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Guidebook 'How to develop a Sustainable Energy and Climate Action Plan (SECAP)'

PART 2 – Baseline Emission Inventory (BEI) and Risk and Vulnerability Assessment (RVA)

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PART 2 A
ELABORATING EMISSIONS INVENTORIES

1 Introduction

In these guidelines, advice and recommendations for compiling a Baseline Emission Inventory (BEI) and successive Monitoring Emission Inventories (MEIs) under the Covenant of Mayors for Climate & Energy (CoM) are provided. The BEI will show where the local authority (LA) was at the beginning (in its baseline year), and the successive MEI_S will show the progress towards the target. Elaborating these reference emission inventories is of critical importance, as they will be the instrument allowing the LA to measure the impact of its Sustainable Energy and Climate Action Plan (SECAP) and adjust it over time. They are also very important elements to maintain the motivation of all parties willing to contribute to the local authority's emissions reduction objective, allowing them to see the results of their efforts.

Some of the definitions, specifications and recommendations are unique to the inventories under the Covenant in order to enable the inventories to demonstrate the progress towards the target of the Covenant. As far as possible, the concepts, methodologies and definitions in internationally agreed standards are followed in these guidelines, while remaining flexible and adjustable to local authorities' needs and capacities. For example, the local authority is recommended to use an approach and emission factors that are in line with those of the Intergovernmental Panel on Climate Change (IPCC). However, the LA is also given the flexibility to use the Life Cycle Analysis (LCA) approach. In order to promote the exemplary role of the local authority, another particularity of the CoM methodology is to require emissions from municipal activities to be reported as separated activity sectors. Moreover, although the methodology mainly focuses on CO_2 (only compulsory gas), other greenhouse gases (GHGs) such as methane (CH_4) and nitrous oxide (N_2O) can also be accounted for in the case that the local authority decides to include them in the BEI and in the SECAP in general.

The CoM principles, concepts and methodologies to elaborate an emissions inventory are presented in Chapter 2, followed by recommendations and tips on the data collection of local sources of GHGs in energy-related activity sectors, with a focus on energy-related key sectors (see Chapter 3 and 4). The calculation of CO_2 or CO_2 equivalent emissions from the different activity sectors is explained in Chapter 5. Requirements in terms of documentation and reporting of the methodology and data are summarized in Chapter 6.

CHANGES FROM LAST EDITION

Apart from new requirements linked to the extension of the target to 2030, the CoM main specifications for building a local emission inventory as defined in the 2010 Guidebook (Bertoldi et al, 2010a) remain unchanged. Nevertheless, few criteria or definitions have been revised which are highlighted with an asterisk*.

The main methodological modification is the way the Local Electricity Production and the purchase of green electricity are defined and accounted for in the GHG emission inventories (section 3.3.1) and reported in the on-line templates (section 6.3).

Unlike in the 2010 guidebook, the CoM Default emission factors are not provided within the document, but as a link to the new on-line JRC CoM Emission Factors (COM-EFE) data collection (http://data.jrc.ec.europa.eu/collection/id-0083), in order to allow for regular and independent updates (section 5.1.1).

This updated version also provides a more extended description of the CoM methodology and further recommendations, as well as special caution notes ❗ in order to facilitate the understanding of the CoM specifications, peculiarities and rules.

The CoM reporting framework uses precise language to indicate which provisions are requirements and which are optional as follow:

- The term "shall" is used to indicate what is required (indicated as "mandatory").
- The term "should" is used to indicate a recommendation, so is not a requirement (indicated as "recommended").
- The term "may" is used to indicate an option that is permissible or allowable that local governments may choose to follow (indicated as "optional").

2 The Covenant of Mayors approach

2.1 Key concepts

In the compilation of the emission inventories and their on-line reporting ([1]) in the frame of the CoM initiative, the following key concepts are of utmost importance:

— Local territory: Geographic jurisdiction/administrative territory of the signatory local authority (LA) (see section 2.3)

— Final energy consumption: Final energy consumption covers all energy supplied to the final consumer (end-user) for all energy uses. It is disaggregated into the final end-use activity sectors.

— Macro-sectors: CoM macro-sectors are the aggregated sectors of the emission inventories. The macro-sectors are:

- **"Buildings, equipment & facilities" (also hereafter referred to as "Buildings macro-sector" in this Guidebook)**
- **"Transport"**
- **"Energy supply"**
- **"Other non-energy related"**

— Activity sectors: Activity sectors are sub-sectors of the above-listed macro-sectors. They are the ones to be included in BEI/MEI inventories and reported in the on-line reporting template (commonly called "SECAP template").

— Key sectors: four key sectors shall be included in the emission inventories:

- **Municipal buildings, equipment/ facilities**
- **Tertiary (non-municipal) buildings, equipment/facilities**
- **Residential buildings**
- **Transport([2])**

— Energy carrier: It refers to the form of energy input (electricity, heat/cold, fossil fuel, municipal waste or renewable energy) required by the energy-related activity sectors of the society to perform their functions. The main *energy carriers* as defined in the frame of the CoM are described in section 0.

— Activity data: Activity data quantifies the human activity occurring in the local territory. The main activity data in the CoM key *sectors* (see chapter 3) are related to *Final energy consumption* and are expressed in MWh per inventory year.

— Emission factors (EF): Emission factors [in tCO_2/MWh or tCO_2-eq/MWh] are coefficients which quantify the emissions per unit of activity (see sections 5.1 and 5.2).

— Emission inventories: Emission inventories quantify the amount of CO_2 or GHG emissions (reported in CO_2 equivalent) in the local territory in a given year. The emission inventories can be built up by multiplying the emission factors with corresponding activity data for each activity sector.

— Baseline year: *The baseline year* (see section 2.4.1) is the year against which the achievements of the emission reductions in 2030 shall be compared.

— Baseline Emission Inventory: The BEI quantifies the amount of CO_2 emitted in the key sectors and other activity sectors opted for reporting in the local territory for the

([1]) http://www.eumayors.eu
([2]) Note that Transport is both a macro-sector and a key sector, while the other key sectors are activity sectors in the buildings macro-sector

baseline year. It allows to identify the principal anthropogenic sources of CO_2 (and other GHGs) emissions and to prioritise the reduction measures accordingly.

— Monitoring Emission inventory: In addition to the inventory of the baseline year (BEI), emission inventories will be compiled for the later years, at least every four years, to monitor the progress towards the reduction target. Such an emission inventory is called Monitoring Emission Inventory (MEI). The MEI shall follow the same methods and principles as the BEI (see section 2.5). Moreover, every two years from the submission of the SECAP (emission inventories and climate and energy action plans), signatories are required to update the status of implementation of actions reported in the energy and climate action plans.

2.2 Guiding principles

The Sustainable Energy and Climate Action Plan (SECAP) ([3]) should be elaborated based on a sound knowledge of the local situation in terms of energy and greenhouse gas emissions. The Covenant proposes a methodology for building emission inventories which:

— focuses on final energy consumption in the activity sectors under the direct influence of the LA,

— focuses on the geographical jurisdiction of the local authority signatory,

— allocates emissions to the consumption side,

— encourages bottom up collection of data,

— allows for monitoring the progress toward the target.

The BEI/MEI ([4]) should conform to the following principles:

— Relevance: The BEI/MEI data should allow assessing final energy consumption and CO_2 emissions by energy carrier and by activity sector. They should be relevant to the particular situation of the local authority. Signatories are encouraged to prefer local data over national/European estimates – whenever relevant and available – as it allows reflecting the efforts made by LAs to reach its CO_2 reduction targets.

— Flexibility: The methodology is based on the principles of simplicity of use and flexibility to suit various regional and local situations, and accommodate cities of various sizes and resources, reflecting the specific activities and policy-making needs of the city by taking into account its capacity and regulatory context

— Sector coverage: The BEI/MEI shall cover the CoM key sectors. The emission inventory also should include other activity sectors in the scope of the CoM, for which the signatory plans to include actions in its SECAP (see chapter 3).

— Completeness: The CoM BEI/MEI inventories are not meant to be exhaustive GHG inventories but to focus on emissions from final energy consumption in CoM key sectors. In order to be complete, the BEI/MEI shall cover all emission sources under the scope of CoM in these sectors. Only complete data will allow for assessing the mitigation performance of the individual CoM signatories and for compiling relevant statistics at EU level in terms of climate mitigation in CoM territories.

— Availability: The data should allow building emission inventories until the target year. Therefore the sources of data used should be available in the future: it is important to identify from the beginning all the data sources, including departments and external stakeholders that will be able to provide data over such a long time period.

— Accuracy: Within the limits of possibility, the BEI/MEI should be accurate, or at least represent a vision of the reality. This requires, in particular, using reliable local

([3]) see Part I of the guidebook on how to elaborate a SECAP
([4])"BEI/MEI" is used when describing issues which are common for both BEI and MEI

activity data and robust methodologies, based on internationally agreed definitions, standards and emission factors, including those presented in this Guidebook.

— Consistency: The methodology, data sources and emission factors should be in line with CoM specifications and consistent through the years. When defining the methodology it is important to ensure a consistent choice of the different options (section 2.4), some of which are inter-related (section 2.6).

— Documentation: The data collection process, data sources and methodology for calculating the BEI should be well documented, if not in the SECAP official document ([5]), then at least in the local authority's records. The methodological choices as defined in section 2.4 and the main aggregated results of the BEI/MEI used to fill-in the on-line template (see section 6.3) should be reported in the SECAP document.

2.3 Boundaries, scope and sectors

The CoM focuses on reducing the energy consumption in the local territory but also matching energy demand with supply of sustainable energy by improving energy efficiency and promoting the use of local renewable energy resources.

The geographical boundaries of the "local territory" are the administrative boundaries of the entity (municipality, region) governed by the local authority which is a signatory to the CoM. The signatories are encouraged to use the Nomenclature of Units for Territorial Statistics (NUTS([6])) standard developed and regulated by the European Union(EU) as a reference.

The BEI/MEI shall cover the CoM key sectors. It is also recommended to include in the BEI/MEI and in the SECAP other activity sectors in the scope of the CoM in which the LA intends to take action, so that the result of those actions can be reflected in the inventory. While the baseline CO_2 inventory will essentially be based on final energy consumption, some non-energy related activity sectors may also be included. The 3 main types of GHG emissions to be potentially included in the BEI/MEI are:

(a) Direct emissions due to final energy consumption. Reducing energy consumption in the local territory should be considered as the priority. The quantification of GHG emissions (mainly CO_2) due to energy consumption is split into the "Buildings, equipment/facilities and industry" and the "Transport" macro-sectors, both of which are mandatory. The direct emissions exclude those from the plants included in the *EU Emissions Trading System* (ETS)([7]).

(b) Indirect emissions related to grid supplied energy (electricity, heat, or cold) that are consumed in the local territory. Production of electricity and heat/cold consumed in the local territory may occur inside or outside the territory. The indirect emissions due to consumption of heat/cold and electricity are included in the BEI/MEI and reported in the "Buildings, equipment/facilities and industry" and the "Transport" macro-sectors (mandatory). Actions to reduce CO_2 emissions in the supply side are accounted for through the local emission factor for electricity and emission factors for heat/cold. Indirect emissions may cover electricity and heat/cold production plants involved in the EU ETS.

(c) Non-energy related direct emissions that occur in the local territory. It is not recommended to include in the BEI/MEI the non-energy related activity sectors unless measures to reduce the associated greenhouse gas (CO_2, CH_4 and N_2O) emissions are included in the SECAP.

The points a) and c) refer to emissions that physically occur in the local territory. Inclusion of these emissions follows the principles of the IPCC used in the reporting of the

([5]) see Part I of the guidebook on how to elaborate a SECAP
([6]) http://ec.europa.eu/eurostat/web/nuts/overview
([7]) https://ec.europa.eu/clima/policies/ets_en

national GHG inventories to the United Nations Framework Convention on Climate Change (UNFCCC, 2017). With the exception of the AFOLU (Agriculture, Forestry and Other Land Use) sector whose emissions are indirectly accounted for through the use of specific emission factors. These are based on the assumption of carbon neutrality of biomass/biofuels consumed in CoM key sectors. The emissions due to grid supplied energy (electricity and heat and cold) that are consumed in the local territory (b) are included in the BEI/MEI regardless of the location of the production (inside or outside of the local territory).

The above definition of the scope of the BEI/MEI ensures that all relevant emissions due to energy consumption in the local territory (except those covered by the EU ETS) are included. For signatories opting for the Life Cycle Assessment (LCA) approach, not only emissions from the use/consumption but also from the supply chains are accounted for (see 2.4.2). Detailed guidance on macro-sectors and activity sectors to be included in the BEI/MEI, ensuring that all the relevant emissions are reported but no double counting is taking place, is given in chapter 3.

2.4 Methodological choices

The CoM initiative allows local authorities to develop a mitigation action plan "*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., 2010a). With this principle in mind, the Covenant has developed a multi-option methodology, based on or adapted from existing standards and methods. The different options, some of which are inter-dependent, concern the choice of the baseline year, the emission inventory approach, the included GHG(s), the emission factors and the definition of the reduction target.

2.4.1 Baseline year

The baseline year is the reference year against which the emissions reduction target shall be compared to. Covenant signatories are free to choose the year for which they can get the most comprehensive and reliable data. However, as the EU commitments to reduce GHG emissions([8]) - by 20 % by 2020 (Kyoto Protocol) and by 40 % by 2030 (EU Nationally Determined Contribution, Paris Agreement) - refer to the year 1990. Signatories who would like to compare their emission reduction with the EU target are then invited to take 1990 as baseline year, provided they follow the following recommendations.

— New signatories may experience difficulties in obtaining sufficiently reliable data in order to compile an inventory for 1990. In such a case, the local authority may choose the closest subsequent year for which sufficiently comprehensive and reliable data are available. However, such an alternative baseline year should not be later than 2005([9])*****. The year 2005, which is the reference year in the EU Effort Sharing Decision ([10]) is also the one which has been the most commonly used by CoM EU signatories (Kona et al., 2017), indicating that data providers are having records for this year. In an exceptional case that a Signatory is unable to gather reliable data for any of the years between 1990 and 2005, it may use a later baseline year than 2005. Such a choice should be transparently justified in the SECAP.

— Signatories who already made a commitment for 2020 target shall continue to use the same BEI year for the 2030 target in order to ensure that 2030 commitment is a

([8]) The Kyoto Protocol entered into force in 2005 covers the period between 2008 and 2020. The Paris Agreement, entered into force in 2016 does not stipulate a common target nor baseline year, but "Nationally Determined Contributions" (NDCs).

([9]*) New criterion as compared to 2010 guidelines

([10]) The Effort Sharing Decision establishes binding annual greenhouse gas emission targets for Member States for the period 2013–2020. These targets concern emissions from most sectors not included in the EU ETS, such as transport, buildings, agriculture and waste (https://ec.europa.eu/clima/policies/effort_en) continuation of efforts towards the 2020 target. Changing the BEI year can be made only in exceptional circumstances, in which, using the original BEI year, it is not possible to compile a consistent time-series from BEI to 2030 (see 2.5).

Note that using 1990 as baseline year allows for an easier evaluation of the CoM achievements in the context of the objectives of the state of the Energy Union ([11]).

2.4.2 Emission inventory approach

Greenhouse gas direct and indirect emissions are calculated for each energy carrier by multiplying final energy consumption (see Chapter 4) by the corresponding emission factor (see Chapter 5). Two approaches can be adopted in the frame of the CoM to calculate these emissions: the activity-based and the *LCA* (Life Cycle Assessment) approach. Several reasons may be behind the decision of a local authority to adopt either the *activity-based* or *the LCA approach*. The different approaches indeed have different aims and consequently present different advantages and disadvantages, as summarised in **Table 1**.

- The activity-based approach, which is the one commonly used in the frame of the Covenant (94 % of the EU signatories and 90 % of the EU-28 CoM population as of September 2016). In this approach, all the CO_2 (or GHG) emissions that occur due to energy consumption within the territory of the LA, either directly (fuel combustion) or indirectly (consumption of electricity and heat/cold) are included. The GHG emissions are directly estimated from the carbon content of the fuel, though a small amount of carbon is un-oxidized (less than 1 %). It is the approach used for the national reporting in the frame of UNFCCC and it is compatible with the EU binding legislation on climate and energy ([12]). Most of the GHG emissions are CO_2 emissions, whereas emissions of CH_4 and N_2O are of secondary importance for the combustion processes in the residential and transport sectors (see 2.4.3).
- The LCA approach, which is also applied by CoM signatories in some EU countries. This is also an internationally standardised approach, originally developed for products' environmental footprints. It is particularly suitable for assessing potential trade-offs between different types of environmental impacts associated with specific policy and management decisions, as it includes the emissions from the whole supply chain and not only from the final combustion. This is of special relevance for biofuels and biomass ([13]) (see 5.1.3).

Another important aspect to be considered when choosing the inventory approach is the availability of data for completing the BEI. The activity-based one includes emissions occurring during fuel combustion and is based on the use of IPCC emission factors that are easily available. The LCA approach includes both emissions from the fuel combustion and those occurring in the production/supply chain, which can be particularly difficult to ascertain (Cerutti et al., 2013).

According to the emission inventory approach chosen and the key activity sectors to be tackled, the local authority has then to define the GHGs (only CO_2 or CH_4 and N_2O as well) to be included in the emission inventory, and the emission factors to be applied.

([11]) https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/building-energy-union
([12]) https://ec.europa.eu/clima/policies/strategies/2030_en
([13]) In these guidelines, biofuel refers to all liquid/gaseous biofuels and biomass to solid biomass.

