. For consistency and comparability, signatories who have already reported GHG emissions using GWP values from a previous IPCC assessment report can decide whether to update previous inventories or to use the same GWP values in subsequent inventories.
- For municipalities using the LC-based approach, it is recommended to consider whether default EF data (e.g., supply chain data related to the origin and transport of fuels) is representative of their local context or whether EFs should be calculated or adjusted with context-specific data.
- When selecting EFs for biofuels (including wood-based biomass), municipalities shall take into consideration carbon neutrality and biogenic carbon accounting guidance (see Section 5.1.3).

5.1 Greenhouse gas emission factors for energy use

5.1.1 CoM default emission factors

The 'CoM data collection' developed by the JRC[23] provides GHG EFs that can be used for the calculation of local GHG emission inventories within the CoM (Bastos et al., 2024). EFs are provided for the activity-based and LC-based approaches. CoM EFs for local energy use include:

- GHG EFs for local use of non-renewable energy sources (NRES);
- GHG EFs for local use of renewable energy sources (RES);
- GHG EFs for local/distributed electricity production from RES;
- GHG EFs for national electricity use by country and year, since 1990 (also referred to as 'National and European emission factors for electricity' or NEEFEs).

EFs for local use of fuels and renewable energy are provided for the most commonly used energy sources and carriers in Europe. EFs are provided in t CO_2/MWh or t CO_2-eq/MWh to apply with activity data (e.g., final energy use) in MWh.

Activity-based EFs draw on IPCC data on stationary combustion, and LC-based EFs add data and emissions associated with the supply of fuels/energy (upstream, supply chain emissions) to the activity-based EFs. CoM LC-based EFs are generally representative of the EU context; however, because supply chain data is highly context-specific (depending on origin, transport and other context-specific processes), it is important to consider whether these EFs are representative of the local territory.

5.1.2 Context-specific GHG emission factors

If municipalities prefer to use other GHG EFs from reference organisations or to develop their own EFs based on detailed properties of the fuels and energy used within the local territory, they are welcome to do so, as long as local data is available and reliable and the calculations are transparent, in line with CoM (IPCC-based) principles. These EFs should be transparently referenced and/or documented in the SECAP. In some cases, it may be necessary to calculate and use weighted EFs, for example:

- if the same energy carrier has different EFs in different activity sectors;
- if an energy source/carrier category includes two or more energy sources/carriers with different EFs, the shares of which may vary among activity sectors.

The SECAP may detail separate EFs used for each activity sector and disaggregate local energy sources/carriers. However, if using automatic calculation tools or reporting platforms (online), such as MyCovenant, where a single EF should be inserted for an activity sector and energy source/carrier, the previous calculation of weighted EFs may be needed. The resulting GHG emissions should be aligned with those detailed with separate EFs in the SECAP documentation.

[23] https://data.jrc.ec.europa.eu/collection/id-00172

It is particularly important to check whether available GHG EFs associated with energy from waste and biofuels reflect the local context; otherwise, data should be used to calculate or adjust EFs. For example, waste-related emissions are highly dependent on waste composition, wood-based biomass emissions depend on the type of wood and biofuel emission accounting depends on the sustainability of harvesting and forest management practices.

Municipalities shall also update these EFs during the monitoring phase, accounting for changes in the composition/properties of the energy sources/carriers. This is particularly important for municipal waste used for energy recovery, for example, for which both waste management and energy generation are often under the direct control or responsibility of the municipality. In such cases, it is important to account for the changes in the composition and treatment phases of the waste management process.

Further complementary guidance and information on GHG EFs is available from:

- the JRC technical report on CoM GHG EFs for local emission inventories (Bastos et al., 2024);
- the IPCC guidelines for acquiring and compiling activity and GHG emission data from different sources (IPCC, 2006);
- the IPCC Emission Factor Database (EFDB)[24], a reference platform with additional EFs, data and technical documentation.

5.1.3 Treatment of biomass

This section provides specific guidance on how to address the use of biomass or biomass-based products in the local territory in CoM inventories.

IPCC guidance recommends that biogenic CO_2 emissions (and sequestration) associated with bioenergy (i.e., biofuels, biomass and/or biomass-based products used for energy purposes) are accounted for in the Agriculture, Forestry, and Other Land Use (AFOLU) sector (through the estimated changes in carbon stocks). These emissions should thus be excluded from the energy-related (i.e., buildings and transport) and waste/wastewater sectors to avoid double counting, but they can be mentioned therein as an informative item (see Volume 1, Chapter 1, of IPCC, 2019). Biogenic CH_4 and N_2O emissions from the combustion of biomass and biomass-based products for energy purposes, however, shall be accounted for in the relevant activity sectors.

CoM inventories typically exclude AFOLU and, thus, double counting issues may not apply. Nonetheless, the same principles apply to ensure consistency and comparability with GHG inventories at the city, regional and national levels. Moreover, the CoM framework follows IPCC guidelines in recommending that biogenic CO_2 emissions associated with the use of biomass and biofuels are excluded from GHG inventories, if these are harvested in a sustainable manner.

The CoM framework assumes a carbon neutrality principle – that is, a carbon balance between CO_2 emissions and carbon sequestration or removal by productive land (Lo Vullo et al., 2022). Biogenic CO_2 emissions may be provided as an informative item in SECAP documentation (not included in the GHG inventory total) to provide further insight into the overall emissions associated with energy

[24] http://www.ipcc-nggip.iges.or.jp/EFDB

generation and use at the city level. If biofuels and biomass-based energy sources are not harvested in a sustainable manner and result in declining carbon stocks, emissions for CO_2 (higher than zero) should be applied, as detailed below.