Table 1. Comparison of activity-based and LCA emission inventory approaches

Advantage or specificity	Activity-based	LCA
Is compatible with the national reporting to the UNFCCC	X	
Is compatible with the monitoring of progress of 2030 climate & energy framework ([14]) and EU Effort Sharing Decision ([15]).	X	
All emission factors needed easily available	X	
Is compatible with carbon footprint approaches		X
Is compatible with Ecodesign and Energy Labelling 2009/125/EC and 2010/30/EU directives ([16])		X
Reflects the total environmental impact also outside the place of use, and further support the choice of the most climate-friendly biofuels/biomass		X
Tools available for local inventories	X	X

Source: JRC own elaboration

2.4.3 Greenhouse gases to be included

Three main long-lived GHGs might be considered in the Covenant: CO_2, CH_4 and N_2O. Inclusion of CH_4 and N_2O depends on whether measures to reduce also these greenhouse gases are planned in the SECAP, and also on the approach chosen (*activity-based* or life cycle assessment).

If the *activity-based* approach following the IPCC principles is chosen, and if only energy-related activity sectors are included in the BEI/MEI, it is sufficient to report only CO_2 emissions, because the importance of other greenhouse gases is small in the CoM *key sectors*. In this case, the box "tonnes CO_2" is ticked in the SECAP on-line template, under "emission reporting unit". However, also other greenhouse gases can be included in the BEI/MEI if the *activity-based* approach is chosen. For example, the local authority may decide to use emission factors that take into account also CH_4 and N_2O emissions from combustion. Furthermore, if the LA decides to include waste and/or wastewater management in the inventory, then the CH_4 and N_2O emissions shall also be included. In this case, the emission reporting unit to be chosen is "tonnes CO_2 equivalent".

In the case of the LCA approach, in addition to CO_2 other greenhouse gases may play an important role. Therefore, a LA that decides to use the LCA approach will likely include also other GHGs than CO_2 in the inventory, and select the emission reporting unit "tonnes CO_2 equivalent". If the local authority uses a methodology/tool that does not include any other GHGs than CO_2, then the inventory will be based on CO_2 only, and the emission reporting unit "tonnes CO_2" is chosen.

The emissions of other greenhouse gases than CO_2 are converted to CO_2-equivalents by using the Global Warming Potential (GWP) values, which shall be kept constant all along the SECAP implementation period (see chapter 5).

([14]) https://ec.europa.eu/clima/policies/strategies/2030_en
([15]) https://ec.europa.eu/clima/policies/effort_en
([16]) https://ec.europa.eu/growth/single-market/european-standards/harmonised-standards/ecodesign_en

2.4.4 Emission factors (EF)

After selecting the emission inventory approach, the local authority can either use local emission factors or default (national/EU/global) emissions factors, such as the IPCC (2006) and the CoM default emission factors provided in this Guidebook (see chapter 5 and Annex 7). When choosing the emission factors (EF), it is worth taking into account the following considerations:

- The CoM emission factors are available for the signatories to use and cover the most commonly used energy carriers. These emission factors are also regularly updated. The BEI/MEI EF should be relevant to the particular situation of the Local Authority (see CoM guiding principles in section 2.2). Therefore, if local authorities prefer to use local or country-specific emission factors or develop their own emission factors based on the detailed properties of the fuels used within their local territory, they are welcome to do so as long as such local emission factors are available and reliable. This can be ensured by following the IPCC (2006) guidelines on energy in the choice and development of emission factors([17]).
- For local authorities using the LCA approach, it is recommended to consider the applicability of the CoM default EF presented in these guidelines before using them for BEI/MEI, and to try to obtain case-specific data where appropriate. It is worth noting that obtaining information on the emissions upstream in the production process may appear challenging and that significant differences may occur even for the same type of fuel.
- New knowledge and technologies can lead to significant changes in the emission factors. In order to ensure the consistency of the time-series, the local authorities using CoM default/national/EU/global EFs shall apply the same emission factors to all BEI/MEI inventories, in order to identify the changes in local emissions that are due to local mitigation actions. Only when the changes in the emission factors reflect changes in the fuel used (e.g. change in fuel properties or using other fuels from the same category), the emission factors can vary between inventories.

2.4.5 Reduction target

In line with the European Union Energy strategy ([18]), the new target for the reduction of CO_2 or GHG emissions proposed by the Covenant of Mayors for Climate & Energy is at least a 40% reduction by 2030 (see Part I of this guidebook). The reduction target, to be achieved through the implementation of the actions for those areas of activity relevant to the local authority's mandate, is defined in comparison to a baseline year, which is set by the LA. While the emissions in the BEI/MEI and the reduction per action have to be calculated and reported as absolute emissions, the local authority can decide to set the overall CO_2 emission reduction target either as '*absolute*' or '*per capita*' reduction.

Setting an absolute reduction target only based on the BEI emissions in the baseline year is possible, simple and allows for an immediate assessment of the level of the targeted 2030 emissions. However, because it ignores any change in population, level of economic development and any other driver, it might lead to set an unappropriated target and action plan. Thus, tough not widely discussed in climate policy debates, population changes can have a significant effect on the capacity of territories to achieve similar near-term emissions. Therefore, in case reliable population projections are available and show a significant change in the population by 2030, it is recommended to use the *per capita* option.

Based on the accuracy CoM key principle, unless significant changes are expected by 2030 in the number of inhabitants in the local territory, the absolute reduction target approach can be used, which avoids adding a source of uncertainties (i.e., on the future population trend) in the calculation of emission reduction needed to reach the target. In

([17]) http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol2.html
([18]) http://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union

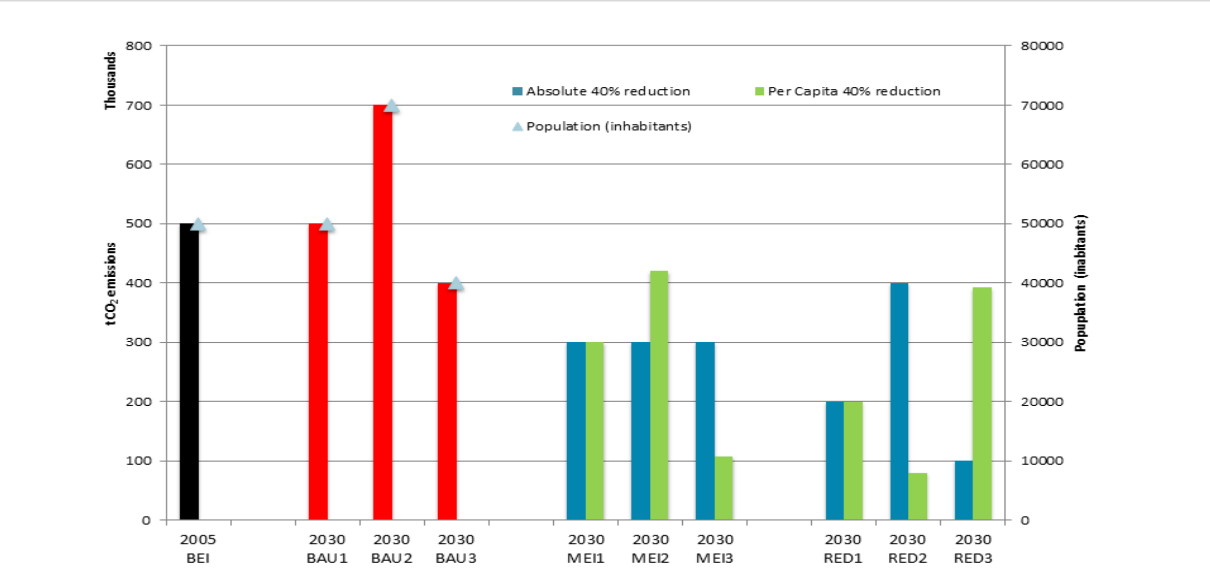
both cases (*absolute* or *per capita* target), the absolute emission reduction needed to achieve the target has to be assessed and should account for the changes in emissions that would place due to the change in population if any. A calculation that would not explicitly foresee an offset of the reduction in emissions due to the increase in population would underestimate the effort needed to achieve the reduction commitment. As illustrated in Box 1, choosing a per capita target requires less reduction effort than opting for an absolute target in case of expected increase of the population. In case of a strong decrease in population over the years, the signatory shall use a per capita objective rather than relying on the absolute decrease due to the decrease in population.

In case local population projections indicate significant changes by 2030, a per capita target should be used. Particular attention has to be paid when calculating the absolute CO_2 emission reduction needed in order to account for the changes in emissions that would take place due to the change in population and illustrated in Box 1.

Box 1. Estimation of the 2030 GHG emissions (MEI) and emissions reduction needed (RED) in case of absolute and per capita 40% reduction targets.

Example of a city of 50,000 inhabitants emitting 500,000 t CO_2 in 2005, assuming 3 different Business As Usual scenario (BAU) in which emissions are only driven by the population trend.

BAU1/MEI1/RED1: No change in population/emissions
BAU2/MEI2/RED2: Increase from 50000 to 70,000 inhabitants
BAU3/MEI3/RED3: Decrease from 50000 to 40,000 inhabitants



See Annex 1 for the calculation formula.

2.4.6 Activity sectors to be included in the BEI/MEI

Local authorities shall report final energy consumption and emission factors for all sources of emissions (direct and indirect and non-energy related) per sector and energy carrier. The classification of the subsectors is based on the jurisdiction of the different actors (municipal/public and private) and it does not recommend the inclusion of the GHG emissions generated by large industrial power plants (covered by cap and trade schemes or similar). Based on these principles LA reports GHG emissions from the three main macro-sectors, namely buildings/stationary energy, transportation, and other non-energy related contributing to the total emission accounting, while the energy supply macro-sector are accounted through the local emission factor for indirect emissions.

- **Buildings, equipment & facilities**

All GHG emissions (direct emission from fuel combustion and indirect emission due to consumption of grid-supplied energy) occurring in stationary sources (i.e. in buildings, equipment and facilities) within the local authority boundary shall be reported. These emissions come from final energy consumption in residential, commercial and municipal/institutional buildings and facilities, as well as from manufacturing, construction industries (below or equal to 20 MW as thermal energy input) and agriculture/forestry/fisheries. GHG emissions from "energy generation" industries/facilities should not be reported under this sector to avoid double counting of emissions.

- **Transport**

All GHG emissions (direct emission from fuel combustion and indirect emission due to consumption of grid-supplied energy) occurring for transportation purposes within the local authority boundary shall be reported. In addition, local authorities are recommended to further disaggregate by mode (on-road, rail, waterborne navigation and off-road) and by fleet type (Municipal, Public and Private and commercial transport). Local authorities are recommended to use the "geographic (territorial)" methodology to estimate activity data in the transport sector. In specific circumstances, other methodologies such as "fuel sales", "resident activity" and "city-induced" can be used (see Annex 4).

- **Other non - energy related**

All GHG emissions non-energy related from disposal and treatment of waste generated within the city boundary shall be reported and desegregated by waste management, wastewater management and other non-energy related. Where waste/wastewater is used for energy generation, emissions should not be reported under this sector to avoid double counting of indirect emission.

- **Energy Supply**

GHG emissions from generation of grid-supplied energy within the local authority boundary, and GHG emissions from generation of grid-supplied energy by facilities owned (full or partial) by the local authority outside the local authority boundary are recommended to be reported, disaggregated by electricity-only, CHP and heat/cold production plants. To avoid double counting, these emissions will not be part of the total direct emissions, but accounted through the local emission factor for indirect emissions.

2.4.7 Activity sectors to be preferably or explicitly excluded from the BEI/MEI

The mitigation commitment of the Covenant signatories is related mainly to the emissions associated with energy consumption in sectors which can be influenced by the local authority (housing, services and urban transport) leaving out other emitters such as ETS industry and transport outside the mandate of the LA (e.g. highways). Including other sources/sectors than the ones defined in section 2.4.6 on which the local authority would not have any influence, is generally not recommended, as this would jeopardize the achievement of the reduction target. Moreover, some specific sources/sectors shall be explicitly excluded in order to ensure the overall consistency of the CoM approach and avoiding double counting.

The activity sectors not recommended or explicitly excluded (marked with an asterisk (*) see below) are notably (see Error! Reference source not found. for details):

— Aviation and Shipping (except local ferries)

— Nuclear energy*

— AFOLU* and other non-energy related sources than the ones reported in **Table 6**

— Carbon Capture and Storage (CCS) technologies

— Emission credits purchased or sold on the carbon market*

— All fugitive emissions from the supply chain

— Process emissions from industrial plants

— Other source included under the Industrial Processes and Product Use (IPPU) sector (IPCC, 2006).

Table 2. Activity sectors not to be included in the CoM inventories

Activity sector	**Description**
Shipping and fluvial transport (mobile combustion)	The mobile combustion from Aviation and Shipping/fluvial transport is not to be included in the inventory/SECAP. The only exception is local ferries used for public transport[19]
Aviation (mobile combustion)	
Other sources/sinks	Nuclear energy*
	CO_2 Capture and Storage (CCS) technologies
	Non-energy related CO_2 emissions/removals in AFOLU*, due to changes in carbon stocks (e.g. tree plantations in urban forests), as this might lead to double counting in the BEI/MEIs
	Other non-energy related emissions in Agriculture: Enteric fermentation, manure management, rice cultivation, fertilizer application, open burning of agricultural waste
	Emission credits
	Fugitive emissions from production, transformation and distribution of fuels([20])
	Process emissions from industrial plants (ETS and non ETS industry)
	Other emissions reported under the IPPU sector

([19]) Energy consumption in airport and harbour buildings, equipment and facilities shall be reported in the Buildings macro-sector under the Tertiary buildings, equipment/facilities activity sector (see Table 4). Energy consumption from off road traffic of vehicles/mobile machinery used in airports and harbours is optionally reported under the Transport macro-sector.

([20]) If LCA approach is used, these emissions may be included in the emission factors as part of the fuel supply chain.

2.5 Monitoring

There are two main monitoring instruments proposed by the Covenant, also included in the monitoring reporting procedure: the Monitoring Emission Inventory (MEI), as described in the current chapter and the Action Implementation Report ([21]). Furthermore, when planning an action, the signatory is encouraged to set relevant monitoring indicators for each key action (see Part I of the current Guidebook) to be checked or estimated on an annual basis or during the key implementation phases. These instruments are complementary and their correlation could give valuable information on the dynamics involved in the SECAP mitigation process.

The current chapter is further developing some specific aspects related to carrying out the Monitoring Emission Inventories such as recommended frequency, ensuring consistency through time and cases when recalculations are necessary.

In order to monitor the energy consumption and CO_2 emissions data effectively and adapt their SECAP accordingly if necessary, Covenant signatories are encouraged to compile Monitoring Emission Inventories (MEIs) on a yearly basis. The advantages are:

— a closer monitoring and better understanding of the various factors that influence the CO_2 emissions,

— an annual input to policy-making, allowing quicker reactions,

— the specific expertise necessary for inventories can be maintained and consolidated.

If the Local Authority considers that such regular inventories put too much pressure on human or financial resources, it may decide to only carry out inventories at 2-yrs or 4-yrs intervals. However, in any case, it is strongly recommend including a last MEI for the 2030 target year.

It is important to correlate accordingly the frequency of compiling the monitoring emission inventories with the mandatory frequency of the reporting procedure within the Covenant. This requires the submission of an Action Implementation Report at least every two years from the submission of the SECAP. At least every second Action Implementation Report should be accompanied by a Monitoring Emission Inventory. That means that a MEI should be reported at least every fourth year.

2.5.1 Time series consistency

One of CoM guiding principles (see section 2.2) on the CO_2 emission inventory is that the inventories are consistent throughout the years, from the baseline year to the target year 2030. In order to ensure consistency between all reported years in all its elements across activity sectors and gases, it is of utmost importance that the BEI and MEIs follow the same methodologies and that consistent data sets are used to estimate emissions from the different activity sectors. Both the data collection and emission inventory (*activity-based* or *LCA*) approaches should be maintained, while accounting for changes in energy consumption and emissions. Because CoM BEI/MEIs are not meant to be exhaustive inventories, a particular attention has to be brought on keeping the same included/excluded activity sectors all along the implementation process.

2.5.2 Recalculations

In general, once the BEI is completed, there is no need to change the numbers later on. By using similar methods also in the MEIs, the local authority can ensure that the results are consistent, and thus the differences between BEI and MEIs correctly reflect the changes of emissions between the baseline year and the monitoring year. However, there are a few occasions when recalculation of BEI (and earlier MEIs) is necessary to ensure that the reported trends in emissions reflect real changes in the emissions, instead of other factors, such as:

([21]) See section II of «The Covenant of Mayors for Climate and Energy Reporting Guidelines», Neves et al, 2016

1. industry delocalisation
2. new information on local emission factors, e.g. to be used instead of default EFs
3. correction of heat consumption for outside temperature (i.e. normalising the heat consumption with the heating degree days)
4. adding or removing optional activity sectors
5. changes in the local territory's boundaries
6. methodological changes (not recommended, only if needed).

Examples of recalculations (for points 1), 2) and 3)) are provided in Annex 2. Please note that in case real changes in the local emission factors (point 2) have occurred between the baseline year and the monitoring year - for instance due to the changes in fuel properties - then different emission factors will correctly reflect the changed circumstances, and recalculation is not needed. In case a signatory decides to add or remove a particular activity sector during the implementation phase (point 4), recalculation is required. When recalculations are needed, the local authority shall recalculate all the inventories (BEI and MEIs compiled for every 4 years). Such recalculations may be carried out at any time. However, in case this would lead to significant changes in the BEI and/or SECAP (such as a considerable change in the overall BEI CO_2 emissions and 2030 reduction target, a shift of priority in the vision and/or in the activity sectors to be tackled), then a SECAP resubmission is required. A specific case of point 6) is the recalculation of the local emission factor for electricity for signatories going from the 2020 to the 2030 target (see 2.5.3).

2.5.3 Going from 2020 to 2030 target

The signatories who already have a commitment for 2020 target shall continue to monitor and report on the progress to 2020 while starting reporting on 2030 targets. They shall use the same baseline year for the 2030 target in order to ensure that their 2030 commitment is a continuation of the ongoing efforts. Changing the baseline year can be made only in exceptional circumstances, in which, using the original baseline year, it is not possible to compile a consistent time-series from BEI to 2030. In such a case, the local authority has to recalculate the BEI and any existing MEIs to reflect the change. The new definition of the local production of electricity (LPE) might also require a recalculation of the indirect emissions from electricity (see section 3.3.1).

2.6 Summary of Covenant options and specificities

The main options, specifications and recommendations for building an emission inventory, many of which are specific to the Covenant, are summarized in **Table 2**. When defining the method to be applied, it is important to ensure a consistent choice between the different options (e.g. including CO_2, CH_4 and NO_2 and using CO_2-eq unit if including non-energy related activity sectors).

There are various methods and tools available for compilation of local emission inventories at all levels - including (for example, the *Global Protocol for Community-Scale Greenhouse Gas Emission Inventory* (GPC, 2014) ([22]), the *Bilan Carbone© ([23])* method used in France, the Climate Protection Planner ([24]) in Germany, *Klimaatmonitor* ([25]) in the Netherlands, the *ECORegion* ([26]) tool used by cities following the European Energy Award approach – to mention just a few). Covenant signatories can choose to use any tools or methods available – provided they are in line with the CoM methodological principles specified and detailed in the present guidebook. These tools and methods are

([22]) GPC (2014); http://www.iclei.org/activities/agendas/low-carbon-city/gpc.html
([23]) https://www.associationbilancarbone.fr/
([24]) https://www.klimaschutz-planer.de/
([25]) https://klimaatmonitor.databank.nl/dashboard/
([26]) https://www.ecospeed.ch/region/en/#licenses

usually quite consistent with the present recommendations, even though none of them fully match the Covenant reporting framework and its associated requirements (see for instance Bertoldi et al. ([27])).

The European Commission and the Covenant of Mayors Office (CoMO) are however exploring how to strengthen the links between the Covenant and other existing reporting platforms. Whatever approach/tool is used, the LA should ensure that the reporting of the inventory in the SECAP document and templates is fully in line with CoM rules and recommendations as described into details in the following chapters.

([27]) https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/existing-methodologies-and-tools-development-and-implementation-sustainable-energy-action

Table 2. Main options and recommendations of CoM methodology for building a local GHG emission inventory

"M", "R", "O/A" columns refer to "Mandatory", "Recommended", "Optional/Alternative" requirements, respectively. *(x)* refers to a *conditional* option/recommendation.

	Key elements	M	R	O/A	General Comment	Specific recommendations and comments
GHG included	CO_2	x	-	-	Emissions to be reported in tCO_2/yr	Minimum requirement
	CH_4, N_2O	-	*(x)*	-	Total (CO_2, CH_4, N_2O) emissions to be reported in tCO_2-eq/yr.	Recommended if LCA approach is used. When using the activity-based approach, recommended if non-energy related activity sectors (waste and/or wastewater management) are included in the inventory. IPCC (2007) GWP to be used to convert the CH_4 and N_2O emissions into tCO2-eq by new signatories is IPCC (2007); Signatories which reported BEI for 2020 target using IPCC (1995) GWP values shall continue using the same values unless the BEI and previous MEIs are recalculated using the IPCC (2007) GWPs
Inventory approach	*Activity-based* approach	-	x	-	Low contribution of CH_4 and N_2O from energy-related sectors; No contribution from carbon neutral biofuels.	Recommended. CoM *activity-based* emission factors (and other IPCC factors) or more country/local specific factors if reliable can be used.
	LCA approach	-	-	x	CH_4 and N_2O contributions might be significant, notably for biofuels/biomass.	CoM emission factors or more country/local specific factors if reliable can be used.
Emission factors (EF)	Country/local specific emission factors	-	x	-	Local authorities are encouraged to use emission factors that are consistent with the fuels used in their local territory.	Provided that such data are available and reliable (see 2.4.4).

	Key elements	M	R	O/A	General Comment	Specific recommendations and comments
	CoM emission factors	-	-	x	Provided by JRC for both *activity-based* and LCA approaches, for the energy carrier(s) most commonly used in the EU.	If more appropriate local, regional or country-specific EFs are not available. New signatories are recommended to use the latest version***** ([28]). All signatories using CoM (and other) default EFs shall use the same ones for the BEI and MEIs. The CoM *activity-based* emission factors are characteristic of stationary sources. If choosing to report in CO_{2}-eq, factors up to 3 % higher might be considered for the transport macro-sector.
Reduction target	Reference year	x	1990	up to 2005*****	1990 or the closest subsequent year with reliable data should be used.	2005 is the EU Effort Sharing Decision reference year, and it is the most commonly used baseline year by CoM signatories. A reference year later than 2005 can be only very exceptionally authorized and should be transparently justified in the SECAP.
	Absolute target	-	x	-	At least - 40% tCO_2/yr by 2030	Recommended except in the case a significant change in the population is expected and reliable population projection data are available. See section 2.4.5 on how to calculate the emission reduction needed to achieve the target.
	Per capita target	-	*(x)*	x	At least - 40% tCO_2/yr per capita by 2030	Not recommended except in the case significant change in the population, based on reliable population projection, is expected. See section 2.4.5 on how to calculate the emission reduction needed to achieve the target. BEI/MEI emissions and planned reduction shall be reported in absolute values in the on-line template.

([28]) Available from the JRC COM-EF data collection (http://data.jrc.ec.europa.eu/collection/id-0083)
*New data, criteria, or definition as compared to 2010 guidebook

	Key elements	M	R	O/A	General Comment	Specific recommendations and comments
Emission sources	Direct emissions from final energy consumption	x	-	-	Energy consumption in Buildings and Transport should be the priority of the SECAP.	Reporting direct emissions in the four key sectors "Tertiary", "Residential", "Municipal" buildings and equipment/facilities and "Transport" is mandatory. See **Table 3**, **Table 4** and Error! Reference source not found. for emissions to be included/excluded. In order to avoid double counting, it is important to make sure that: -Energy consumption for rail and road (and off road if applicable) transportation within the local territory is reported under the relevant activity sector of the Transport macro-sector (**Table 4**) and is not double counted in the Buildings macro-sector (**Table 3**). This is particularly relevant if data on total electricity consumption in the local territory is used, which may for example include rail transportation under "service" or "public" sector. It might become relevant also if the share of road electric vehicles increases. -Energy consumption in waste incineration plants that do not produce energy is reported under the Municipal buildings, equipment/facilities or Tertiary (non-municipal) buildings, equipment/facilities, depending on the ownership -Energy consumption and related emissions from waste incineration plants that produce electricity or heat are not reported as final energy consumption in the Buildings and Transport macro-sectors but in the "Energy supply" section, similarly to any other energy production plant. -Mandatory and recommended activity sectors to be included in the Building and Transport macro-sectors are described in detail in **Table 4** and **Table 4**, respectively. The "key" symbol refers to the CoM mandatory key sectors. Further guidance on the collection and reporting of the fuel combustion data is provided in sections 4.2 and 4.3, respectively.
	Indirect emissions from electricity and heat consumption	x	LPE*	-	Indirect emissions from local consumption of electricity/heat/cold regardless of the production location should be included.	Part of the mandatory reporting in CoM key sectors (see above). National or European Emission Factor for Electricity to be used as a starting point to determine the local emission factor for electricity (EFE). It is also recommended* to account for the local production of electricity (LPE) and mandatory to account for the local heat/cold production, if any (see section 4.4).

	Key elements	M	R	O/A	General Comment	Specific recommendations and comments
	Non-energy related sources	*(x)*	-	x	It is necessary to include the non-energy related emissions from activity sectors in the scope of the CoM, if the signatory intends to take action in these sectors	Emissions should be reported in CO_2 eq. Covenant does not provide guidance for the non-energy related activity sectors, but recommends using methodologies developed by other international organisations (see section 5.4). See Error! Reference source not ound. for the activity sectors excluded in the scope of the Covenant.

3 Setting up an emission inventory

To build the BEI/MEI emission inventories, the GHG emissions from final energy consumption are calculated for each energy related activity sector by multiplying the activity data by the emission factor per energy carrier (see Box 4).

— Activity data ([29]) are defined as data on the magnitude of human activity resulting in emissions or removals taking place during a given period of time, expressed in MWh. Data collection is an integral part of developing and updating the emission inventory. The methodological principles of activity data collection are set out in Chapter 4.

— An emission factor is defined as the average emission rate of a given GHG for a given source, relative to units of activity ([30]), expressed in in tCO_2/MWh or tCO_2-eq/MWh. The methodological principles of calculating the emission factors are set out in Chapter 5.

Box 2. How to calculate the GHG emissions from the activity data

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

Local authorities shall report activity data (i.e. final energy consumption) and emission factors for all sources of emissions (direct and indirect and non-energy related) per sector and energy carrier. The classification of the subsectors is based on the jurisdiction of the different actors (municipal/public and private). Based on these principles LA reports GHG emissions from three main macro-sectors, namely buildings/stationary energy, transport, and other non-energy related contributing to the total emission accounting, while the energy supply macro-sector are accounted through the local emission factor for indirect emissions.**Building sector**

The focus of the Covenant is to reduce direct and indirect (from consumption of electricity and heat/cold) emissions from local final energy consumption in the key sectors. Mandatory (i.e. shall be reported) and recommended (i.e. should be reported) activity sectors to be included in the Buildings macro-sector are described in detail in **Table 4**.

The term "equipment/facilities" covers all energy consuming entities that are not buildings. This includes water and waste management units. If such units are owned by the LA they should be included under "Municipal buildings, equipment/facilities", otherwise they should be reported under "Tertiary (non-municipal) buildings, equipment/facilities".

A special case is the Municipal sector where the energy consumption share is typically small, yet it was considered that, by serving as an example to the citizens, the actions implemented herein could have a high replicability potential in the other key sectors. For the same purpose, the lighting in the municipal buildings should be reported under a specific CoM activity sector "Public lighting", whereas other public lighting should be included in the activity sector "Tertiary (non-municipal) buildings, equipment/facilities". Energy consumption in other buildings (e.g. primary sector and industry) should not be included unless the SECAP includes energy/emission reduction measures in these activity sectors.

([29]) According to the revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories
([30]) https://unfccc.int/process/transparency-and-reporting/greenhouse-gas-data/greenhouse-gas-data-unfccc/definitions

Table 3. Activity sectors and data to be included in the CoM inventories - "Building" macro-sector

Activity sector		Description
Municipal buildings, equipment/facilities		All final energy consumption and related GHG emissions occurring in buildings and facilities public or owned by the local authority **shall** be reported in this activity sector; e.g. government offices, schools, police stations, hospitals, etc. All final energy consumption due to the operation (e.g. electricity for pumping, natural gas for heating, etc.) of municipal water supply system, solid waste and wastewater treatment and disposal facilities are also included here. Energy generation from municipal facilities (e.g. power and/or heat production from waste incineration) should not be reported under this activity sector, but in the "Energy supply" macro-sector.
Tertiary buildings, equipment/facilities		All final energy consumption and related GHG emissions occurring in buildings and facilities of the tertiary sector (services) **shall** be reported in this activity sector; e.g. offices of private companies, banks, commercial and retail activities, private schools, hospitals, etc. All final energy consumption due to operation (e.g. electricity for pumping, natural gas for heating, etc.) of private water supply system, solid waste and wastewater treatment and disposal facilities **shall** be reported in this activity sector.
Residential buildings		All final energy consumption and related GHG emissions occurring in buildings that are primarily used as residential buildings for cooking, heating & cooling, lighting and appliances usage **shall** be reported in this activity sector. All final energy consumption occurring in social housing **shall** be reported in this sector.
Public lighting		Electricity usage in public lighting, owned or operated by the local authority (e.g. street lighting and traffic lights), **should** be reported under this activity sector.
Industries	Non-ETS industries or similar (below or equal to 20 MW as thermal energy input)	All final energy consumption and related GHG emissions occurring in manufacturing and construction industries not covered in the EU Emissions Trading Scheme (EU-ETS) (31) or similar (below or equal to 20 MW as thermal energy input) **should** be reported, if related mitigation measures are planned in the in SECAP. Energy generation industries should not be reported under this subsector, but in the "Energy supply" subsector. Integrating the ETS or similar industries (above 20 MW as thermal energy input) into emission inventories **is not recommended**, unless such plants were included in previous energy plans and in the local authority's emission inventories.
	Industries ETS or similar (above 20 MW as thermal energy input)	
Other: Agriculture, Forestry, Fisheries		All final energy consumption 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 **should** be reported under this subsector.

CoM key sector

([31]) Signatories having a Baseline year before 2005 (EU ETS start) shall not include in the BEI plants which have since then become part of EU ETS.

The "key" symbol refers to the CoM mandatory key sectors. Further guidance on the collection and reporting of the fuel combustion data is provided in chapter 4. The general criteria for selecting the four sectors as CoM key sectors were their high share of the energy consumption in the urban areas and also the larger degree of influence that the municipality could have on them.

3.2 Transport sector

The Covenant of Mayors defines the transport activity sectors, according to ownership and functionality criteria, as follows: Municipal fleet; Public transport and Private and commercial transport. Mandatory and recommended activity sectors to be included in the "Transport macro-sectors are described in detail in **Table 4**.

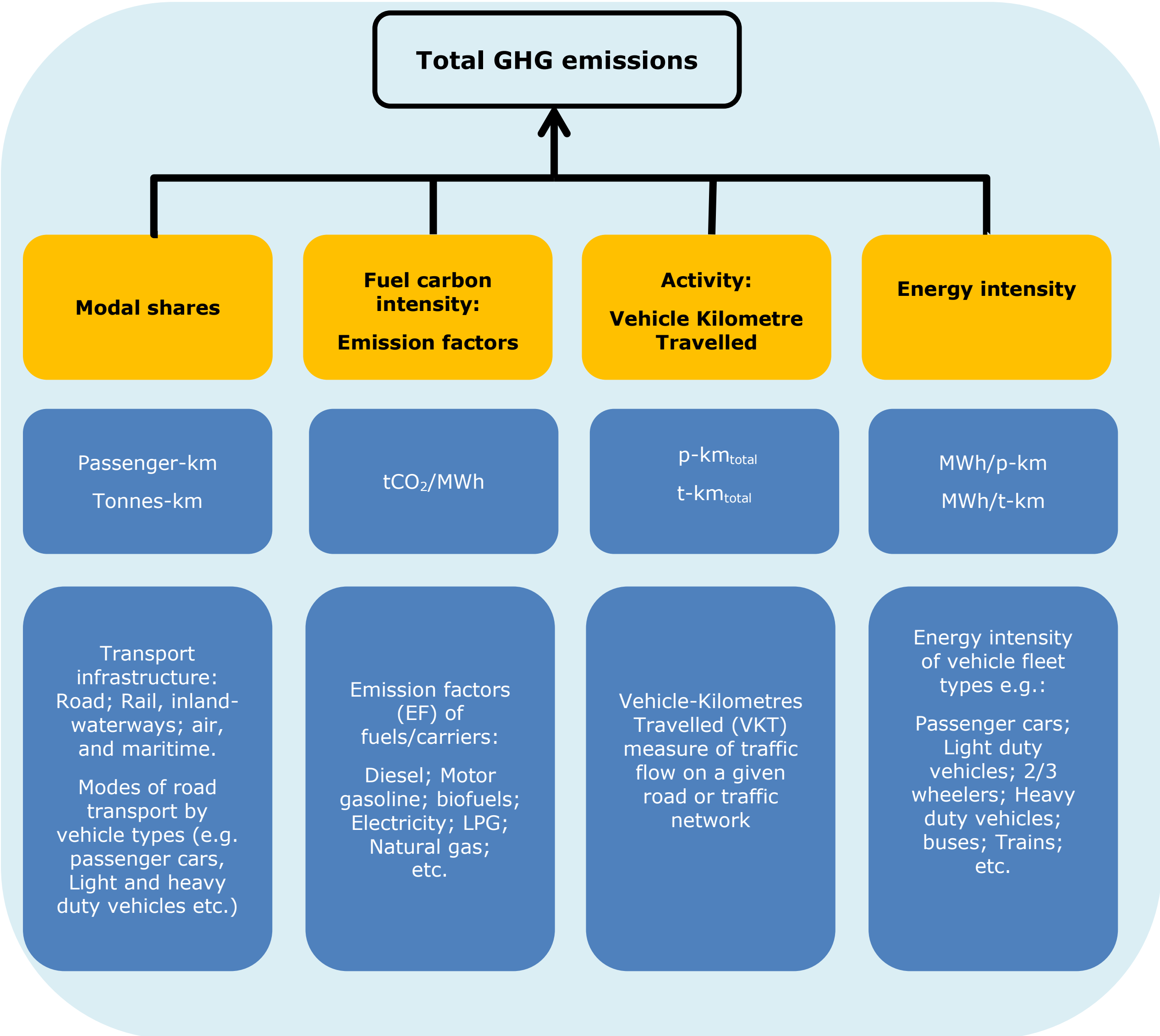
Table 4. Activity sectors and data to be included in the CoM inventories - "Transport" macro-sector

Activity Sector	**Description**	
Municipal fleet	Road transportation (see 4.3.1)	All final energy consumption and related GHG emissions from fuel combustion and use of grid-supplied energy (e.g. electricity) for transportation occurring in urban street network under the competence of the local authority **shall** be reported in this sector
Public transport		All final energy consumption and related GHG emissions from fuel combustion and use of grid-supplied energy (e.g. electricity) for transportation occurring in roads serving a larger area and/or not under the competence of local authority (e.g. highways) are **recommended** to be included if mitigations actions are planned in that area
	Off-road transport	All final energy consumption and related GHG emissions from fuel combustion and use of grid-supplied energy (e.g. electricity) occurring in off-road transportation (vehicles/mobile machinery in any activity sector) **are recommended** to be included if mitigations actions are planned in that area
	Rail transportation (see 4.3.2)	All final energy consumption and related GHG emissions from fuel combustion and use of grid-supplied energy (e.g. electricity) for transportation occurring in the local transport (e.g. metro, tram and local trains) **shall** be reported in this sector
Private and commercial transport		All final energy consumption and related GHG emissions from fuel combustion and use of grid-supplied energy (e.g. electricity) occurring for transportation from long-distance trains, intercity trains, regional and cargo rail transportation **are recommended** to be included if mitigations actions are planned in that area
	Waterborne navigation	All final energy consumption and related GHG emissions from fuel combustion and use of grid-supplied energy (e.g. electricity) occurring for transportation from local ferries in public transport acting on the local territory **are recommended** to be included if mitigations actions are planned in that area

CoM key sector

This section aims also to provide practical approaches to build emission inventories for the transport macro-sector focusing on CO_2 and where possible CH_4 and N_2O. There are relatively simple to more sophisticated ways to estimate transport emissions, but all are usually based on the following parameters (**Figure 1**):

Figure 1. Transport GHG emission accounting approach



Source: JRC own elaboration, adapted from IPCC 2014 ([32])

- The modal share and distribution of trips to different types of vehicles (fleet distribution), describing the portion of trips by different modes: Road (passengers and freight transport); Rail, inland-waterways; air and maritime. In urban areas the most important mode relates to road passenger, which can be further disaggregated into vehicle types (e.g. passenger, light-duty or heavy-duty for road vehicles);
- Fuel carbon intensity relates to the emission factors of the fuels (e.g. diesel, motor gasoline/petrol, electricity, hydrogen etc.);
- The Vehicle-Kilometres Travelled (VKT) as a measure of traffic flow, determined by multiplying the number of vehicles on a given road or traffic network by the average length of their trips measured in kilometres; it can be measured as passenger-

([32]) Sims R., et.al. Transport. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA kilometre (a unit of measure = 1 passenger transported a distance of 1 kilometre) and tonne-kilometre (a unit of measure: 1 tonne transported a distance of 1 kilometre);

— Energy intensity as a measure of the fuel consumption (actual in-use or alternatively average) assessed as the product of the average fuel consumption of vehicle the type [l fuel/km] and the Net Calorific Value (NCV) of the fuel [e.g. in Wh/l];

In order to ensure the overall consistency of the CoM methodology, it is suggested using the below equation (Box 3), to assess the total GHG emission in the transport sector.