5.1.3.1 Accounting for biogenic CO_2 emissions

In national GHG inventories under the UNFCCC, the estimations of the emissions and removals of CO_2 due to domestic biomass/biofuel production are based on the changes in ecosystem carbon stocks (above-ground and below-ground biomass, dead organic matter and soil organic matter). Net losses in total ecosystem carbon stocks are used to estimate CO_2 emissions to the atmosphere, and net gains in total ecosystem carbon stocks are used to estimate removal of CO_2 from the atmosphere. The term 'carbon neutrality' used in this guidebook in relation to biomass/biofuels considers that the net gains are equivalent to the net losses – that is, that the CO_2 emissions to the atmosphere associated with end-user energy use/consumption are entirely compensated by the CO_2 removals of productive land.

Box 9. Further guidance and materials on how to account for biogenic CO_2

— See the IPCC report 'Good practice guidance for land use, land-use change, and forestry' (IPCC, 2003) and Volume 4 of the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC, 2006). These sources provide guidance on activity-specific issues relating to identifying land areas and estimating carbon stock changes and emissions/removals of CO_2 and non-CO_2 GHGs.

— See the Renewable Energy Directive (Directive (EU) 2023/2413) on sustainability criteria for biofuels and biomass and on GHG emission accounting for renewable energy sources.

— See the Biograce GHG calculation tool (http://www.biograce.net/home), which is one of the voluntary schemes recognised by the European Commission to report EFs within the framework of the Renewable Energy Directive. It uses up-to-date input values provided by the JRC based on consultation and interaction with fuel producers.

— See the JRC report *The use of woody biomass for energy production in the EU* (Camia et al., 2020) on the value chain of wood-based biomass, including available data sources and the climate change impacts of the different forest management practices.

— See the JRC report *Solid and Gaseous Bioenergy Pathways* (Agostini et al., 2017) describing the input data, assumptions and methodological approach for calculating GHG emissions for different biomass pathways.

— See the special report *Renewable Energy Sources and Climate Change Mitigation*, in particular Section 2.5.3 'Modern bioenergy: Climate change including land use change effects' (Edenhofer et al., 2012).

The JRC dataset on 'CoM emission factors for local energy use' includes EFs for bioenergy sources under 'Renewable energy sources'. In the activity-based approach, two EFs are provided, one excluding biogenic CO_2 emissions (assuming carbon neutrality) and another including biogenic CO_2 emissions.

In the activity-based approach, EFs considering zero CO_2 emissions should be applied if the biofuels/biomass meet the above carbon neutrality criteria (cn). For fuels that do not meet carbon neutrality criteria (e.g., in the case of declining carbon stocks in a forest), EFs should reflect biogenic CO_2 emissions, above zero (i.e., those that are not carbon neutral (ncn)). Signatories may use intermediate values, based on the carbon stock changes of the ecosystems, if adequate information is available on harvesting, production and supply of biofuels/biomass. These details should be clearly documented in the SECAP.

5.2 GHG emissions associated with local generation and supply of electricity

The reduction of indirect emissions associated with electricity under the CoM framework should focus on increasing local electricity generation from RES, which can be reinforced by additional actions (e.g., purchases and sales of certified 'green' electricity). In order to estimate and account for GHG emissions (and benefits) associated with local electricity generation, a local energy emission factor for electricity ($LEEF_{EL}$) is calculated. The $LEEF_{EL}$ takes into account the following components:

a. the GHG EF for grid-supplied electricity (e.g., the national grid mix EF);

b. indirect GHG emissions from the local generation and supply of electricity;

c. the use of certified 'green' electricity.

Even when no measures affecting local generation and supply of electricity are envisaged in the SECAP, the CoM framework recommends that signatories calculate and include the $LEEF_{EL}$. However, if the municipality does not envisage actions affecting local electricity generation and supply, it may be excluded. In this case, figures on local electricity generation and the associated GHG emissions shall be zero.

5.2.1 GHG emission factors for grid-supplied electricity

The EF for grid-supplied electricity shall be used as a starting point to calculate the $LEEF_{EL}$. This is typically a national electricity EF calculated by dividing overall GHG emissions of grid-supplied electricity by the total electricity supplied, and it considers all emissions from primary energy inputs (sources/carriers) for electricity generation and supply. As part of the EFs for local energy use, the JRC collection provides yearly EFs for national grid-supplied electricity from 1990 onwards for all Member States and several other countries and regions. In the JRC EFs, electricity generated by 'main activity producers' and 'autoproducers' is included, for both electricity-only and CHP plants. In the case of CHP plants, the fuel inputs and related emissions are allocated to heat and electricity generation, as described by Bastos et al. (2024).

The following considerations should be taken into account:

- Signatories may use the latest EF datasets available from the JRC's 'COM data collection', or any other grid-supplied electricity EFs from a reliable reference source.
- In cases where the EF for national grid-supplied electricity shows significant differences from year to year, the CoM framework recommends using an average value over a 3-year period in CoM inventories, to limit the potential effects of short-term fluctuations.
- EFs for national grid-supplied electricity may change across CoM inventories (e.g., between the BEI and MEIs) due to changes in the electricity generation mix and associated GHG emissions. It is important, however, to use reliable EFs and data from reference organisations.[25] A constant factor may also be considered to highlight changes in GHG emissions resulting solely from changes in local demand/use and that are thus closely linked to local action and efforts.

5.2.2 Indirect GHG emissions from local generation and supply of electricity

All plants that are to be included in the local generation and supply of electricity (see Section 4.4) should be listed, together with the corresponding data on electricity generated locally (local electricity, LE, in MWh), primary energy inputs for electricity generation and corresponding GHG EFs.

Waste-to-energy plants with electricity generation are treated similarly to any other power plants (whereas waste treatment without energy recovery is included in the waste management sector). In the case of CHP plants, the allocation of energy inputs and GHG emissions between electricity and heat is needed, as explained in Annex 3.

Local electricity generation from renewable and non-renewable energy sources, and the corresponding GHG emissions, should be disaggregated by source/carrier and/or type of power plant. For convenience, similar generation units may be grouped (such as photovoltaic or CHP units). Then, for each type of local electricity generation, GHG emissions are calculated as follows:

$$GHG_{LE} = LE \times EF$$

where:

GHG_{LE} = GHG emissions associated with local electricity generation (t CO_2 or t CO_2-eq)

LE = local electricity generation (MWh)

EF = GHG emission factor (in t CO_2/MWh or t CO_2-eq/MWh)

EFs for the different sources/carriers of local electricity can be based on any reliable source, including the JRC CoM data collection.

[25] If the SECAP considers prospective (future) EFs when setting the GHG reduction target and estimating the GHG reductions of its actions, it should provide detailed data on the development trends of the electricity generation mix and GHG emissions to support the prospective EF definition.

5.2.3 Use of certified 'green' electricity

CoM inventories should include data on certified 'green' electricity (CE) purchased from outside the local territory as well as certified electricity generated within the local territory and sold to third parties outside its administrative boundaries. Certified 'green' electricity is the electricity identified through disclosed attributes such as guarantees of origin (GO) and other tracking instruments that meets the criteria for the guarantee of the origin of energy produced from renewable sources set in the Renewable Energy Directive (Directive (EU) 2023/2413). Essentially, instead of purchasing the 'average mix' grid-supplied electricity, the municipality and other local actors may purchase certified 'green' electricity.

The amount of certified electricity that will be used in the calculation of the $LEEF_{EL}$ is the 'certified electricity use' ($\sum CE$):

$$\sum CE = \sum CE_{purchased} - \sum CE_{sold}$$

where:

$\sum CE$ = certified electricity use (in MWh)

$\sum CE_{purchased}$ = amount of certified electricity purchased (in MWh) from outside the local territory (not accounted for under local generation and supply of electricity)

$\sum CE_{sold}$ = amount of local electricity generation (in MWh) that is sold with certification for use outside the local territory – that is, locally generated electricity (in accordance with the criteria for inclusion in local generation and supply of electricity in Sections 3.3 and 4.4), for which a guarantee of the origin of electricity produced is sold to third parties outside the administrative boundaries.

The electricity supplied/sold and the corresponding guarantee of origin should be obtained from the supplier(s), who shall provide a certificate of origin as defined under the Renewable Energy Directive, or other independent reliable evidence that that electricity has been generated from RES or using high efficiency cogeneration.

! Local energy generation that is supplied to third parties and/or with final use or consumption outside the local territory shall not be considered in CoM inventories.

5.2.4 Calculation of the $LEEF_{EL}$

Based on the considerations, definitions and assumptions presented in Sections 5.2.1 to 5.2.2, the $LEEF_{EL}$ shall be calculated as follows.

(a) If the total electricity consumption is higher than the sum of the total local electricity generated and the total certified electricity use (i.e., $TCE - \sum LE - \sum CE$) is higher than 0:

$$LEEF_{EL} = \frac{(TCE - \sum LE - \sum CE) \times EF_{EL} + \sum GHG_{LE} + \sum GHG_{CE}}{TCE}$$

(b) If the total electricity consumption is lower than the sum of the total local electricity generated and the total certified electricity use (i.e., $TCE - \sum LE - \sum CE$) is lower than 0:

$$LEEF_{EL} = \frac{\sum GHG_{LE} + \sum GHG_{CE}}{\sum LE + \sum CE}$$

where:

$LEEF_{EL}$ = local energy emission factor for electricity consumption (in t CO_2/MWh or t CO_2-eq/MWh)

TCE = total electricity consumption (in MWh) in the local territory (in final energy use data)

$\sum LE$ = total local electricity generation (MWh)

$\sum CE$ = certified electricity use (in MWh)

EF_{EL} = emission factor for grid-supplied electricity (in t CO_2/MWh or t CO_2-eq/MWh)

$\sum GHG_{LE}$ = GHG emissions associated with local electricity generation (in t CO_2 or t CO_2-eq)

$\sum GHG_{CE}$ = GHG emissions associated with certified electricity use (in t CO_2 or t CO_2-eq)

If an activity-based approach is used (see Section 2.4), the EF for certified electricity use shall be zero. If the LC-based approach is used, a GHG EF should be provided by the certified electricity provider(s) or calculated by applying LC-based EFs for local renewable electricity generation sources. If the municipality chooses not to account for local electricity generation and/or certified electricity use in the CoM inventory, the first formula (a) may be applied, with the corresponding figures set to zero.

Transport, distribution and transmission losses are not included, auto-consumption of energy producers/transformers may be excluded, and local electricity generation may be double counted (as it may be included in the national grid-supplied EF). However, these approximations are expected to have minor effects on the $LEEF_{EL}$ and CoM inventories.

Note that the $LEEF_{EL}$ shall not have a negative value. As such, GHG emission reductions may only be accounted for in MEIs until the $LEEF_{EL}$ equals zero.

5.3 GHG emissions from local generation and supply of heat/cold

A local energy emission factor for heat/cold ($LEEF_H$ or $LEEF_C$, hereafter $LEEF_{H/C}$) should be calculated considering:

- generation of heat/cold in the local territory and the associated GHG emissions;
- imports of heat/cold from other locations to use in the local territory and the associated GHG emissions;
- exports of heat/cold generated in the local territory and used outside and the associated GHG emissions.