Box 3. How to calculate the GHG emissions in the Transport sector

$$\boldsymbol{GHG\,emissions} = \sum_{MODES} \sum_{FUELS} [Emission\ factor * VKT * \ Energy\ intensity]$$

One of the specificities of calculating the energy consumption/GHG emissions in urban transport is related to the potential high share of sources moving across the border of the urban territory, which makes it difficult to allocate the energy consumption to a certain territory. Therefore, several methodologies could be used as described at point 4.3 and Annex 4.

3.3 Energy supply

Local energy (electricity and heat/cold) production is not included as an activity sector of the BEI/MEI, but is accounted for through the calculation of the local emission factors to be applied to the calculation of the GHG indirect emissions due to the consumption of the electricity and heat/cold and reported under the *Energy Supply* macro-sector, as below:

— Local production of electricity (LPE)*, divided into: renewable energy only; combined heat and power and electricity-only with a capacity limit of 20 MW of thermal input;

— Local production of heat/cold (LPH)*, divided into: combined heat and power and district heating only;

The rules for including or not energy locally produced and the associated emissions in the calculation of indirect emissions are summarized below (see detail in section 4.4).

3.3.1 Local production of electricity (LPE)

The methodology specifically developed in the frame of the Covenant allows defining and assessing the "*Local production of electricity*" (in MWh). The amount of electricity to be reported in as local electricity production will have a direct influence on the value of the local emission factor for electricity (section 5.2.4) and consequently on the emissions associated with the local consumption of electricity.

The following selection criteria and method have been developed in order to identify the plants or installations that **are recommended** to be included in the calculation of the total LPE.

These selection criteria are based on the geographical location and source/type/size of the local electricity generation facility.

Consequently, the information on the total amount of electricity produced in all plants/units that meet the selection criteria and the associated GHG emissions are accounted for in the calculation of the local emission factor for electricity (EFE).

a) Geographical location of the plant/installation: the location of the energy plant/installation in the local territory is the first general criterion.

   All the electricity produced by installations/plants (refer to as "unit" hereafter) located on the local authority's territory should be included provided that they comply with one of the following criteria described at point b) of the current section.

The only exemption to this criterion is related to the units that are under the direct control of the LA which could be optionally included even if outside the local territory*. All plants/installations under the direct control of the local authority (operated and/or at least partly owned by the municipality) can be accounted for in the calculation of the LPE provided that they comply with one of the following criteria described at point b of the current section. This refers to any plant running on renewable or non-renewable energy sources as defined below, some of which are of particular interest for the municipality, such as plants using the municipal wastes or cogeneration plants providing heat for the municipal district heating network. The information on the electricity production can be assessed according to the responsibility of the LA and to the share of ownership of all partners (municipalities or commercial partners).

b) Source, type and size of local electricity production plant/installation

The local authority is recommended to include all the individual electricity generation plants in the local territory, (as well as any plant outside the local territory that is owned and/or operated by itself), that meet the following criteria:

Local electricity production from renewable sources in particular: wind, solar (solar thermal and solar photovoltaic), geothermal energy, ambient heat, hydropower, etc.) and combustible renewables (biofuels, bioliquids, biogas, solid biofuels and combustible wastes of renewable origin) shall be included. The amount of energy from renewable sources corresponding to guarantees of origin (Article 15 of Directive 2009/28/EC) transferred to a third party outside the local administrative boundaries, shall be deducted from the local energy production from renewable sources (see section 5.2)*.

Local electricity production from non-renewable sources:

- all combined heat and power (CHP) plant/installations shall be included. The amount of energy produced from high-efficiency cogeneration, corresponding to guarantees of origin (Article 15 of Directive 2009/28/EC) transferred to a third party outside the local administrative boundaries, shall be deducted from the local energy production (see section 5.2)*.
- electricity-only producing units shall be included if they are not part of the European Emissions Trading Scheme (ETS ([33])) and/or their size/capacity is below or equal to 20 MW as thermal energy input.

The criteria above are based on the assumption that small plants/units primarily serve the community needs, where the local authority has more control or influence, whereas ETS power plants primarily produce electricity to the national grid and the emissions are regulated through a cap and trade scheme. For renewables and cogeneration units, which are local by definition, in order to avoid double counting of the benefits of producing from RES and high efficiency cogeneration, the certified electricity (e.g. through guarantees of origin) that is sold outside the local territory is excluded from the calculation of the local emission factor for electricity consumption.

The selection of the plants to be reported in the as local electricity production will have a direct influence on the value of the local emission factor for electricity (section 5.2.4) and consequently on the emissions associated with the local consumption of electricity. Therefore, when building the subsequent MEI(s), consistency in the selection of

([33]) Annex I to the ETS Directive (2003/87/EC. According to this directive and subsequent amendments, all combustion installations above 20 MW of thermal input should be part of the scheme with the exceptions of installations exclusively using biomass, installations for the incineration of hazardous or municipal waste and installations used for research, development and testing of new products. Some installations are also temporary or conditionally excluded from ETS such as hospitals and some of the installations below 35 MW (excluding emissions from biomass).

production units is required to ensure that the local emission factor reflects the real changes in local electricity production. For example, for the installations running on renewable energy sources, all the additional units reported in MEI(s) should be new installations, installed after the baseline year.

3.3.2 Local heat/cold production

The signatory shall identify all the installations providing heat/cold to end users within the local territory, regardless of their geographical location and ownership. In order to estimate the indirect emissions due to heat consumption (see 5.3.1), it is then necessary to identify the heat/cold produced in the local territory, exported outside and the imported ones and the associated energy input and emissions (in tCO_2 or tCO_2-eq).

Table 5. Energy supply and related emissions accounted for in the calculation of indirect emissions

Energy supply		Description
Local production of electricity (LPE)*****	Renewable energy only (e.g. Wind; Hydroelectric; Photovoltaics; Geothermal)	The amount of local electricity production from renewable sources and combustible renewables, regardless of the technology and capacity **are recommended** to be reported under this sector, with the exclusion of electricity sold to third parties outside the local administrative boundaries, identified through disclosed attributes such as Guarantees of Origin (GO) and other tracking instruments.
	Combined Heat and Power	All electricity production from cogeneration units, regardless of the capacity*****, **are recommended** to be reported under this subsector (see section 4.4.1). The emission allocated to electricity production should be assessed as explained in Annex 5. "The efficiency method in case of CHPs."
	Electricity-only with a capacity limit of 20 MW of thermal input	Electricity produced and related GHG emissions from non ETS power and from power plants with a capacity limit of 20 MW of thermal input, **are recommended** to be reported under this subsector.
Local production of heat/cold (LPH)*****	Combined Heat and Power	Heat/cold production from cogeneration units and distributed through district networks, regardless of the capacity, **shall be** reported under this subsector (see section 4.4.2). The emission allocated to heat/cold production should be assessed as explained in Annex 5. "The efficiency method in case of CHPs".
	District heating (heat-only)	Heat/cold production from local generation units and distributed through district networks, regardless of the capacity, **shall be** reported under this subsector (see section 4.4.2).

- This LPE definition only applies to the signatories having committed to the 2030 target. Signatories going from 2020 to 2030 should check the list of plants to be included as per above rules and recalculate all the BEI/MEIs if needed.
- When building the MEI(s), consistency in the selection of production units is required to ensure that the local emission factor reflects the real changes in LPE.

3.4 Other non - energy related sectors

Including non-energy related sectors in the SECAP is generally not recommended in the frame of the Covenant. Nevertheless, such emissions, which are usually small in the local territories can be included if measures to reduce the emissions of the associated greenhouse gases (CO_2, CH_4 and N_2O) are planned in the SECAP, in cases where these activities are under the direct responsibility of the municipality (i.e. waste and waste water management). For the activity data collection and the calculation of the GHG emissions in the non-energy related sectors (**Table 6**), the local authority is recommended to use methodologies developed by other international bodies (see section 5.4).

Table 6. Non-energy related activity sectors/data to be potentially included in the CoM inventories

Activity sector	**Description**
Waste management	GHG emissions not related to energy consumption coming from the management and treatment process of solid waste, such as landfills emitting CH_4, reported in CO_2-eq. Reporting of GHG emission from waste management **is recommended** to be reported if related mitigation measures are planned in the SECAP.
Wastewater management	GHG emissions not related to energy consumption, coming from the management and treatment process of wastewater, such as wastewater treatment plants emitting CH_4 and N_2O, reported in CO_2-eq. Reporting of GHG emission from wastewater management **is recommended** to be reported if related mitigation measures are planned in the SECAP.

4 Activity data collection

This chapter provides recommendations and tips, based on CoM key concepts and guiding principles for building a BEI/MEI for the data collection regarding local sources of GHG in the CoM key sectors and other activity sectors. The focus is on final energy consumption data from the building and transport macro-sectors.**Activity sectors and energy carriers**

In the context of the Covenant, the local authority has to report the final energy consumed (in MWh) within its local territory in CoM activity sectors and energy carrier classes. As mentioned in the previous section, the BEI/MEI shall cover three of the key sectors (**Table 3** and **Table 4**) and it is recommended to cover other activity sectors in the scope of the CoM in which the LA intends to take action. Because the focus of the CoM is on reducing the energy demand in the local territory but also improving energy efficiency and promoting the use of local renewable energy resources, reducing GHG emissions through these paths should be considered as a priority in the SECAP.

Activity sectors

The activity sectors are defined in chapter 3, and further documented in **Table 3**, **Table 4**, **Table 6**, as follows:

- Mandatory requirements refer to CoM key sectors.
- Reporting in non-key CoM sector in the BEI/MEI is recommended if the signatory includes mitigation measures for it in its SECAP (which is not mandatory).

Local electricity and heat/cold production is included in the inventory through the use of the local emission factors, and is therefore not included as a specific activity sector (**Table 5**).

The activity sectors which are not in the scope of the CoM and are therefore not recommended or to be excluded are defined in section (0) and listed in Error! Reference ource not found..

Energy carrier categories

The energy carriers consumed by the end-user, as defined in the Covenant include:

- "Electricity", which refers to the total electricity consumed by end-users, whatever the production source, is. Electricity consumption is reported as the annual amount of electricity consumed by end-user. The local electricity production, if any, is reported separately and included in the calculation of the local emission factor for electricity.
- "Heat/cold", which refers to heat/cold that is supplied as a commodity to end-users within the local territory (for example from district heating/cooling plant, a combined heat and power (CHP) plant or waste heat recovery). Heat/cold consumption is reported as the annual amount of heat/cold consumed by end-user. The local heat/cold production, if any, is reported separately and included in the calculation of the local emission factor for heat/cold.
- "Fossil fuels", which includes all fossil fuels consumed by end-users for space heating, sanitary water heating, or cooking purposes within the local territory. It also includes fuels consumed for transportation purpose and, in some cases, as an input in combustion processes in the industrial and primary sectors. Fossil fuel consumption is reported in the on-line template as the annual amount of fuel consumed by the end-users, into the 8 energy carrier classes: "Natural gas", "Liquid gas", "Heating oil", "Diesel", "Gasoline", Lignite", "Coal" and "Other fossil fuels*".* Energy carriers which do not fit into any of the other classes, such as peat and municipal wastes (non-biomass fraction) are to be reported under "Other fossil fuels".
- "Renewable energies" which cover the "Biofuel" (includes bio-gasoline and biodiesel), "Plant oil" (other liquid biofuels), "Other biomass" (includes biogas, municipal solid bio-waste, wood, wood wastes and other primary), "Solar thermal" and "Geothermal"

energy categories. Renewable energy consumption is reported as the annual amount of energy consumed by the end-users.

Mixture of fossil and renewable fuels (e.g. municipal wastes ([34])) should be either split between the two above categories (recommended) or reported under the "Other fossil fuels" class of the "Fossil fuels" category, together with the appropriated emission factor(s).

On the on-line reporting of the consumption data into the fuel categories

The above energy carrier classes, which are the ones included in the Covenant on-line templates for the automatic calculation of the GHG emissions, correspond to the fuels the most commonly used in the EU. Because the fuels used by the signatories may be different, special care is required to ensure that the energy consumed locally is correctly reflected in the on-line template, so as to allow for the calculation of GHG emissions that are consistent with the ones reported in the official SECAP document. In order to achieve this, the local authority may need to aggregate its energy carriers into the relevant classes and calculate relevant weighted emission factors for them.

Energy reporting unit

The carbon content may vary considerably both among and within primary fuel types on a per mass or per volume basis. Converting to the amount of consumed fuel to energy units using Net Calorific Values ([35]) (NCV) allows aggregating all the data. NCV values for different types of fuels are available as default (IPCC, 2006) and country specific (e.g., IEA, 2017) values. All the energy related activity data shall be reported in MWh in CoM on-line template. The conversion factor from the other commonly used energy units is provided in the **Table 7**.

Table 7. Conversion table of basic energy units

To	**TJ**	**Mtoe**	**GWh**	**MWh**
From	Multiply by:			
TJ	1	2.388×10^{-5}	0.2778	277.8
Mtoe	4.1868×10^{4}	1	11630	11630000
GWh	3.6	8.6×10^{-5}	1	1000
MWh	0.0036	8.6×10^{-8}	0.001	1

4.2 Collection of data in the "Buildings" macro-sector

Collecting information from every individual energy consumer within the local territory is not always possible or practical. Therefore, a variety of approaches are likely to be needed to develop an estimate of energy consumption. Several options are available, and often a combination of them is necessary to have an overall picture of the energy consumption within the local territory. Before starting the data collection process, it is

([34]) See chapter 5 and Annex 7 for the emission factor to be applied to the non-biomass fraction of the municipal wastes.
([35]) A calorific value is a conversion factor (e.g. in MWh/t, MJ/l) used to convert a fuel quantity between natural units (mass or volume) and energy units (energy content).

recommended to investigate if there are already national or regional mechanisms, which could help to collect relevant data for the building of the local GHG inventory.

I. Getting data for municipal/institutional buildings and facilities

II. Getting data from regional/ national sources

III. Getting data from the market operators

IV. Getting data from a consumer survey

V. Making and reporting estimates

4.2.1 Getting data for municipal buildings and equipment/facilities

The local authority should be able to collect accurate and comprehensive final energy consumption data related to its own buildings and facilities. Well-advanced local authorities already have a full energy accounting system in place. For other local authorities who have not yet initiated such a process, the energy data collection could require the following ten steps:

1) identify all buildings and equipment/facilities owned/managed by the Local Authority,
2) identify all energy delivery points (electricity, natural gas, heat from heating district network, fuel oil tanks…);
3) identify the person / department receiving the invoices and energy data
4) organise a centralised collection of these documents/data;
5) select an appropriate system to store and manage the data (could be a simple spreadsheet or a more elaborate software, available commercially);
6) make sure the data are collected and introduced in the system at least every year. Tele measurement is possible and can ease the process of data collection;
7) note that this process of data collection may be the opportunity to deal with other important energy related issues;
8) rationalise the number of energy delivery and invoicing points; regarding heating oil or other energy carriers delivered periodically as bulk, it is often preferable to install a measurement device (gauge, metre…) to help determine exactly the quantity of energy consumed during a given period. An alternative is to assume that the fuel purchased each year is equal to fuel consumed. This is a good assumption if the fuel tanks are filled at the same period each year, or if many deliveries of fuel occur each year;
9) renew/improve contractual arrangements with energy suppliers; If the local authority buy electricity from renewable sources with guaranteed origin or similar, this will not affect its energy consumption, but it may be counted as a bonus to improve the CO_2 emission factor;
10) initiate a real energy management process within the local territory: identify buildings which consume most energy and select them for priority action, such as daily/weekly/monthly monitoring of energy consumption allowing identifying abnormalities and taking immediate corrective action.

Regarding heating oil or other energy carriers delivered periodically as bulk, it is often preferable to install a measurement device (gauge, metre,) to help determine exactly the quantity of energy consumed during a given period. An alternative is to assume that the fuel purchased each year is equal to fuel consumed. This is a good assumption if the fuel tanks are filled at the same period each year, or if many deliveries of fuel occur each year.

Renewable heat and cold consumed locally by end-users should be measured and reported separately (columns related to "Renewable energies" in Final Energy Consumption Section of the on-line template).