The $LEEF_{H/C}$ shall be calculated as follows:

$$LEEF_{H/C} = \frac{\sum GHG_{LHC} + \sum GHG_{ImpHC} + \sum GHG_{ExpHC}}{TCHC}$$

where:

$LEEF_{H/C}$ = local energy emission factor for heat or cold (in t CO_2/MWh or t CO_2-eq/MWh)

$\sum GHG_{LHC}$ = GHG emissions associated with generation of heat/cold in the local territory (in t CO_2 or t CO_2-eq)

$\sum GHG_{ImpHC}$ = GHG emissions associated with imported heat/cold from outside the local territory (in t CO_2 or t CO_2-eq)

$\sum GHG_{ExpHC}$ = GHG emissions associated with exported heat/cold from the local territory (in t CO_2 or t CO_2-eq)

TCHC = total consumption of heat/cold (in MWh) in the local territory (in final energy use data)

In the case of CHP plants, the allocation of energy inputs and GHG emissions between electricity and heat is needed, as described in Annex 3.

District cooling (i.e., purchased chilled water) is in principle a similar product as purchased district heating. However, the process to produce district cooling is different from the process to produce district heating, and there is greater variability in generation processes. If there is local district cooling, information on the use of energy sources/carriers and GHG emissions should be provided by the district cooling supplier to calculate and apply adequate EFs.

5.4 GHG emissions associated with waste and wastewater management

The CoM framework recommends that signatories tackle in the SECAP and include in CoM inventories direct GHG emissions associated with waste and wastewater management. GHG emissions associated with waste and wastewater treatment should be aligned with the IPCC's 2006 guidelines and their 2019 refinement (Volume 5 on 'Waste') (IPCC, 2006, 2019). Further detailed guidance and data may draw on GHG accounting frameworks from reliable reference organisations, such as the *Global Protocol for Community-scale Greenhouse Gas Inventories* (WRI et al., 2021).

EFs reflecting direct GHG emissions for waste and wastewater treatment shall be calculated by waste type and treatment. The same calculations and EFs apply regardless of the inventory approach (i.e., for both activity- and LC-based approaches), but it is particularly important for inventories including emissions associated with waste and wastewater management to go beyond CO_2 emissions and include (at least) the three reference GHGs: CO_2, CH_4 and N_2O.

This section provides guidance on the calculation and application of EFs for waste and wastewater treatment for solid waste disposal, biological treatment of organic solid waste and domestic wastewater treatment. In 2022, 39% of waste generated in the EU was treated without recovery (including recycling, backfilling and energy recovery); of this, about 78% was landfilled, 1% was incinerated and 8% went through other types of treatment. [26]

5.4.1 Solid waste disposal

GHG emissions associated with solid waste disposal are usually dominated by methane (CH_4) emissions. These significantly depend on the mass of waste disposed of and on waste composition, particularly on its degradable organic content (DOC).

Alternative approaches may be applied to estimate CH_4 emissions associated with solid waste disposal, including the 'methane commitment' and the 'first order of decay' approaches (WRI et al., 2021). In brief, the 'methane commitment' approach may be used to estimate GHG emissions associated with the waste generated and disposed of in landfills in a reference (inventory) year, regardless of when these emissions occur (GHG emissions will occur in the reference and subsequent years). The 'first order of decay' approach may be used to estimate GHG emissions occurring in a reference (inventory) year, regardless of when this waste was generated and disposed of in landfills (GHG emissions in this year are associated with waste disposed of in the same and previous years).

CoM inventories should use the '*methane commitment'* approach and account for GHG emissions associated with waste generation and disposal in the reference year. This is recommended in the CoM context to (directly) reflect local efforts and action, which – in line with the waste management hierarchy – should prioritise waste prevention (i.e., reducing waste generation).

An EF for CH_4 emissions shall be calculated for municipal solid waste (MSW) and industrial solid waste disposal, considering:

- mass of generated solid waste disposed of in landfills [27] (in t)
- methane generation potential (L_0)
- the landfill characteristics, considering the fraction of CH_4 recovered (f_{rec}) and an oxidation factor (OX).

First, the **degradable organic content (DOC)** of the solid waste stream should be estimated and used to calculate a **methane generation potential (L_0)**. Then, **CH_4 emissions associated with the disposal of MSW** can be calculated.

[26] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Waste_statistics

[27] Solid waste disposal sites (SWDS)

Degradable organic content (DOC) of solid waste

The DOC of a solid waste stream consists of the amount of carbon per unit of waste (e.g., expressed as kg C/kg waste). It may be estimated by calculating a weighted average of the carbon content of various fractions of the solid waste (by multiplying the share of all its waste fractions) – such as the share of food waste, paper and textiles and non-organic waste - and the corresponding fraction of DOC. Default DOC coefficients for MSW and industrial waste fractions are available from the IPCC (2019, Tables 2.4 and 2.5, respectively).

Methane generation potential (L_0)

The methane generation potential (L_0) expresses the potential of the generated waste to produce CH_4, and it may be calculated as:

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

where:

L_0 = CH_4 generation potential

MCF = methane correction factor (ranging from 0.4 to 1.0; 0.6 may be used as the default)

DOC = degradable organic content of solid waste (described above)

DOC_F = fraction of degradable organic content that decomposes (0.6 as default value)

F = fraction of methane in generated landfill gas (0.5 as default value)

16/12 is the molecular weight ratio of CH_4 and carbon

The MCF reflects the effect of site management on the amount of CH_4 that will be emitted: generally, an unmanaged landfill produces less CH_4 than a managed landfill for the same amount of waste (IPCC, 2006). The IPCC provides default MCFs from 0.4 to 1.0 for unmanaged to managed landfills, and a default 0.6 value may be used for 'uncategorised sites' (IPCC, 2006, Table 5.1).

The DOC_F is the fraction of DOC that is ultimately degraded. If waste composition data is available, default DOC_F values should be used for the corresponding waste types, ranging from 0.1 to 0.7 (IPCC, 2019, Volume 5, Chapter 3, Table 3.0). Otherwise, a default value of 0.6 may be used.