It is important that all fuel supplied for purposes of producing electricity or district heating or cooling are tracked and reported separately as fuel used for electricity or district heating/cooling generation (Subsection B of the on-line emission inventory template referring to the Energy supply).

If the local authority and inhabitants buy electricity from renewable sources with guaranteed origin, this will not affect its energy consumption, but it may be counted as a bonus to improve the CO_2 emission factor. The quantity and the guarantee of origin can be obtained from the supplier, who has to provide a certificate of origin as defined under Directive 2001/77/EC, amended by Directive 2009/28/EC, or any other independent proof that a corresponding quantity of electricity has been produced from RES or high-efficiency cogeneration (see section 5.2.2 for details). The amount of electricity purchased has to be reported in Section B. Energy table of the SECAP on-line template (together with the corresponding CO_2/$CO_{2\text{-eq}}$ emissions, if any).

The local authority should be able to collect all data regarding Public lighting. If it is not the case, an identification and data collection process similar to the one indicated in the previous paragraph may have to be initiated. In some cases, it may be necessary to place additional meters, for instance when an electricity supply point feeds both public lighting and building/facilities. Note that any non-municipal public lighting should be included in the activity sector "Tertiary (non-municipal) buildings, equipment/facilities".

4.2.2 Getting data from regional/ national sources

National central databases and tools

The process of energy data collection is being more and more facilitated for the local authorities in recognition to their potential role in the greenhouse gases mitigation process and in the sustainable energy management. In particular at EU level, several directives include recommendations for the Member States to encourage and facilitate the implementation of the Sustainable Energy Action Plans at local level. In some Member States, such as the Netherlands, Denmark and Cyprus, as well as the UK, a central database and/or tool has been developed to provide local specific data to local authorities. Before starting the activity of data collecting process, it is therefore valuable to check what is already available at regional or national level (from statistical, energy, environmental or economic ministries or agencies or from regulatory authorities for gas and electricity).

Box 4. Examples in the Netherlands, Denmark, Cyprus and the United Kingdom

Netherlands and Denmark have since long developed tools which provide energy and climate data per activity sector, broken down at least at municipal level. Cyprus Energy Agency has also developed a tool, which provides the local authorities with all the energy consumption data required to establish their CO_2 inventory. The main aim of these tools is to assist the local authorities in implementing and monitoring local energy and climate action plans (Meshartility, 2014):

- Climate Monitor, Netherlands, since 2009: www.klimaatmonitor.databank.nl

- Municipal Carbon Inventory Tool, Denmark, since 2008: http://www.ens.dk/undergrund

- Cyprus Energy Agency website: http://www.cea.org.cy/app/CEA_energy.html

In the UK, the local authorities have also access to an open source database, which covers the period starting from 2005 (http://naei.defra.gov.uk/data/local-authority). It contains the CO_2 emissions associated with the consumption of electricity and gas and with the fuel consumption for the road transport for the activities under the influence of local authorities.

Covenant coordinators

Building up on the Covenant of Mayors and in support of the regional climate mitigation plans, several mechanisms were put in place at regional level to facilitate the access of the local authority to the necessary activity data for building up its inventories. Thus, many Regional Authorities – in particular the ones officially acting as Covenant Coordinators ([36]) - (see section 3.3 of Part I) have taken upon them to provide data to the local authorities under their coordination. This is particularly true in the case of Italy and Spain, in which the Covenant signatories include a high number of villages and small towns, which may lack the necessary resources to compile their emissions inventory on their own. The list of the Covenant Coordinators is publicly available on the Covenant of Mayors website ([37]). The Covenant signatories are encouraged to approach the one that is most relevant for them and ask if it could provide the data at local level.

Box 5. Example of the Province of Limburg (Netherlands)

"The province of Limburg, in collaboration with partners, established a data base containing the results of Baseline Emission Inventory, Renewable energy scan, Sustainable building scan and a Set of climate indicators prepared for each of the Limburg municipalities. This was done to encourage municipalities to sign the Covenant of Mayors and draft up a Sustainable Energy Action Plan. By doing this, the province of Limburg wants to reach its goal, set in 2008: becoming climate neutral in 2020" (Meshartility, 2015)

Regional Energy and GHG Emissions Observatories

Prior to the Covenant framework, several regional data centres existed, which were providing energy and GHG emissions data to the local authorities. Based on these previous experiences and building on the Covenant framework, the Data4Action EU project further helped in extending the model to other regional centres (*Data4Action, 2016*). These regional data centres, also referred to as "Regional Energy and GHG Emissions Observatories" ([38]), proposed a collaboration model for local data sharing in which a third party provides one-stop shop services and is responsible for brokering all collaboration agreements and the data exchange process between the energy data providers and local authorities. Furthermore, the European Network ENERGee-watch has been created, with the aim of standardising data at a European level (See Annex 3 for further details).

4.2.3 Getting data from the market operators

Since the liberalisation of gas and electricity market, the number of actors has increased, and the data related to energy consumption is becoming commercially sensitive and more difficult to obtain from energy suppliers. Therefore, in order to get the data from them, local authorities have to identify which suppliers are active on their local territory and prepare a table that they would have to fill.

([36]) Local authorities, which do not have sufficient skills or resources to draft and implement their own SECAP, can be supported by Covenant Coordinators, which are sub-national and national authorities (provinces, regions and public groupings of municipalities, ministries, national agencies) that are in a position to provide strategic guidance, technical and financial support to Covenant of Mayors signatories and municipalities signing up to it. The full list of Covenant Coordinators is available on the Covenant website:
https://www.covenantofmayors.eu/about/covenant-community/coordinators.html

([37]) http://www.covenantofmayors.eu/about/covenant-coordinators_en.html.
More examples can be found:
Supporters: Role, actions and lessons learned (EN), CoMO, 2017
https://eumayors.adobeconnect.com/p5zydiq0xlg/
Covenant Coordinators 2016 Report (CoMO, 2016)
https://www.covenantofmayors.eu/index.php?option=com_attachments&task=download&id=74
Case Study | Emilia-Romagna Region, Italy: Boosting Covenant signatories, the role of a Covenant Territorial Coordinator (CoMO, 2015)
https://www.covenantofmayors.eu/index.php?option=com_attachments&task=download&id=251

([38]) http://data4action.eu/regional-energy-observatory/

As several energy suppliers may be active, it may be simpler to contact grid operators (for heat, gas and electricity) whenever possible (it is not very likely that more than one of them is active on the local territory, for each energy carrier).
Because such data are generally considered as commercially sensitive, in the best case it will probably be possible to get only aggregated data. Ideally, a disaggregation between the residential, tertiary and industry activity sectors, for the different energy carriers (electricity, natural gas…) for all the postal code(s) that relate to the local municipality should be obtained.

If a greater level of disaggregation is available, then it is recommended to ask for it (e.g. to distinguish between the various sub-sectors for services and industry, private or public, individual houses or apartments). If the NACE code (statistical classification of economic activities in the European Community) ([39]) is available, this could help to classify the energy consumption in the appropriate sector. However, the NACE code may be misleading since offices of an industrial company will be classified as industrial, whereas they rather belong to the tertiary sector (they do not correspond to an actual industrial activity in the local territory). Some fine-tuning or questionnaires may be necessary to solve this question.
Other interesting information relates to the names and addresses of the largest energy consumers within the local territory, and their overall energy consumption (individual energy consumption is not likely to be available as it would be commercially too sensitive). This may be useful for targeted actions and questionnaires.

In the absence of an established practice at national level, it is highly recommended to require that the communicated results are delivered with detailed information on the assumptions made when aggregating the results (e.g. the definition of the sectors). This information should be useful for the supplier when repeating the procedure for the subsequent inventories and should be stored and used in further correspondence during the monitoring phase.

In some situations, in order to facilitate the cooperation and ensure that the data would be accessible through all the monitoring period, it is recommended to formalize the agreement between the Local Authority and the market operators. After investigating several cooperation patterns in 12 European countries ([40]), the Meshartility (Measure and share data with utilities for the Covenant of Mayors) EU project ([41]) recommended a memorandum as a form of cooperation with the market operators. The English version (Zoellner, 2015) can be downloaded from the project website (see Annex 3).

Box 6. Example of Italy

In Italy, according to Law 192/2005 art. 9, municipalities are authorized to request information about private consumption in their municipal area. However, it is not necessary to invoke this law to obtain the data. In most cases, it is sufficient to send a formal request signed by the Mayor and by the Secretary to obtain the needed information from utilities in one or two months or more rapidly in some cases.
A good example where the energy provider or distribution services company (DSO) provides data directly to municipalities is given by ENEL Distribuzione S.p.A. The ENEL company has defined a template to share the electricity consumption data (in compliance with the regulation on privacy and the CoM requirements), as well as the unified way of sending data requests. These should be prepared on a special form that may be downloaded from the company's website and should be sent back – signed by the Mayor – to ENEL by certified mail."

Meshartility, 2015

([39]) See REGULATION (EC) No 1893/2006 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.
([40]) http://www.buildup.eu/en/news/eu-project-meshartility-supports-energy-data-collection-74-cities
([41]) "Measure and share data with utilities for the Covenant of Mayors (MESHARTILITY)", co-financed by the European Commission through the "Intelligent Energy Europe (IEE)" program.

Even if some energy suppliers and grid operators may still be reluctant to provide consumption data to the LA (for reasons related to confidentiality, commercial secrecy, and administrative burden especially in the case where many local authorities would ask similar data from the same operators) there is an increasing pressure on the market operators to become pro-active in achieving energy savings and to become more transparent regarding energy consumption of their customers.

Under the Directive 2012/27/EU ([42]) on Energy Efficiency (Article 7), the energy market operators which are designated by the state, shall provide on request, but not more than once a year, aggregated statistical information on their final customers, including, where applicable, customer segmentation and geographical location of customers to an agency assigned by the Government.

Yet, although the directive specifically acknowledges the Covenant of Mayors initiative and the role of local authorities in achieving significant energy savings it is not explicitly aimed at energy data sharing between energy suppliers and local authorities. Nevertheless, there are some cases where national laws, transposing this Directive, have specifically introduced provisions, which facilitate the access of municipalities to energy data (e.g. Slovenia).

Box 7. Example of Slovenia

"In March 2014 the new Slovenian Energy Act (EZ-1, Official Gazette No. 17/2014) came into force. In Article 326 it is specified that all final consumers are obliged to provide the data on energy consumption to local authorities, for the purpose of energy planning. The data relates to produced heat, heat demand, waste heat energy and estimates of heat energy consumption for the next five years."

Meshartility, 2015

4.2.4 Getting data from a consumer survey

If all data cannot be obtained in the desired format from the market operators or from other entities, it may be necessary to make some inquiries directly to the energy consumers, in order to obtain the missing data. This is especially the case for energy carriers which do not pass through a centralised grid (fuel oil, wood, natural gas supplied in bulk, etc.). If it is not possible to identify all suppliers active in the local territory and to get data from them, it may be necessary to ask the consumers themselves.

It is worth bearing in mind that energy or statistical agencies may already be collecting such data, so make sure that data are not available elsewhere before considering sending a questionnaire.

Several options are possible:

- For sectors where there is a large number of small consumers (like the residential sector), it is recommended addressing a questionnaire to a representative sample of the population (depending on the size of the population[43]), spread over all districts of the Local Authority. The questionnaire may be on-line, but in this case make sure that this does not prevent some categories of customers from providing data, otherwise the results will be biased.
- For sectors where the number of players 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 where there is a great number of players, but where there are some large ones (e.g. tertiary sector), it may be worthwhile making sure to address the

([42]) The current directive repeals Directives 2004/8/EC on cogeneration and 2006/32/EC on end-use energy efficiency and energy services.
([43]) Using sample size calculator, e.g. https://www.checkmarket.com/sample-size-calculator

questionnaire at least to all large players (e.g. all supermarkets, hospitals, universities, housing companies, large office buildings, etc.). Their identification can be done through knowledge, statistical or commercial data (such as telephone directories) inquiry to the grid operator (ask who are the main electricity/gas consumers in the local territory). Another option to identify large electricity consumers is to ask 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?

It may be tempting to ask a lot of questions in the questionnaire (e.g. "is your building insulated?", "do you have solar panels?", "have you recently done energy efficiency improvements?", "do you have air conditioning?" etc.). However, it should be kept in mind that it is very important to keep the questionnaire simple and short (ideally not more than 1 page), in order to obtain a satisfactory rate of answers. Besides the type and quantity of energy consumed and eventual local energy production (renewable, CHP, …), 1 or 2 questions related to indicators of energy consumption (e.g. floor space (m²) of a building, number of inhabitants, number of pupils in a school) could be included for comparison or extrapolation purpose. For industry or services, ask the branch they belong to (propose some categories, if possible). For the residential sector, it is useful to ask questions that would allow extrapolation of the collected data. This depends on what kind of statistical information is available at the municipal level. It could be for example: household size (number of occupants), class of revenue, location (postal code and/or rural/urban area), dwelling type (detached house, semi-detached house or apartment), size of the dwelling (m²), etc.

Box 8. Tips to build a questionnaire

— Make sure the questions are clear and precise so that they will be understood by all in the same manner. Provide some short instructions if necessary.

— To increase the amount and quality of answers, inform clearly about the purpose of the questionnaire (energy statistics and not tax purpose for example). Motivate people to answer (for example, inform that the questionnaire allows to measure progress in reaching the CO_2 reduction objectives of the local authority, or provide any other relevant incentive).

— Make the inquiries anonymous (especially in the residential sector) and explain that the data will be kept confidential.

— Do not hesitate to send reminders to those who do not reply on time, in order to increase the rate of answers; and to call directly the largest energy consumers to make sure they reply.

— Make sure that the collected data sample is representative of the population. You should be aware that the response rate is generally low and those who respond are generally the most educated and climate-aware, and therefore there is the risk that the data collected is strongly biased, even if the questionnaire was addressed to a representative sample of the population. To avoid this, it may be advisable to organise data collection via face-to-face or phone interviews, especially in the residential sector.

— Decide in advance what you want to do with the data collected, to make sure that you really ask the useful and necessary questions.

— Do not hesitate to get the help of specialists (statisticians) to design your inquiry.

— It is advisable to communicate in advance your aims (SECAP development) through the local media, explaining the context and expected benefits for your local community.

What to do with the data?

Generally speaking, data collected via inquiries should help the local authority to construct the energy and CO_2 data related to the local territory. Here are few examples of possible usages:

— Aggregated data should be broken down into sectors and sub-sectors, in order to target the actions and measure the results achieved by different target groups.

— Fuels ratios obtained from the sample can be used to assess the overall energy consumption for each individual fuel. For example if the overall energy and gas consumption for a given sector is available, but not the heating fuel oil consumption, the electricity/fuel oil ratio or the natural gas/fuel oil ratio of the sample can be extrapolated to the whole population, provided that the sample is representative.

— Data on the energy consumption per square metre or per inhabitant in the household sector for different types of buildings and different classes of revenues can be extrapolated to the entire sector using relevant local statistical data.

Ideally, this kind of exercise should be done with the help of statisticians to make sure the data collected and method of extrapolation provide results that are statistically meaningful. In addition, checks should be carried out to make sure that the overall results are compatible with the data available at a more aggregate level.

4.2.5 Making and reporting estimates

The energy consumption estimated from the data collected will then need to be disaggregated (e.g. between biofuels/non biofuels fractions) or aggregated into the CoM energy carriers categories and activity sectors (see section 0), in order to be reported in the SECAP on-line template. The emission inventory shall cover the Tertiary, Residential and Municipal buildings and equipment/facilities. It is recommended to cover also other activity sectors in the scope of the CoM in which the local authority intends to take action.

If the data collected do not allow distinguishing the municipal consumption from other usages, then there is a risk of double counting. To avoid this, subtract the municipal usage (calculated separately, see above) from the overall energy consumption and report it in the relevant section of the template.

Only if energy consumption data cannot be disaggregated between all above individual activity sectors, aggregated data can be reported at the level of the macro-sector. In this case, it is important to specify in the on-line template, which are the individual sectors included in the Building macro-sector (see Chapter 6).

4.3 Collection of data in the "Transport" macro-sector

Measuring transport emissions and collecting associated data is vital to guide climate change mitigation actions, but can also guide wider transport policy and planning.

This section aims to provide practical approaches to build emission inventories for the transport macro-sector focusing on CO_2 and where possible CH_4 and N_2O. Different resources and capabilities of local authorities are taken into account and options are provided that are considered to be feasible to be implemented in mid-sized and even smaller local authorities.

It is not required (but recommended when possible) to provide energy data for each individual Transport activity sector (municipal fleet, public transport, private and commercial transport) but only at the macro-sector level. The reason is that most of the methods commonly used to collect energy consumption data for transport do not allow for distinguishing between vehicles as a function of their use. Nevertheless, it is always required to specify which of the above individual activity sectors are included in the aggregated data when reporting on-line.

The data to be collected mainly concern the road and rail transport (see **Table 4**):

- Road and rail transport should be included if it is serving mainly the local territory and/or regulated by the local authority, e.g. the highways and regional trains could be excluded if no actions are included in the SECAP.
- The off-road transportation should be reported under this activity sector it serves, i.e. municipal, public, or private/commercial transport, and be included only if related actions are included in the SECAP.

Air and waterborne transport, with the exception of the local ferries used for public transport, are specifically excluded from the scope of the CoM.

4.3.1 Road transportation

It can be challenging to account for road transport activity sector emissions in urban areas given the nature of the road transport, which contains numerous mobile sources moving within but also across the boundaries of the urban territory, according to various patterns. Depending on the aim of the inventory, the energy consumption and associated emissions could be accounted for in different ways. Among the most common methodologies are: fuel sales method, territorial method, residential method and city induced method (see detailed description in annex 4).

The top down "*Fuel sales method,* which calculates on-road transportation emissions based on the total fuel sold is primarily relevant for the national level and only offers very basic information for the local level. The fuel sold on the territory is used as a proxy for transportation activity occurring in the same territory. To identify levers for policy interventions it is vital to go beyond the accounting of tonnes of CO_2 and develop an understanding of travel patterns using a bottom up approach.