Methane emissions associated with the disposal of municipal solid waste

CH_4 emissions for MSW disposal should be calculated as:

$$CH_4 = MSW \times L_0 \times (1 - f_{rec}) \times (1 - OX)$$

where:

MSW = mass of solid waste disposed of in landfills (e.g., in t)

L_0 = methane generation potential (e.g., in t CH_4/t waste)

f_{rec} = fraction of methane recovered

OX = oxidation factor (0 as default value)

The OX expresses the amount of CH_4 that is oxidised in the soil or other material covering waste. The default IPCC OX value for 'managed, unmanaged and uncategorised landfills' is 0 if the landfill is not covered with aerated material, and 0.1 for managed landfills covered with CH_4 oxidising material (IPCC, 2019, Volume 5, Chapter 3, Table 3.2). Any CH_4 recovered must be subtracted from the amount of CH_4 produced, before applying the OX.

Illustrative example

If MSW is composed of 40% food waste, 20% garden and park waste, 20% paper waste, 10% wood waste, and 10% textile waste; and default carbon content values from the IPCC are applied (IPCC, 2006, Volume 5, Table 2.4), the DOC may be calculated as:

$$DOC = 0.40 \times 0.38 + 0.20 \times 0.49 + 0.20 \times 0.44 + 0.10 \times 0.50 + 0.10 \times 0.30$$

where:

DOC = degradable organic content of solid waste (in kg C/kg waste)

Methane generation potential (L_0)

The methane generation potential (L_0) may be calculated as:

$$L_0 = 0.6 \times DOC \times 0.6 \times 0.5 \times 16/12$$

where:

0.6 is a default methane correction factor (MCF) (0.4 to 1.0, depending on site management)

DOC = degradable organic content of solid waste (calculation described above)

0.6 is a default value for the fraction of DOC that is ultimately degraded (DOC_F)

0.5 is a default value for the fraction of methane in landfill gas

16/12 is the molecular weight ratio between CH_4 and carbon.

Methane emissions associated with the disposal of MSW

CH_4 emissions for MSW disposal may be calculated as:

$$CH_4 = MSW \times L_0 \times (1 - f_{rec}) \times (1 - 0)$$

where:

MSW = mass of solid waste disposed of in landfills (in t)

L_0 = methane generation potential (calculation described above)

f_{rec} = fraction of methane recovered at landfills

1 – 0 subtracts the oxidation factor (OX), considering 0 as the default value for OX

5.4.2 Biological treatment of solid waste

As mentioned, GHG emissions associated with the composting and anaerobic digestion of organic solid waste should include CH_4 and N_2O, aggregated into t CO_2-eq with IPCC GWP values (see Section 5). Default EFs for biological treatment of organic solid waste are provided in Table 8, calculated by multiplying the IPCC default EFs for CH_4 and N_2O (IPCC, 2006) by the corresponding IPCC GWP values (IPCC, 2021).

If there is gas recovery from anaerobic digestion, the corresponding CH_4 emissions should be subtracted. If the gas is used locally to generate energy, it should be considered in the 'Local energy generation and supply' section of the CoM inventory.

Table 8. GHG EFs for the biological treatment of organic solid waste

Biological treatment	**GHG EFs (t CO_2-eq/t waste)**	
	Dry waste	Wet waste
Composting	0.434	1.092
Anaerobic digestion at biogas facilities	0.054	0.218

Source: JRC analysis, based on IPCC (2006, 2021).

5.4.3 Domestic wastewater treatment

GHG emissions from domestic wastewater treatment include CH_4 and N_2O. Domestic wastewater treatment EFs for CH_4 and N_2O depend on the composition of wastewater, namely on the quantity of organic matter in wastewater and on the quantity of nitrogen, which depends on the population's protein consumption.

As such, the CoM framework recommends the use of city-specific inputs and data to calculate GHG emissions associated with wastewater treatment, otherwise, the IPCC provides default values to estimate GHG emissions associated with wastewater treatment (IPCC, 2006, 2019).

For CH_4, the organic content of domestic wastewater should be first calculated as:

$$ORG_{WW} = Population \times BOD \times 1.25$$

where:

ORG_{WW} = total organic content in domestic wastewater (in kg BOD/year)

Population = municipality population

BOD = biochemical oxygen demand (BOD) (in kg/person-year)

1.25 is a default correction factor for additional industrial BOD (a value between 1.00 and 1.25 may be used, for collected and uncollected wastewater, respectively)

CH_4 emissions per kilogram of BOD depend on:

- the maximum CH_4 producing potential (B_0), which is a function of the quantity of organic matter in wastewater (and of the resulting biochemical oxygen demand, BOD), and
- a methane correction factor (MCF), which is specific of the treatment and discharge system.

CH_4 EFs expressed as kg CH_4/kg BOD for a given domestic wastewater treatment should be calculated as (IPCC, 2019):

$$EF = 0.60 \times MCF$$

where:

EF = CH_4 emission factor in kg CH_4/kg BOD

0.60 is a default value for the maximum CH_4 producing potential (B_0) in kg CH_4/kg BOD

MCF = methane correction factor (default values for a set of sludge treatments are available in IPCC (2019, Table 6.3).

N_2O emissions associated with wastewater treatment can be estimated based on the population's protein consumption, applying a default EF of nitrogen emissions per kilogram of protein.

Further details for calculating GHG emissions associated with wastewater treatment are provided in IPCC (2006, 2019) and in WRI et al. (2021).

6 Documentation and reporting of GHG emissions

CoM inventories are a key element of a SECAP. Specifically, the GHG mitigation pillar of a SECAP draws on a baseline emission inventory (BEI), the GHG emission reduction target, a set of climate change mitigation actions and the estimated energy savings and GHG emission reductions to be achieved by those actions by the target year. Then, monitoring emission inventories (MEIs) should be prepared regularly to track progress.

The data collection process, data sources and methodology for calculating GHG emissions and preparing CoM inventories should be well documented, publicly available and consistent throughout the years. Consistent, transparent and robust GHG emission inventories and data improve trust in and uptake of GHG mitigation actions and enable their adequate design, implementation, monitoring and evaluation. Table 9 provides an overview of the elements that should be included in accompanying documentation when preparing a CoM inventory.

Table 9. Overview: elements CoM inventory documentation and the related sections in this document.

Key information	Description	Related sections
Geographical boundaries	The local territory should be adequately identified, including name/scope and geographical boundaries (e.g., NUTS code, a map of the municipality).	2.3
Baseline and reference year	The SECAP includes a baseline year (e.g., 2005) and a target year (e.g., 2030). A reference year is selected for each inventory (BEI and/or MEI).	2.4
Emission reduction target	The SECAP sets an emission reduction target in (as a percentage). Targets can be defined on an 'absolute' or 'per capita' basis.	2.4
Population	Population in the inventory's reference year should be provided. This document includes guidance on how to consider potential population changes when establishing a reduction target.	2.4
Inventory approach	The approach (e.g., activity-based or an LC-based) should be clearly described, including all relevant methodological choices, assumptions, EFs and any changes (e.g., in scope or methodology) since a previous inventory.	2.4 5
GHGs	The documentation should clearly identify which GHGs are accounted for (e.g., CO_2, N_2O, CH_4).	2.4
Units	All units should be clear, including activity data (e.g., figures for energy in MWh and for waste generation in t), EFs (e.g., t CO_2 or t CO_2-eq per MWh of energy or per t of waste) and the related GHG emissions (t CO_2 or t CO_2-eq).	3
Activity sectors and emission sources	The documentation should describe the CoM activity sectors considered and relevant activities and emission sources, together with the rationale/choices made regarding the inclusion or exclusion of sectors, activities or sources.	2.4 3
Local energy generation	The documentation should include details on local energy generation, used to calculate the local energy emission factors (LEEFs), together with the rationale for inclusion or exclusion of any local energy generation units.	3.3 4.4
Emission factors	The documentation should include the EFs used and any related references/sources and calculations.	2.4 5
Data collection and analysis	The documentation should include all data sources and calculations (e.g., energy use, waste generation).	4
GHG emissions	The inventory should provide GHG emissions by activity sector, with a clear structure and an adequate disaggregation level. The documentation should include all details to allow for an adequate interpretation of data.	3

Source: JRC analysis.

It is important to document in detail the methodological choices, sectors and activities covered and the data collection process, data sources, EFs, tools, assumptions and calculations behind CoM inventories. All related documents and files should be carefully archived, to aid interpretation and ensure consistency when compiling subsequent inventories.

It is highly recommended that signatories prepare a detailed report (or section in a report) for each CoM inventory, with clear and complete details, as described in Table 9. This should also include information, discussion and comments, which may help with understanding and interpreting the inventory. For example, it may be useful to provide explanations of which drivers have influenced GHG emissions since previous reference years/inventories, such as economic conditions or demographic factors. Lastly, summary tables in SECAP documentation with key elements and figures may ease communication, reporting and transparency.

6.1 Reporting platforms and tools

This document provides general guidance on GHG emission accounting in the SECAP preparation and monitoring under the CoM framework. CoM signatories also commit to reporting data and information on their SECAP and its implementation through an officially recognised reporting platform, such as MyCovenant or CDP-ICLEI Track.

SECAP information and data reported on MyCovenant uses template tables, including CoM emission inventory tables. Input tables for activity data (e.g., final energy consumption by sector and by energy source/carrier), local energy generation and supply data and default EFs allow for the 'automatic calculation' of GHG emissions.

All information reported through online tools or platforms, including MyCovenant, should be aligned and consistent with that in the SECAP document approved by the local administration and with the guidance provided here.

Detailed guidance on online reporting through MyCovenant can be found on the CoM EU website.[28]

[28] https://eu-mayors.ec.europa.eu/en/resources/reporting

7 Conclusions

In the Covenant of Mayors for Climate and Energy (CoM) framework, signatories voluntarily commit to developing and implementing a Sustainable Energy and Climate Action Plan (SECAP), which includes the development of greenhouse gas (GHG) emission inventories. In brief, activity data (mostly on energy use) is collected and/or calculated for a set of urban sectors, and emission factors are then applied to estimate the GHG emissions associated with urban activities for a reference year.

To support local and regional authorities and robust climate change mitigation action, this document complements the CoM guidebook main document '*How to prepare a Sustainable Energy and Climate Action Plan (SECAP)*' and it provides detailed guidance on how to prepare GHG emission inventories under the CoM framework. It builds on the previous editions of the CoM guidebook, and it updates and improves guidance to enable a meaningful, accurate and sound estimation of GHG emissions in line with the CoM framework.

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List of abbreviations and definitions

Abbreviation	Definition
AFOLU	Agriculture, forestry and other land use
BEI	Baseline emission inventory
BOD	Biochemical oxygen demand
CH_4	Methane
CHP	Combined heat and power
C&D	Construction and demolition
CHP	Combined heat and power
CO_2	Carbon dioxide
CO_2-eq	Carbon dioxide equivalent
CoM	Covenant of Mayors for Climate and Energy
CoM EU	Covenant of Mayors for Climate and Energy - Europe
DOC	Degradable organic content
DOC_F	Fraction of degradable organic content that decomposes
EF	Emission factor
ETS	Emissions trading system
ETS2	Revised EU Emissions Trading System Directive
GHG	Greenhouse gas
GWP	Global warming potential
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial processes and products use
JRC	Joint Research Centre
LC	Life-cycle
LEEF	Local energy emission factor
$LEEF_{EL}$	Local energy emission factor for electricity
$LEEF_{H/C}$	Local energy emission factor for heat or cold
MCF	Methane correction factor
MEI	Monitoring emission inventory