Information about travel patterns, commuter behaviour is relevant for all types of local authorities, whether large, medium or small cities, towns or municipalities. However, resources and capacities to collect data and to analyse it vary greatly among local authorities. The method to be used in the frame of the Covenant is the territorial method ([44]). Reasons for recommending the use of this bottom up approach is that it is the only one fully in-line with the scope and principles of the Covenant (see section 2.3): it is based on the mileage driven within the local territory and it can be relatively simple to apply, while allowing identifying and quantifying mitigation actions ([45]). Using a territorial approach is also a good compromise in terms of accuracy and needed resources concerning the data collection, the estimation of the CO_2 emissions and the analysis of the impact of local actions, which can therefore be done by all CoM signatories, including small local authorities.

Box 9. On the limitations of the fuel sale method

Kennedy et al. (2009) showed that the use of fuel sales data is more precise for cities for which the number of vehicle trips over the city borders is small compared with the number of trips within the city. They compared the results of using fuel sales data, scaling down from wider regions, and estimating emissions based on mileage for three megacities: Toronto, New York City and Bangkok, and concluded that the differences between the methods may be less than 5 %.

([44]) CoM does not require to build a comprehensive inventory but to focus on the "urban road travel" as defined in 3.1.1.

([45]) The more complex *resident activity* and *induced activity* bottom up methods, which are of particular relevance for local planning related to transport (see Annex 4) should only be used in case of cities having a large share of local travel and a small share of transit travel, and/or having already an on-going plan based on such approaches.

However, fuel sold in the territory of the local authority may not in most of the cases correctly reflect the fuel used in the territory. The amount of fuel sold and fuel consumed may be different for various reasons (comfort of fuelling, availability of filling stations, prices etc.). This is the case especially for smaller cities in which the number of filling stations is small. In addition, the factors having an impact on fuel sales may change in time (opening/closing of filling stations) and therefore the changes in fuel sales data may not correctly reflect the changes in traffic (fuel use).

The "*territorial approach"* requires more data collection and analysis than the fuel sales method, but also provides far more useful information to guide local policy and planning. There are relatively simple to more sophisticated ways to apply to this method, but all are usually based on the following parameters:

— The modal share and distribution of trips to different types of vehicles (fleet distribution), describing the portion of trips by different modes. In urban areas the most important mode relates to road passenger, which can be further disaggregated into vehicle types (e.g. passenger, light-duty or heavy-duty for road vehicles);

— Fuel carbon intensity relates to the emission factors of the fuels (e.g. diesel, motor gasoline/petrol, electricity, hydrogen etc.) and the share of biofuels in the fuels;

— The Vehicle-Kilometres Travelled (VKT) as a measure of traffic flow;

— Energy intensity as a measure of the fuel consumption (actual in-use or alternatively average) assessed as the product of the average fuel consumption of vehicle the type [l fuel/km] and the Net Calorific Value (NCV) of the fuel [e.g. in Wh/l].

In order to ensure the overall consistency of the CoM methodology, it is suggested using the below equation, to assess the total GHG emission:

$$\boldsymbol{GHG\ emissions} = \sum_{MODES} \sum_{FUELS} [Emission\ factor * VKT * \ Energy\ intensity]$$

— The following provides guidance on the collection of the data required to assess the energy consumption from the "urban road travel" using the CoM territorial approach as described above. Potential sources of data are also provided in

Table 8 and **Annex 4**.

4.3.1.1 Modal share and vehicle fleet distribution

The vehicle fleet distribution indicates the share of each vehicle type of the total stock. It can also distinguish between vehicles of different vintages. Optimally, information on travel per vehicle by vehicle type is available to weight the information for the amount each vehicle is used.

At minimum, the fleet distribution should distinguish between

— passenger cars and taxis

— heavy and light-duty vehicles

— buses and other vehicles used for public transport services

— two-wheelers

The fleet distribution can be estimated based on one of the following sources:

— traffic counts (this does not reveal relative driving levels)

— vehicles registered in the municipality

— national statistics

— Eurostat statistics at national or regional level.

Use of any of the above data sources should be accompanied with a consideration on whether it represents an appropriate estimate of the distribution of mileage driven in the local territory. For instance, the share of mileage driven in a city by heavy-duty vehicles may be lower than the share of heavy duty vehicles registered at national level. Some of the existing tools for local emission inventories include default fleet distributions for different regions, which can be used if they are considered appropriate by a local authority. The fleet distribution can be further adjusted to better suit to the local territory if needed. For instance, the fleet distribution in rural municipalities is usually different from the ones in cities (different proportion of two wheelers and busses, older car technologies, etc.).

4.3.1.2 Fuel carbon intensity and share of biofuels

Fuel carbon intensity relates to the emission factors of the fuels (e.g. diesel, motor gasoline/petrol, electricity, hydrogen etc.).

If the local authority plans to promote the use 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 making polls to the most important fuel distributors in the local territory and surrounding areas.

In the case of the use of biofuels in the municipal fleet (beyond the average use in the local territory), the LA is likely to have access to the amount of biofuel consumed, especially if special filling stations are used for municipal fleet.

For local authorities that do not intend to promote biofuels, national average shares can be found from Eurostat statistics ([46]).

4.3.1.3 Vehicle-kilometres travelled [VKT]

While acknowledging the fact that local authorities may find it difficult to collect mileage data, they are recommended to do so in order to be able to prepare as accurate as possible emission inventories in the road transport sector. There are various options to estimate the number of vehicle kilometres travelled on the street network of a local authority, which can be based on information on traffic flows and length of the street network. As the first step, local authorities can 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 LA's own fleet and public transportation, fleet the mileage driven can be estimated using the information in the odometers of the vehicles. Alternatively, fuel consumption by municipal and public transportation fleet can be estimated based on fuelled amount. However, attention has to be paid to the fact that the BEI/MEI should consider only mileage driven (and fuel used) in the local territory. In the case of contracted services for public transport or other services, the information should be available from the operator.

4.3.1.4 Energy intensity

Energy intensity as a measure of the fuel consumption (actual in-use or alternatively average) assessed as the product of the average fuel consumption of vehicle the type and the Net Calorific Value (NCV) of the fuel.

Average fuel consumption of each vehicle category depends on the types of vehicles in the category, their age and also on a number of other factors, such as the driving cycle. The local authority is recommended to estimate 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 in the region. Auto clubs and national transport associations are also sources of useful information.

([46]) http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&plugin=1&language=en&pcode=tsdcc340

Use of national level average fuel consumption for each vehicle category may produce biased estimates, in particular for urban areas. This might occur especially in countries with a dense motorway network linking cities and where a high number of rural trips are made, as the national average figures for fuel consumption would not be representative for urban areas.

Especially if the LA is planning measures to reduce the average fuel consumption of vehicles, for instance by promoting the use of electric or hybrid vehicles, it is recommended not to use national or European average fuel consumption figures, but to make a more detailed estimate (as explained above) including hybrid and electric cars separately([47]). This is because if averages are used, the reduction in fuel consumption due to measures will not be visible when comparing the BEI and MEI.

While, net calorific values for different types of fuels are available as default values (IPCC, 2006).

Table 8. Basic data and potential sources for estimating emissions from road transportation

DATA	**SOURCE**
Vehicle kilometres travelled	
Vehicle flow and mileage driven for transport planning purposes	Local transport department, public
Travel Surveys including numbers of vehicles passing fixed points per unit time (traffic volumes) Household transport surveys (origin and destination surveys)	Some surveys count vehicle numbers by type of vehicle, but information on the fuel (e.g. diesel or gasoline) is usually not available.
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	UITP: http://www.uitp.org/(not free of charge)
"Big data" such as smart phones and other travel data loggers that can provide details of trips	Various voluntary web apps
Vehicle fleet distribution	
Data on mode share for many European cities	Eurostat: http://ec.europa.eu/eurostat/web/cities/data/database
Passenger travel mode share surveys	Various national or city-level surveys
DATA	**SOURCE**
Average fuel consumption per km	
Fuel consumption per km and vehicle type	EMEP/EEA 2016 air pollutant emission inventory guidebook 2016 (EEA, 2016)
Fuel efficiency and CO_2 emission data sources for vehicle types	National inventories of vehicles
Local estimates of fuel economy for different vehicle types	Local vehicle registration data
Fuel NCV	
Default Net Calorific Value in TJ/Gg	IPCC (2006)

([47]) Individual mobility: From conventional to electric cars, JRC 2015, EUR 27468 EN, doi:10.2790/405373

4.3.1.5 Example of calculation of GHG emissions from road transportation

An example of the application of the GHG emissions using IPCC (2006) net calorific values is given in Box 10. Where the mileage (VKT) and/or fleet (type of vehicles) data are missing, fuel sales data could be used by cities in which the number of vehicle trips over the city borders is small compared with the number of trips within the city. However, this proxy should always be completed with local traffic/fleet data or estimates, in order to better allow identifying local mitigation actions (see **Annex 4** for further guidance on data sources and tools).

Box 10. Example of calculation of GHG emissions from road transportation

Input data:

1) Total mileage VKT = *4 500 million km* and fleet type distribution (in % of VKT)

2) Average fuel consumption; Net Calorific Values and Emission factors

Input data: Fleet type distribution (in % of VKT)

	Passenger cars	Light duty vehicles	Heavy duty vehicles	Busses	Two wheelers	Total
All fuels	**67%**	**15%**	**2%**	**3%**	**13%**	**100%**
- Gasoline/petrol	25%	1%	-	-	13%	39%
- Diesel	37%	14%	2%	3%	-	56%
- Electric cars	5%	-	-	-	-	5%

Input data: Average fuel consumption, NCV and Emission factors

	Passenger cars	Light duty vehicles	Heavy duty vehicles	Busses	Two wheelers	Net Calorific value (NCV)	Emission factors (EF)
	(l/km)	(l/km)	(l/km)	(l/km)	(l/km)	(Wh/l)	(tCO_2-eq/MWh)
- Gasoline	0.0768	0.13	-	-	0.04	9,200	0.249
- Diesel	0.0658	0.098	0.298	0.292	-	10,000	0.267
- Electricity	-	-	-	-	-	-	0.46

Calculation of the energy consumption and GHG emission related

Step 1.

Estimated activity/mileage per fleet type [million km]=
Total VKT [million km] ***x*** *Fleet type distribution (in % of VKT)*

	Passenger cars	Light duty vehicles	Heavy duty vehicles	Busses	Two wheelers	Total
- Gasoline	1139	40.5	-	-	580.5	1,760
- Diesel	1661	639	104	113	-	2,516
- Electric cars	225	-	-	-	-	225

Step 2. *Energy intensity per fleet type [Wh/km]= Average fuel consumption [l/km] x Net calorific value [Wh/l]*						
	Passenger cars	Light duty vehicles	Heavy duty vehicles	Busses	Two wheelers	Total
- Gasoline	707	1196	-	-	368	
- Diesel	658	980	2980	2920	-	
- Electric cars	186	-	-	-	-	
Step 3. *Estimated Final energy consumption per fleet type [MWh]= Estimated mileage per fleet type [million km]* ***x*** *Energy intensity [Wh/km]*						
	Passenger cars	Light duty vehicles	Heavy duty vehicles	Busses	Two wheelers	Total
- Gasoline	804,419	48,438	-	-	213,624	1,066,481
- Diesel	1,092,609	626,220	308,430	328,500	-	2,355,759
- Electric cars	41,850	-	-	-	-	41,850
Total final energy consumption	1,938,878	674,658	308,430	328,500	213,624	**3,464,090**
Step 4. *Estimated GHG emissions per fleet type [tCO_2-eq]= Estimated Final energy consumption [MWh]* ***x*** *Emission factors [in tCO_2-eq/MWh]*						
	Passenger cars	Light duty vehicles	Heavy duty vehicles	Busses	Two wheelers	Total
- Gasoline	200,300	12,061	-	-	53,192	265,554
- Diesel	291,727	167,201	82,351	87,710	-	628,988
- Electric cars	19,251	-	-	-	-	19,251
Total GHG emissions	511,278	179,262	82,351	87,710	53,192	**913,792**

4.3.2 Rail transportation

As for road transportation, the rail transportation in the local territory can be divided into two parts:

— Urban rail transportation, for example tram, metro and local trains. The inclusion of this urban rail transportation in the "public transport" activity sector in the BEI is strongly recommended.

— Other rail transportation, which covers the long-distance, intercity and regional rail transportation that occurs in the local territory. Other rail transportation does not only serve the local territory, but a larger area. Other rail transportation includes also freight transport. These emissions can be included in the BEI if the local authority has included measures to reduce these emissions in the SECAP.

There are two types of activity data for rail transportation: consumption of electricity and consumption of fuel in diesel locomotives. Use of diesel locomotives in urban rail transportation is less common for local services. Number of providers of rail transport in the local territory is usually low. The LA is recommended to ask the annual electricity and fuel use data directly from the service providers. If such data are not available, the LA can estimate the emissions based on mileage travelled and average electricity or fuel consumption.

4.4 Collection of data on local production of energy

The local production of energy and associated direct emissions **are not part of the activity sectors** included in the BEI but are considered in the calculation of **the local emission factors** to be applied to the local consumption of electricity and heat/cold. The principle is to allow signatories to reduce their emissions associated with the consumption of distributed energy, by encouraging both energy saving measures and measures related to the implementation of local energy production (see section 3.3.1)([48]).

In order to calculate the indirect CO_2 emissions to be attributed to the local production of energy, Covenant developed a specific methodology as explained in the sections below.

4.4.1 Local production of electricity (LPE)

In many cases, the information on local production ([49]) is directly available or assessable from the local (private or public) electricity provider, costumer and/or unit operator. For the large plants (such as CHPs), the information on the (distributed or centralised) local electricity production can usually be obtained via direct contact with the plant manager (municipal power agency or private company) or with the operators of the distribution network.

In other cases, the data can either be obtained through questionnaires to the local producers/suppliers (e.g., energy communities) and/or costumers or be derived from statistics (e.g., number of permits delivered, if required; number of subsidies granted) related to the amount of installations and power. Energy market operators may also have data about entities that provide electricity to the grid (e.g., from the certified green electricity).

This list of the selected plants together with corresponding energy inputs, generated electricity and CO_2 emissions have to be updated all along the implementation process so as to account for the changes in local production of electricity and to avoid double counting across signatories. In case a given installation falls into different categories (included/optional/excluded) during the SECAP implementation process, the local

([48]) The energy used by the plant for its own use (not for the production) and the related emissions should be excluded.
([49]) See also section 3.2 on data collection of energy consumed in the Building macro-sector

authority might need to recalculate the BEI/MEI(s) accordingly. This would be the case for instance of a small combustion installation, which would have grown above the 20 MW threshold and been excluded meanwhile by the signatory (see Annex 2).

The generated electricity, the energy inputs and the associated CO_2 emissions to be accounted for in the calculation of the local emission factor for electricity consumption should be then individually reported (or sum up) in the specific tables of the "Energy supply" section of the SECAP template. The CO_2 emissions from each individual plant shall be estimated by using the appropriated emission factor(s), as explained in section 5.1. In case of CHP power plants, the energy input has to be split between electricity and heat/cold production, as explained in Annex 5.

Micro cogeneration units may be too small, too numerous and scattered to obtain individual data, notably about the energy produced. In such a case, the energy input of those units, when available, should be reported as final energy consumption in the on-line Section A, and no heat or electricity should be reported in "Energy supply" section. Electricity produced should be deducted from total electricity consumption if the electricity from micro cogeneration was included in the data on total electricity consumption and similarly, heat production by such plants should not be reported under heat/cold in Section A of the on-line template.

4.4.2 Local heat/cold production

The signatory shall identify all the installations providing heat/cold to end users within the local territory, regardless of their geographical location and ownership. In order to estimate the indirect emissions due to heat consumption (see 5.3.1), it is then necessary to collect the data on:

- heat/cold produced on the local territory, energy inputs and associated emissions (in tCO_2 or tCO_2-eq);
- heat/cold exported outside the local territory and associated energy input and emissions (in tCO_2 or tCO_2-eq);
- heat/cold imported in the local territory and associated energy input and emissions (in tCO_2 or tCO_2-eq).

The data should be obtained via direct contact (or questionnaires) with the plant managers, as mostly large units will be listed here.

The plants should be listed in the specific Energy Supply Section of the SECAP on-line template, with the corresponding quantity of generated heat/cold, energy inputs, and corresponding CO_2 emissions. In case of CHP plants, the splitting of the energy inputs and CO_2 emissions between electricity and heat/cold productions can be done as explained in Annex 5. In principle, the total amount of heat/cold produced referenced in the section B of the on-line template on Energy supply should be equal (or very close) to the quantity of heat/cold consumed locally and reported in the "Heat/cold" column of the Final Energy Consumption Section of the on-line template. Differences may occur due to:

- auto-consumption of heat/cold by the utility producing it;
- transport & distribution losses of heat/cold.

When heat/cold from a plant located in the territory of the local authority is partly used in the local territory and partly exported, the Energy Supply Subsection of the on-line template should include only the heat/cold produced, energy input and emissions corresponding to the share of heat consumed in the local territory. Similar approach should be used for imported heat/cold, i.e. only the heat/cold produced, energy input and emissions corresponding to the share of heat consumed in the local territory should be included. Please note that energy consumption and CO_2 emissions related to heat and cold locally produced by end-users for their own usage should already be reported in the Final Energy Consumption and Emissions Section (columns for fossil fuel and renewable energy consumption) of the on-line template.

5 Emissions factors

The estimation of the local emissions may significantly vary according to the i) methodological approach, ii) the emission factors and iii) the greenhouse gases selected:

i. The local authority can choose between the *activity-based* approach, in line with IPCC principles (i.e., only including the emission occurring during fuel combustion), or the *LCA* approach (including the emissions from both fuel combustion and the supply chain).

ii. After selecting the emission inventory approach, the local authority can either use default emission factors as the ones provided in this Guidebook, or choose emission factors that are considered more appropriate.

   a. The *CoM emission factors* and/or other *standard* (see Annex 7) and LCA emission factors can be used if more appropriate local, regional, or country-specific emission factors are not available. If local authorities prefer to use EFs that better reflect the properties of the fuels used in their territory, they are welcome to do so.

   b. The *activity-based* emission factors depend on the carbon content of the fuels and therefore do not vary significantly from case to case. In the case the LA would prefer to use its own factors, it should ensure that they are in line with the recommendations provided in IPCC (2006) guidelines on energy (http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol2.html).

   c. EFs and GWP values for the fossil fuels are expected to remain constant over the monitoring period (i.e. the same reference should be used for both BEI and MEI).

   d. For local authorities using the LCA approach, it is recommended to consider the applicability of the default emission factors presented in these guidelines before using them for BEI/MEI, and to try to obtain case-specific data where appropriate. Although, it is worth noting that obtaining information on the emissions upstream in the production process may be challenging and that considerable differences may occur even for the same type of fuel.

   When selecting emission factors for biomass/biofuels, the local authority shall take the *carbon neutrality* criteria as defined in section 5.1.3 into consideration.

iii. The local authority has the choice to account for CO_2 emissions only or also include CH_4 and N_2O GHG emissions (see **Table 2** for guidance) in the BEI/MEI. If CH_4 and N_2O are included, it is recommended to apply the IPCC Fourth Assessment Report (IPCC, 2007) Global Warming Potential (GWP) values (also used for the national inventory reporting in the so-called *Annex I countries* under the UNFCCC (UNFCCC, 2013)) in order to convert emissions of these GHGs into CO_2 equivalent (CO_2-eq). However, the LA may decide to use other IPCC GWP values. Notably, for consistency and comparability, the signatories having already built their BEI in the frame of their commitment to the 2020 target, using IPCC Second Assessment report (IPCC, 1995) GWP values are recommended to keep on using (e.g. for MEI) the same GWP values (**Table 9**).

Table 9. IPCC (1995) and IPCC (2007) GWP values

		IPCC (1995)	IPCC (2007)
Greenhouse gas	Mass of GHG (tons)	Mass of GHG (tons CO_2-eq)	Mass of GHG (tons CO_2-eq)
Carbon dioxide	1 t CO_2	1 t CO_2-eq	1 t CO_2-eq
Methane	1 t CH_4	21 t CO_2-eq	25 t CO_2-eq
Nitrous oxide	1 t N_2O	310 t CO_2-eq	298 t CO_2-eq

5.1 Emissions from the direct use of energy carriers

5.1.1 CoM default emission factors

The 'CoM Default Emission Factors' data collection (COM-EF; http://data.jrc.ec.europa.eu/collection/id-0083) from the JRC consists of emission factors and coefficients provided to the Covenant of Mayors initiative for the calculation of local Greenhouse Gas (GHG) emission inventories, using activity-based (e.g. based on IPCC factors) or LCA (Life cycle assessment) approaches. The collection includes Tables of factors for the calculation of CO_2 and GHG50 direct and indirect emissions.

The "Covenant of Mayors Default emission factors - Version 2017" (Koffi et al. 2017b) includes tables for:

a. Emission factors for the consumption of fossil fuels and wastes
b. Emission factors for the consumption of biofuels, biomass, solar thermal and geothermal renewable energy sources (RES)
c. Emission factors for local electricity production from wind, hydroelectric and photovoltaics (in case of LCA approach)
d. Annual National and European Emission Factors for Electricity consumption (NEEFE) as calculated from IEA (2016) extended set of energy data, using IPCC (2006) emission factors.

As with the previous versions, the emission factors for the direct consumption of fuels and use of RES (above points a, b and c) are only provided for the most commonly used energy carriers in Europe. The National and European emission factors for electricity consumption are now provided for each country and each baseline year from 1990. The CoM standard default EFs are the IPCC (2006) default factors for stationary combustion (see Annex 7). The LCA default emission factors have been calculated by adding to the IPCC (2006) factors, emissions from the supply chain as estimated from the latest version of the European Life Cycle Database (ELCD, 2015), as well as other databases and literature reviews. Because LCA values have a period of validity, both the previous (valid up to 2007) and present (valid from 2008) LCA factors are reported. The GHG emission factors, which include CO_2, CH_4 and N_2O have been updated using the IPCC (2007) Global Warming Potential values.

([50]) The emission factors for fuel combustion are expressed as t/MWh. Therefore, the corresponding activity data to be used must also be expressed as MWh.

The CoM default emission factors are regularly updated in the JRC "COM-EF" data collection (http://data.jrc.ec.europa.eu/collection/id-0083). Because more recent knowledge and technologies can give substantial changes in the CoM default emission factors, new signatories are recommended to use the latest version, which is also available in the on-line library of Covenant, under "Technical documents".

For the signatories having already prepared a BEI, it is important to use the same CoM default emission factors in the MEIs, in order to identify the trends and changes in local emissions that are due to local energy consumption and production.

Table 10. CoM default emission factors - Version 2017

	Inventory approach	**Species**		**Emission factor(s) per energy carrier or activity sector**	**Geographical coverage**
		CO_2 (tCO_2/MWh)	**CO_2, CH_4, N_2O (tCO_2eq/MWh)**		
Emissions from consumption of fuels and use of RES	*Activity-based*	X	X	One factor for each most commonly used fuel/RES	Global
	LCA	-	X		Global + EU-28 or global for the supply chain
Indirect emissions from electricity consumption	*Activity-based*	X	X	Annual NEEFE factor from all input energy carriers ([51]) consumed for electricity production	National and EU-28
	LCA	-	X		National and EU-28 + EU-28 or global for the supply chain

Source: JRC COM-EF EU 2017 dataset ([52])

5.1.2 Local specific emission factors

If local authorities prefer to use country specific emission factors or develop own emission factors based on the detailed properties of the fuels used within the local territory when calculating their local CO_2 or GHG emissions they are welcome to do so as long as such local data are available and reliable. In some cases the local authority shall calculate weighted emission factors for the reporting in the online SECAP template (Section C). This is the case when:

— The same energy carrier has different emission factors in different activity sectors

— An energy carrier included in Section A includes aggregated data for two or more local energy carriers with different emission factors, the shares of which vary across activity sectors.

Reporting weighted EFs is needed to allow the automatic calculation of CO_2 or CO_2-eq emissions, that are as close as possible to the ones estimated in the BEI as published in

([51]) No GHG emission is accounted for renewable municipal waste; biofuels and biomass in the calculation of the NEEFEs in the case of the *activity-based* approach (see section 2.3.1).

([52]) http://data.europa.eu/89h/jrc-com-ef-comw-ef-2017 their SECAP official document, for each key sector. The local authorities shall also update these factors during the monitoring phase in case of changes in the composition/properties of the energy carriers consumed locally. This is particularly important for municipal wastes, for which both the supply chain and combustion process 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 (plant) phases of the waste management process.

For local authorities seeking for further guidance on emission factors that better reflect the fuels used in their territory or being more generally interested on how estimating GHG emissions using activity-based and LCA approaches, additional information is available from:

- IPCC (2006) default emissions factors, which can be used when country-specific data are unavailable (Annex 7)
- IPCC (2006) report, which provides general guidance for acquiring and compiling information from different sources and for applying the default emission factors. (http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html)
- EFBD Emission Factor Database (http://www.ipcc-nggip.iges.or.jp/EFDB/main.php), which is a recognised library, where users can find additional emission factors and other parameters with background documentation or technical references
- The EPLCA European Platform on Life Cycle Assessment (http://eplca.jrc.ec.europa.eu/)
- The JRC ILCD Handbook (Wolf al., 2012).

5.1.3 Carbon neutrality of bioenergy

This section provides CoM specific guidance on how to deal with biomass or biofuel ([53]) which are used in the territory of the local authority and for which default emission factors are reported under "Renewable energy sources" carriers of the SECAP templates.

5.1.3.1 Reported sectors

In the national GHG inventories under the UNFCCC (which follow 2006 IPCC Guidelines with relevant supplements), the changes in carbon stocks due to domestic biomass/biofuel production are reported under land use, land use change and forestry (LULUCF) and agriculture sectors also referred to collectively as agriculture, forestry and other land use (AFOLU). AFOLU sources/sinks of GHG emissions are not included in CoM activity sectors. Instead, the carbon stock changes due to production of biomass/biofuel are accounted for in the biomass/biofuel emission factors used in the CoM macro sectors (Buildings and Transport).

5.1.3.2 Emission factors

In national GHG inventories under the UNFCCC, the estimations of the emissions and removals of CO_2 due to domestic biomass/biofuels 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" ([54]) used in this Guidebook considers that the net gains are equal or superior to the net losses, i.e., that the CO_2 emissions to the atmosphere due to the end-user consumption are entirely compensated by the CO2 removal on the productive land.

([53]) In these guidelines, biofuel refers to all liquid biofuels, including transportation biofuels, vegetable oils and other fuels in liquid phase. Biomass, instead, refers to solid biomass such as wood, biowaste etc.
([54]) Stands for the terms "Sustainable/non sustainable" as currently reported in the 2016 CoM on-line templates

— If the local authority uses *activity-based* approach*,* the emission factor should be reported zero if the biofuels/biomass meets the above CO_2 neutrality criteria (*cn*) in terms of CO_2 emissions versus CO_2 assimilation by plants. For fuels that do not meet the above carbon neutrality criteria (e.g., in case of declining carbon stocks in a forest), the *ncn* (not carbon neutral) IPCC (2006) emission factors reflecting the biomass/biofuel carbon content should be used as a default factor. In case signatories would like to use intermediate values, based on the carbon stock changes of the ecosystems, they are welcome to do so, given that relevant information is available from the fuel producer/supplier or any other source and well documented in the SECAP.

— If the local authority uses the *LCA approach*, the use of emission factors that take into account all the emissions over the entire life cycle of the biomass/biofuels is needed, i.e. by adding the emissions from the supply chain to the emissions from the fuel consumption. While the carbon stored in the biofuels themselves may be CO_2 neutral, the cropping and harvesting (fertilizers, tractors, pesticide production) and processing to the final fuel may consume a lot of energy and result in considerable CO_2 releases, as well as N_2O emissions from the field. The various biofuels differ considerably regarding the life cycle GHG emissions, and therefore the LCA approach supports the choice of the most climate-friendly biofuels and other biomass energy carriers.

— It is important to note that *no negative emission factors* can be applied in the calculation of energy-related emissions from both *activity-based* and LCA approaches in the frame of the CoM: in case of net CO_2 uptake, a standard factor of 0 has to be applied.

— In the case of a *biofuel blend*, the energy consumption should be split between biofuel and fossil fuels content when reporting.

5.1.3.3 Carbon balance

Links to guidance on evaluating carbon balance are proposed hereafter.

— IPCC (2003) report on Good Practice Guidance for Land Use, Land-Use Change, and Forestry (GPG-LULUCF) and Volume 4 of the IPCC (2006) guidelines that gives guidance on activity-specific issues relating to identifying land areas and to estimating carbon stock changes and emissions/removals of CO_2 and non-CO_2 greenhouse gases.

— IPCC (2012) Special Report on Renewable energy sources and climate change mitigation (SRREN), in particular section 2.5.3 on "Modern bioenergy: climate change including land use change effects".

— Directive (EU) 2015/1513 of the European Parliament and of the Council amending Directive 98/70/EC relating to the quality of petrol and diesel fuels and amending Directive 2009/28/EC on the promotion of the use of energy from renewable sources[55].

— Statistics on the national use of renewable energy in the EU from Eurostat ([56]).

— Specific guidance ([57]), studies ([58]) and overview ([59]) from the European Commission (EC).

It is worth noting that how GHG emissions from the consumption and supply chain of bioenergy sources are accounted for in the frame of the Covenant might be revised in the

([55]) http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015L1513&from=EN
([56]) http://ec.europa.eu/eurostat/statistics-explained/index.php/Renewable_energy_statistics
([57]) e.g. Biograce (http://www.biograce.net/home) which is one of the voluntary schemes recognised by the EC to report emission factors in the frame of the Renewable Energy Directive. It uses up-to-date input values provided by the JRC based on consultation and interaction with fuel producers.
([58]) Giuntoli et al. (2017)
([59]) https://ec.europa.eu/energy/en/topics/renewable-energy/biomass

future, as their increasing use in the EU (Banja et al., 2017) is expected to pursue, and the UNFCCC/EC related national reporting recommendations expected to change by 2030.

5.2 Indirect emissions from the consumption of electricity

In order to calculate the indirect CO_2 emissions to be attributed to the local production of electricity, Covenant developed a specific methodology of estimating the local emission factor for electricity (EFE) taking into account the following components:

a. National or European emission factor for electricity consumption (NEEFE)

b. Indirect emissions from local electricity production (LPE)

c. Purchase and sale of Certified Electricity (CE)

5.2.1 National and European emission factors for electricity consumption

The national or European emission factor for Electricity (NEEFE) shall be used as a starting point to determine the local emission factor for electricity. These emission factors are calculated by dividing total CO_2 emissions for the different input energy carriers consumed to produce electricity, by the total final electricity consumption. The underlying assumption of the NEEFE definition is that all emissions produced nationally shall be allocated to the electricity consumed within the country. As part of the "COM-EF" data collection, the JRC now provides a yearly update of NEEFE time series from 1990 onwards for all Member States ([60]), based on the above definition (as in previous guidelines), but using a single methodology and data source.

Both "main activity producers" and "auto-producers" and both power (electricity-only) and combined heat and power (CHP) plants are accounted for, assuming carbon neutrality of the biomass/biofuels. In the case of CHP plants, the fuel inputs and related emissions are split between heat and electricity generation.

— New CoM signatories are recommended to use the latest version available from the JRC its "COM-EF" data collection.

— For some EU countries, the NEEFE fluctuates considerably from year to year due to the heating/cooling demand, availability of renewable energies, energy market situation, import/export of electricity and so on. For this reason, it is recommended to check the inter-annual variability of the NEEFE value around the BEI year. In the case of high fluctuation, a more representative value, e.g. an average value over a 3-yrs (BEI year ±- 1) or 5-yrs (BEI year ± 2) period, should be applied.

— As with the other CoM default Emission factors (Section 5.1.1), the general rule is to use the same emission factor in the monitoring phase as in the Baseline Emission Inventory. The benefit of using a constant NEEFE is that the trend in the local authority's emissions from electricity consumption will be solely driven by local consumption and, if applicable, by local electricity production (see section 5.2.2) and purchase of green electricity (see section 5.2.2). This helps understanding the trend and changes in emissions from local energy consumption, which should be the focus of the SECAP ([61]).

— Current signatories, who would like to use a more recent NEEFE estimation, would need to recalculate their BEI emissions and the absolute value of the reduction target.

([60]) Koffi et al. (2017), EUR 28718 EN, Publications Office of the European Union, Luxembourg, 2017, ISBN 978-92-79-71478-8 (print); 978-92-79-71479-5 (online), doi:10.2760/28586 (print), doi:10.2760/290197 (online)

([61]) A CoM signatory who would have accounted for the trend in the NEEFE to set the reduction target as reported in its official and already accepted SECAP, should include a specific "NEEFE trend" action in the on-line "Mitigation Actions" section of the on-line templates, to be defined as "Other (national, regional...)" origin, and report there the related emissions savings.

The reduction of indirect emissions from electricity should focus on measures aiming at increasing local electricity production from Renewable Energy Sources, which can be reinforced by additional actions (purchases and sales of green electricity and energy/emissions saving in the local production of electricity), all of which have to be reported as "Local" in the "Origin of Action column" of the on-line template.

5.2.2 Indirect emissions from local electricity production

Reducing CO_2 emissions through improvement of energy efficiency and local renewable energy projects is a priority of the Covenant. However, also other actions to reduce CO_2 emissions in the supply chain can be accounted for.

Even in case no SECAP measure is planned in the local production of electricity (LPE), inclusion of LPE in the calculation of the BEI/MEI emissions is recommended ([62])*. This rule allows accounting for (changes in emissions from) local energy production, whenever the plant has been built or renewed, in the calculation of indirect emissions from local electricity consumption. If the signatory does not need (no action planned) nor wish to report Local electricity production, then the LPE and related emissions (CO_{2LPE}) terms in equations of Section 5.2.4 are zero.

All plants that are to be included in LPE (see 4.4.1) should be listed in Section B. Energy supply of the SECAP template (see 6.3), with corresponding quantity of locally generated electricity, energy inputs, and CO_2 emissions. For convenience, similar production units may be grouped (for example PVs or combined heat and power plants (CHPs)). Waste incineration plants that produce electricity are treated similarly to any other power plants (whereas waste incinerated in plants that do not produce electricity or heat is included in Section A of the SECAP template).

The emissions from local electricity production (CO_{2LPE}) are estimated, in the case of plants combusting fossil fuel, wastes and biomass/biofuels, by using the emission factors provided in Tables 1 and 2 of the 2017 CoM default emission factors or the last update downloadable from "COM-EF" on-line data collection (see section 5.1.1) and shall be reported in the specific Section B of the on-line template. Local renewable electricity production other than biomass/biofuels is reported separately, together with their potential related emissions (LCA approach), which can be estimated by using the emission factors provided in Table 3 of the "CoM default emission factors –Version 2017" (Koffi et al., 2017b) or its last update (http://data.jrc.ec.europa.eu/collection/id-0083).

5.2.3 Purchase and sale of certified electricity (CE)

Local authorities should report in the emission inventory i) any certified electricity (CE) purchased from outside and in addition ii) the amount of certified electricity generated within the local territory and sold to third parties outside its administrative boundaries.

Certified electricity is the electricity identified through disclosed attributes such as Guarantees of Origin (GO) and other tracking instruments, which meets the criteria for guarantee of origin of energy produced from renewable sources set in Article 15 of Directive 2009/28/EC.

— Instead of purchasing the "mixed" electricity from the grid, the local authority/other local actors can decide to purchase certified electricity. The LA will report the amount of purchased electricity ($\sum \boldsymbol{CE_{purchased}}$), which is not already reported under LPE, in the corresponding Table B of the SECAP template.