Abbreviation	Definition
MSW	Municipal solid waste
N_2O	Nitrous oxide
NCV	Net calorific value
NUTS	Nomenclature of units for territorial statistics
OX	Oxidation factor
RES	Renewable energy source
SECAP	Sustainable energy and climate action plan
UNFCCC	United Nations Framework Convention on Climate Change
vkm	Vehicle-kilometre
VKT	Vehicle-kilometre travelled

List of boxes

List of figures

List of tables

List of tables in Annex 4

Annexes

Annex 1. Recalculation examples

In general, once an inventory has been compiled and accepted, it is used as a reference for monitoring progress and there should be no need to change it. However, as mentioned in Section 2.4, on some occasions the recalculation and updating of previous inventories may be needed during implementation to ensure consistency among inventories and adequate monitoring of progress and results.

This annex provides examples of recalculations associated with:

- the relocation of an industrial facility or activity;
- new information on emission factors (EFs);
- changes in the boundary, scope and coverage of inventories due to updates to guidance.

A1.1. Recalculation due to industry relocation

Emission reductions due to industry relocation shall not be considered in the CoM framework. Industry relocation includes the displacement of an industrial plant or facility or of some of its activities to another territory, for example. If the GHG emissions associated with the relocated facility or activity account for more than 1% of the baseline GHG emissions, a recalculation is needed to exclude these emissions from the BEI.

Considering for example a municipality that included GHG emissions associated with an industrial facility or activity (not covered by the EU ETS) in the BEI because the SECAP included actions to reduce their GHG emissions (e.g., by increasing energy efficiency in the plant), the displacement of this facility or activity to another location, or the closure of the facility or activity during SECAP implementation, should not result in energy savings or GHG emission reductions. The GHG emissions associated with this facility or activity would not be included in any subsequent monitoring GHG inventories, and therefore they should also be removed from the BEI and any previous MEIs.

It is important to ensure consistency over time and among GHG inventories, in this case by applying meaningful and consistent boundaries, scope and coverage.

A1.2. Recalculation due to new information on emission factors

Recalculation due to new information on EFs or methodological changes should be carried out if and when the new information enables a more accurate estimate and description of GHG emissions in the baseline year than the information that was previously used. However, if real changes in EFs occur between the baseline year and a monitoring year - for instance due to the use of different fuel types - then different EFs may be used, as they will correctly reflect the changed circumstances. In this case, recalculation is not needed.

For example, a municipality may use a default EF for calculating the emissions of combustion of a fuel used in district heating and learn during implementation, through the local district heating provider, that the fuel used in the territory actually has a different carbon content than the one considered in the default EF. The district heating provider may provide new information on the fuel that was used already in the baseline year and, in this case, the municipality may revise a previously submitted BEI (and any MEIs) to improve the GHG emission estimates based on the new information available.

This would increase the accuracy of GHG emission estimates, while maintaining consistency and comparability among GHG inventories across the implementation process.

A1.3. Recalculation due to the exclusion of a local power plant

Electricity produced locally within the territory should be considered through a local energy emission factor for electricity ($LEEF_{EL}$) in accordance with the guidance provided in Sections 3.4 and 4.3. If a small energy generation facility using fossil fuels and initially included in the BEI increases its capacity to above 20 MW during the implementation process, it should be excluded from subsequent CoM inventories. In this case, the corresponding activity and GHG emissions would have to be recalculated for the BEI and any previous MEIs.

Similarly to the example in Section A1.1 of this Annex, this is important to ensure consistency by applying meaningful and consistent boundaries, scope and coverage.

In this example, the situation changed in the municipality during SECAP implementation, but there are also cases where changes in the inclusion/exclusion of activities or GHG emissions result from an update to the guidance or criteria. If a change in terms of guidance or criteria is made that results in the exclusion (or inclusion) of a facility or activity that was included (or excluded), consistency should be ensured by revising previous inventories accordingly.

Annex 2. Summary of approaches, tools and data on road transport

A2.1. Common approaches for estimating final energy use and GHG emissions

Several approaches and methods for estimating final energy use in road transport have been developed, which may be associated with significant differences in terms of data requirements, calculation/analysis requirements and the level of information or detail provided. These can be divided into top-down and bottom-up approaches.

A commonly used top-down approach is the fuel sales method, which is primarily applicable at the national level and offers very basic and limited information at the local level. This method calculates on-road transportation emissions based on the total fuel sold within the city boundaries. In other words, the fuel sold within the territory is used as a proxy for road transport activity occurring in the local territory.

Unlike the fuel sales approach, bottom-up approaches based on transport and travel data can help identify priority areas for policy intervention. Many cities already apply bottom-up approaches in their local plans (e.g., in sustainable urban mobility plans). The main disadvantage of these approaches is that they often have higher resource requirements related to data collection and analysis.[29]

Bottom-up approaches

As mentioned, bottom-up approaches for estimating GHG emissions from road transport have higher requirements in terms of data collection and analysis than the fuel sales method, but they provide more detailed and useful insights for guiding local policies and planning. Three common approaches can be identified depending on the way energy use and GHG emissions are allocated to the local territory:

- **Territorial approach.** This approach is the recommended approach within the CoM framework, and it estimates energy use and GHG emissions associated with road transportation occurring within local boundaries, regardless of the trips' origin or destination or whether the driver is a resident of the municipality. In this approach, traffic counts are needed to estimate the number of vehicles traveling and their annual travelled distance, ideally by type of vehicle.
- **Resident activity approach.** This approach quantifies energy use and GHG emissions associated with road transport of residents, considering all their trips within, across or outside local boundaries. It requires information on resident vehicle kilometre travelled (VKT) from vehicle registration records and/or surveys on the travel behaviour of residents. Modest data collection and processing efforts are required to get relatively solid estimates, based on a combination of vehicle fleet registration, statistical data and surveys on residents' travel behaviour.

[29] For further insights into approaches, methods and data for estimating GHG emissions associated with road transport see, for example, ITF (2024) and Dünnebeil et al. (2012).

— **City-induced activity approach.** This approach draws on a more sophisticated methodology, and it identifies the underlying travel dynamics in the region in detail, which can be relevant for local, regional and national policymaking. Essentially, it uses advanced modelling to analyse road transport in a city and to evaluate the potential effects of actions (e.g., scenario analyses considering transport policies or urban planning decisions), but it requires a substantial amount of data on the road transport use of city residents and other travellers, which can be gathered through different sources, including data collection at major routes, big data (e.g., from smart phones) and satellite data.

A2.2. Examples of tools for estimating the GHG emissions of road transport

To develop a GHG emission inventory for the transport sector and to assess the direct and indirect GHG emission reduction potential of a bottom-up approach, there are a number of tools that can aid data analysis and processing, requiring only minimal data and no modelling efforts. These tools include:

— the European Environment Agency and Emisia's Copert4 road transport emission model (https://copert.emisia.com/);

— the Greenhouse Gas Protocol's GHG emissions from transport or mobile sources calculation tool (https://ghgprotocol.org/calculation-tools-and-guidance#sector_specific_tools_id);

— Google's Environmental Insights Explorer (https://insights.sustainability.google/).

Annex 3. Allocation of emissions between electricity and heat from CHP generation

It is important to divide GHG emissions associated with combined heat and power (CHP) generation, allocating shares to both heat and electricity outputs. The fuel use – and consequently the associated emissions - can be allocated based on the energy inputs required to produced heat and electricity separately (i.e., without cogeneration), considering:

$$GHG_H = \frac{\frac{Output_H}{\eta_H}}{\frac{Output_H}{\eta_H} + \frac{Output_{EL}}{\eta_{EL}}} \times GHG_{Total}$$

$$GHG_{EL} = GHG_{Total} - GHG_H$$

where:

GHG_{Total} is the total amount of GHG emissions associated with CHP generation (in t CO_2-eq)

GHG_H is the amount of GHG emissions associated with heat generation (in t CO_2-eq)

GHG_{EL} is the amount of GHG emissions associated with electricity generation (in t CO_2-eq)

$Output_{EL}$ is the amount of electricity generated (i.e., electricity output) (in MWh)

$Output_H$ is the amount of heat generated (i.e., heat output) (in MWh)

η_{EL} is the efficiency of electricity generation without CHP (national efficiency factors for electricity generation or the EU average may be used, as described next)

η_h is the efficiency of heat generation without cogeneration (the typical default value of 90% may be used)

Data from Eurostat Complete Energy balances[30] may be used to calculate the national efficiency of electricity generation without CHP. It can be calculated by dividing the sum of **Transformation outputs** for electricity for 'main activity producer electricity only' and for 'autoproducer electricity only' by the sum of their **Transformation inputs**.

[30] https://doi.org/10.2908/NRG_BAL_C

Annex 4. Municipal solid waste data by European region

Table A4.1. Annual generation of municipal solid waste (MSW) per capita and treatment shares

Region	MSW generation (t/capita)	Type of treatment (%)			
		Landfill disposal	Incineration	Composting	Other, unspecified
Eastern Europe	**0.37**	**71**	**6**	**4**	**19**
Bulgaria	0.52	74	0	0	26
Czechia	0.33	65	15	2	18
Hungary	0.45	70	10	4	16
Poland	0.32	62	0	7	31
Romania	0.36	76	0	10	14
Northern Europe	**0.48**	**47**	**20**	**9**	**24**
Denmark	0.76	3	48	18	31
Estonia	0.31	66	0	8	26
Finland	0.47	45	22	13	20
Iceland	0.48	72	8	5	15
Ireland	0.62	53	4	4	40
Latvia	0.32	91	0	1	9
Lithuania	0.40	86	0	2	12
Sweden	0.44	1	51	14	34
Southern Europe	**0.47**	**76**	**4**	**3**	**17**
Croatia	0.38	94	0	1	5
Greece	0.53	83	0	2	15
Italy	0.55	46	17	12	25
Malta	0.60	91	0	0	9
Portugal	0.52	62	19	7	11
Slovenia	0.49	57	1	2	40
Spain	0.51	62	9	12	18
Western Europe	**0.59**	**8**	**40**	**21**	**31**
Austria	0.56	30	35	32	30
Belgium	0.46	17	40	21	37
France	0.53	43	34	17	18
Germany	0.60	30	37	17	46
Luxembourg	0.68	27	36	19	27
Netherlands	0.57	11	49	24	25

NB: Data are based on weight of wet waste. Default data for 2010 was used, although for some countries the data for 2010 were not available (see data source).

Source: IPCC, 2019, Volume 5, Tables 2.1 and 2A.1 (values for 2010).

Table A4.2. Municipal solid waste composition (%)

Region	Food waste	Garden waste	Paper/ cardboard	Wood	Textiles	Nappies	Plastic	Metal	Glass	Other
Eastern Europe	31.8	2.4	17.1	2.5	3.1	0.1	4.6	0.7	1.8	35.9
Northern Europe	30.3	5.2	13.8	1.8	3.2	1.2	4.9	1.4	4.3	33.9
Southern Europe	37.3	2.2	19.2	1.4	3.2	1.1	11.8	1.9	3.6	18.3
Western Europe	33.2	2.7	17.2	2.3	5.9	3.0	20.5	1.5	1.4	12.3

Source: IPCC, 2019, Volume 5, Table 2.3.

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