$\sum \boldsymbol{CE_{purchased}}$ = Certified electricity purchased [MWh] (Part B of the SECAP template)

([62]) *New criterion as compared to 2010 guidelines

— The amount of renewable energy produced by facilities that are located inside the local territory for which the guarantee of origin of electricity produced from renewable sources is sold to third parties outside the administrative boundaries should not be accounted as local energy production ($\sum \mathbf{CE_{sold}}$)

$\sum \boldsymbol{CE_{sold}}$ = Electricity produced and certified by the guarantee of origin which is sold to third parties [MWh] (Part B of the SECAP template)

Therefore, the amount of certified electricity that can be accounted for in the calculation of the local emission factor for electricity consumption results as follows:

$\sum \boldsymbol{CE}$: Certified electricity accounted in the inventory

$$\sum \boldsymbol{CE} = \sum \boldsymbol{CE_{purchased}} - \sum \boldsymbol{CE_{sold}} \quad (1)$$

5.2.4 Calculation of local emission factor for electricity (EFE)

Based on the considerations and assumptions presented in sections 5.2.1 to 5.2.2, the local emission factor for electricity (EFE) to be reported in Emission factors Table of the on-line SECAP template (see section 6.3) should be calculated has follows:

— In the case where the local authority would not be a net exporter of electricity (TCE ≥ LPE + GE) ([63])

$$\boldsymbol{EFE} = \frac{[(\boldsymbol{TCE} - \sum \boldsymbol{LPE} - \sum \boldsymbol{CE}) * \boldsymbol{NEEFE} + \sum \boldsymbol{CO2_{LPE}} + \sum \boldsymbol{CO2_{CE}}}{\boldsymbol{TCE}} \quad (2)$$

— In the case where the local authority would be a net exporter of electricity (TCE < LPE + CE)

$$\boldsymbol{EFE} = \frac{\sum \boldsymbol{CO2_{LPE}} + \sum \boldsymbol{CO2_{CE}}}{\sum \boldsymbol{LPE} + \sum \boldsymbol{CE}} \quad (3)$$

Where:

$\boldsymbol{EFE}$ = local emission factor for electricity consumption $[\frac{\mathbf{t\,CO_2}}{\boldsymbol{MWh}}]$ (Part C of the SECAP template)

$\boldsymbol{TCE}$ = Total electricity consumption [MWh] in the local territory (as per Table A of the SECAP template)

$\sum \boldsymbol{LPE}$ = local electricity production from RES and non RES facilities [MWh] as defined in section 3.3.1 (Part B of the SECAP template)

$\sum \boldsymbol{CE}$ = Certified electricity accounted in the inventory as defined in (2) (Part B of the SECAP template)

$\boldsymbol{NEEFE}$ = national or european emission factor for electricity consumption $[\mathbf{t\,CO2}/\boldsymbol{MWh}]$ as defined in section 5.2.1 (Part C of the SECAP template)

$\sum \boldsymbol{CO2_{LPE}}$ = CO_2 emissions due to local energy production $[\mathbf{t\,CO_2}]$ (Part B of the SECAP template)

([63]) This formula neglects transport and distribution losses in and to the local territory, as well as auto-consumption of energy producers/transformers and tends to double count the local production already included in the NEEFE. However, at the scale of the local authority, these approximations will have a minor effect on the local CO_2 balance and the formula may be considered as robust enough to be used in the context of the Covenant of Mayors.

$\sum CO2_{CE}$ = CO_2 emissions [tCO_2] due the purchase/sold of CE certified electricity (Part B of the SECAP template): In the case that the standard approach is used (see 2.4.2), the emission factor for certified electricity is zero. If the LCA approach is used, the local authority has to estimate the LCA CO2CE either by requesting required information from the power provider or by using the CoM default factors provided for local renewable electricity generation (see section 5.1.1) if they are deemed suitable.

In the case of CHP plants, it is first required to distinguish between the energy input and emissions due to heat and electricity production as explained in Annex 5.

The local emission factor for electricity cannot have a negative value. Therefore, emission reductions from measures related to local electricity production or purchase can only be accounted for in the MEI until this factor equals zero.

5.3 Indirect emissions from the consumption of heat/cold

Indirect emissions from the consumption of heat/cold are estimated based on the emissions occurring due to the production of locally consumed heat/cold. If a part of the heat/cold that is produced in the local territory is exported, then the corresponding share of CO_2 emissions should be deducted when calculating the emission factor for heat/cold (EFH). In a similar manner, if heat/cold is imported to the local territory from a plant situated outside the local territory, then the share of CO_2 emissions from this plant that correspond to heat/cold consumed in the local territory should be accounted for when calculating the emission factor for heat/cold.

5.3.1 Calculation of emission factor for heat/cold (EFH)

The following formula should be applied to calculate the CO_2 emission factor for heat/cold, taking the above mentioned issues into consideration.

$$\mathrm{EFH} = \frac{(\sum CO_{2\,LPH} + CO_{2\,IH} - CO_{2\,EH})}{LHC} \tag{4}$$

Where:

EFH = emission factor for heat/cold [tCO_2/MWh or tCO_2-eq/MWh] (as per Emission factors Table of the on-line SECAP template)

$\Sigma CO2_{LPH}$ = Total CO_2 emissions [tCO_2 or tCO_2-eq] due to the local production of heat/cold as defined in section 4.4.2 (as per Energy supply section of the on-line SECAP template)

$CO2_{IH}$ = CO_2 emissions related to any imported heat/cold from outside the local territory [tCO_2 or tCO_2-eq]

$CO2_{EH}$ = CO_2 emissions related to any heat/cold that is exported outside of the local territory [tCO_2 or tCO_2-eq]

LHC = Local heat/cold consumption [MWh] (as per Final energy consumption Table of the on-line SECAP template)

In the case of CHP plants, it is first required to distinguish between the emissions due to heat and electricity production as explained in Annex 5.

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 a larger variety of production methods. If local production of district cooling occurs, or if district cooling is consumed as a commodity by end-users, the local authority is recommended to contact the district cooling provider for information on the use of fuels or electricity to provide cooling. Then the emission factors for fuels and electricity presented in this guidebook can be applied.

5.4 Emissions from non-energy related sectors

The main focus of the Covenant is to achieve reduction of greenhouse gas emissions by the target year, through measures on final energy consumption, energy efficiency and use of renewable energy. However, the signatory may also include waste and wastewater management in its SECAP, in which case it is recommended that these emissions be included in the BEI/MEI. Other non-energy related activity sectors are excluded from the BEI/MEI. In order to calculate the emissions from non- energy related sectors, the local authority is recommended to use methodologies developed by specialised organisations.

If the LA has chosen to use the standard emission factors in line with IPCC principles, it may consider using the methodologies described in the Intergovernmental Panel on Climate Change (IPCC) 2006 Guidelines and in the GPC.

- The 2006 IPCC Guidelines[64] focus on emission inventories at national level. The specific volume that is relevant for CoM local authorities regarding non-energy related emissions is Volume 5, “Waste”.
- The GPC is available at http://ghgprotocol.org/sites/default/files/ghgp/standards/GHGP_GPC_0.pdf and contains a detailed methodology, based on the IPCC one, on how to assess, at city level, the emissions from waste and wastewater (Chapter 8 “Waste”).

If the local authority has chosen to use the LCA approach, emission factors for landfills are available from the ELCD (2015) database (‘Landfilling’ class).

([64]) 2006 IPCC Guidelines for National Greenhouse Gas Inventories

6 Documentation and reporting of the GHG emission inventories

The documentation and reporting of the GHG emission inventories and of the estimation of the reduction target are key elements when preparing a Sustainable Energy and Climate Action Plan (SECAP). Notably, the data collection process, data sources and methodology for calculating the BEI should be well documented, publicly available and consistent throughout the years, so that stakeholders can be confident with the inventory and with the evaluation of the impacts of the mitigation actions.

— The SECAP document refers to the official document approved by the municipal council and may be prepared in the local language. Covenant signatories are also required to fill in an online SECAP template in English, which allows them to summarise the results of their Baseline Emission Inventory and of the Climate Change Risk and Vulnerability Assessment, as well as the key elements of their SECAP (see Part I of this Guidebook).

— In addition to these mandatory documents, the signatories are recommended to document the BEI/MEI methodology in a separated document/archive (see section 6.1) and to report the key elements of the Emission Inventory approach/options in a concise way in the SECAP document (see section 6.2). This will facilitate the BEI reporting in the on-line template (see section 6.3) and the compilation of the MEIs by the signatory in the following years. This will allow for a better transparency and facilitate the evaluation of the SECAP by the JRC, notably in terms of consistency of the information between the on-line templates and the official document.

6.1 Local authority's records: BEI/MEI "inventory reports"

It is the interest of the local authority to document in detail not only the methodological choices and the results of the emission inventory, but also the data collection process, data sources, emission factors, tools, assumptions and calculation approaches used to build the BEI/MEI inventories. All related documents and files should be carefully archived, including the spreadsheets used for the compilation of the BEI. This will facilitate the compilation of the MEI in the following years. It is notably recommended to prepare a BEI/MEI inventory report which covers a clear and detailed documentation of:

— the key elements of the BEI/MEI inventory approach and target reduction (see 6.2)

— the definition of the local territory, including a map with its geographical boundaries

— the emission factors used and their associated references/sources

— the information on the data sources and/or collection methods

— the choices made regarding inclusion of activity sectors beyond the key sectors

— the localisation and characteristics of the local electricity generation plants and rationale for their selection as part of the local electricity production the localisation and characteristics of the local heat/cold plants

— the invoices on green electricity purchase, if any

— the assumptions made

— the references and tools used

— the information on any change (approach, methodology, data sources) since the previous inventory

— the eventual comments that would help to understand and interpret the inventory. For example, it may be useful to provide explanations on which drivers have influenced CO_2 emissions since last inventories, such as economic conditions or demographic factors

— the names and contact information of people who provided the above information.

Unlike the SECAP official document, the BEI/MEI inventory reports do not need to be uploaded on 'My Covenant' platform but should be archived in the local authority's records.

6.2 SECAP document

The recommended structure and content of the SECAP document is described in Part I of this Guidebook. In the specific section on the building of the emission inventories and the estimation of the needed emission reduction by the target year (see "C" point of the "Recommended SECAP structure" section of Part I, section 1.6) the following main information should be reported:

— Definition of the local territory, including the LAU 2 (municipality) or NUTS 3 codes([65])

— Population in BEI year

— BEI year

— Reduction target (in %)

— Reduction target type (absolute or per capita)

— Emission inventory approach (standard or LCA)

— Emission reporting unit (CO_2 or CO_2-equivalent)

— Emission factors used (CoM or other default EF, local EF) and sources

— Responsible body/department/consultant

— Detailed results (energy consumption/supply, emissions) per activity sector and energy carrier

— Results of the estimation of the planned emission reduction per key sector

If relevant, the following information should be also included:

— Population in target year (mandatory for per capita target)

— Inclusion of activity sectors other than key sectors, if any

— Population in the target (2020/2030) years, if a per capita target is used

— Particular inventory method, assumptions or tool used, if any

— Clear reference to the BEI inventory report (see 6.1)

It is also recommended reporting the key elements of the BEI/MEI in a summary Table, such as the one below (**Table 11**). This will allow for a better transparency and facilitate the on-line reporting.

Table 11. Key elements of the BEI/MEI

Key information	**Name of local territory**
Population in BEI year	50 000 inh
Population in 2030 target year	70 000 inh
Reduction target objective (%)	40%
Reduction target type	Per capita reduction

([65]) http://ec.europa.eu/eurostat/web/nuts/local-administrative-units

Key information	Name of local territory
Emission inventory approach	Standard
Reporting unit	tCO_2 eq
Specific Emission factors used	CoM Default emissions factors for Buildings; Local (biofuel) and other (IPCC) emissions factors for Transport
Emission Inventory tool(s)	EXPTOOL (www.exp-tool.com)
Main contact	M. Agent (CA Consultancy Agency) ; agent.fc101@gmail.com
Total BEI emissions	500 000 tCO_2-eq
Total planned emission reduction	280 000 tCO_2-eq

In addition to the above requirements, detailed information on the activity data and sources, emission factors, tools and calculation approaches used to build the BEI/MEI should be gathered and referenced in the BEI/MEI inventory reports, as explained in section 6.1.

6.3 On-line template

The main information and data which have to be reported on the Covenant of Mayors for Climate & Energy website (http://www.eumayors.eu) using the on-line template tables should reflect the content of the politically approved SECAP document. The results of the BEI/MEI emission inventories are reported in the specific BEI and MEI templates, which consist of A, B and C sections, as briefly explained hereafter. More detailed information on the on-line reporting of the BEI/MEI emission inventories are found in the "*Covenant of Mayors for Climate and Energy Reporting Guidelines"* (see Neves et al. (2016) and subsequent updates), available under the Covenant of Mayor Website, as well as in the different chapters of the present Guidebook.

6.3.1 Section A - Final energy consumption section

It is where the signatory has to report final energy consumption data by activity sector and by energy carrier. The final energy data reported here should cover the key sectors plus other activity sectors in the scope of the CoM in which the signatory plans to take action, following the recommendations and criteria described in the previous sections, so that the results of those actions can be reflected in the monitoring emission inventories. In order to accommodate a certain degree of flexibility for signatories, the template provides the opportunity to report at different sector levels. This flexibility was essentially based on the fact that the data availability and emission inventory practices differ across local authorities, regions and countries. For instance, if the energy consumption data are not available at the individual activity sector level (residential, tertiary, etc.) in the 'Buildings, equipment/facilities and Industries' macro-sector, aggregated data can be reported at the level of the macro-sector. The same applies for transport data (i.e. municipal fleet, public transport, private and commercial transport can be aggregated into the 'Transport' macro sector). In this case, it is important to specify the activity sectors included by ticking the corresponding boxes in the on-line template, even if no detailed data is provided. The energy carrier classes correspond to those most commonly used in EU. Local authorities are therefore also requested to report/aggregate all their activity data within these energy carrier classes in the most consistent manner possible, according to the properties and mixture of the fuels used in their territory (see also point C).

6.3.2 Section B - Energy supply section

It is where the signatory has to report data related to green electricity purchases and local energy production, if applicable (see section 4.4). Energy production is not part of the activity sectors of the BEI (Table A) but the related emissions are reported in Section B of the on-line template so as to be considered in the calculation of the local emission factors for the local consumption of electricity and heat/cold. If local production of electricity is reported in Section B, then the energy and related emissions must be accounted for in the local factor of electricity consumption (Section C) and vice versa (if the local factor for electricity is different from the national one, then Local Production of Electricity should be reported in Section B). The same also applies to the local production of heat/cold. All the related energy inputs (i.e. those used to produce electricity and/or heat/cold reported in Section B) must be excluded from the Section A, in order to avoid double counting.

6.3.3 Section C - The CO_2 emissions tables

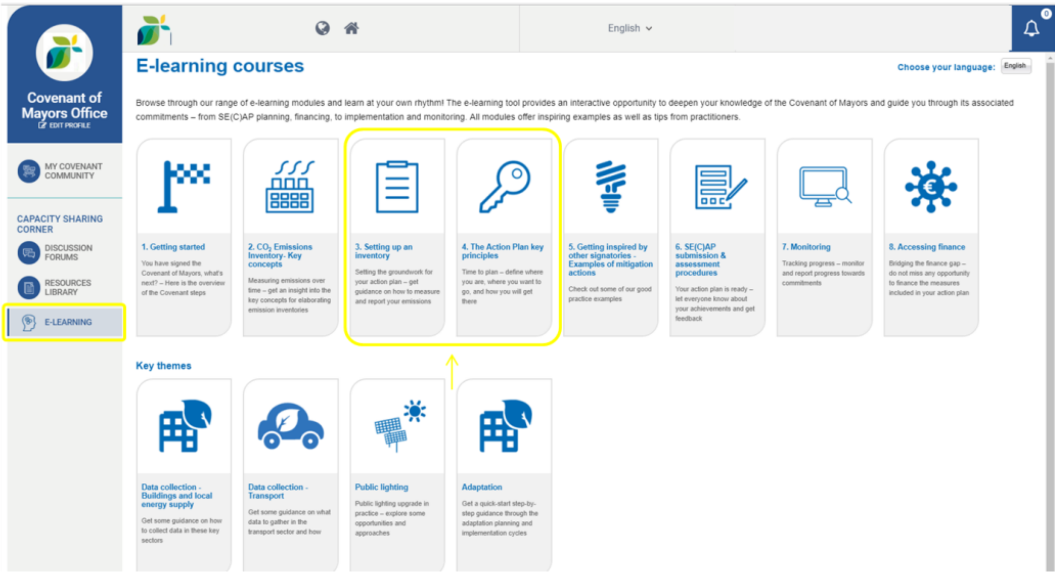
In the case of energy related emissions, the Emission Inventory Section is automatically calculated from the "Final energy consumption" (Section A) and the Emission factors (EF) provided in this section C. The factors proposed by default in the menu of the EF Table are the IPCC or LCA CoM default emission factors (see 5.1.1). The template provides user the option to use these default data or to enter any other emission factors used in its BEI/MEI. Because it is important that the on-line computed emissions are consistent with the emissions reported in the SECAP official document, local authorities need to pay particular attention to calculating the actual (weighted) emission factors per energy carrier, where relevant (see section 5.1.2).

6.4 Reference Covenant Materials

6.4.1 EU Covenant E-learning Modules – a Key Reference Tool for signatories

This tool provides an interactive learning opportunity for those wishing to deepen their technical knowledge of the Covenant of Mayors. It aims at building the capacity of both signatories and coordinators and it guides them through their Covenant commitments; from SEAP planning to implementation. Users are able to browse and learn at their own rhythm and improve their understanding of dedicated topics. Two modules are dedicated to the elaboration of emission inventories. All modules offer practical and inspiring examples, videos, case studies and self-assessment questions and are available in the 5 main EU languages (EN, FR, DE, ES, IT).

Figure 2. E-learning modules

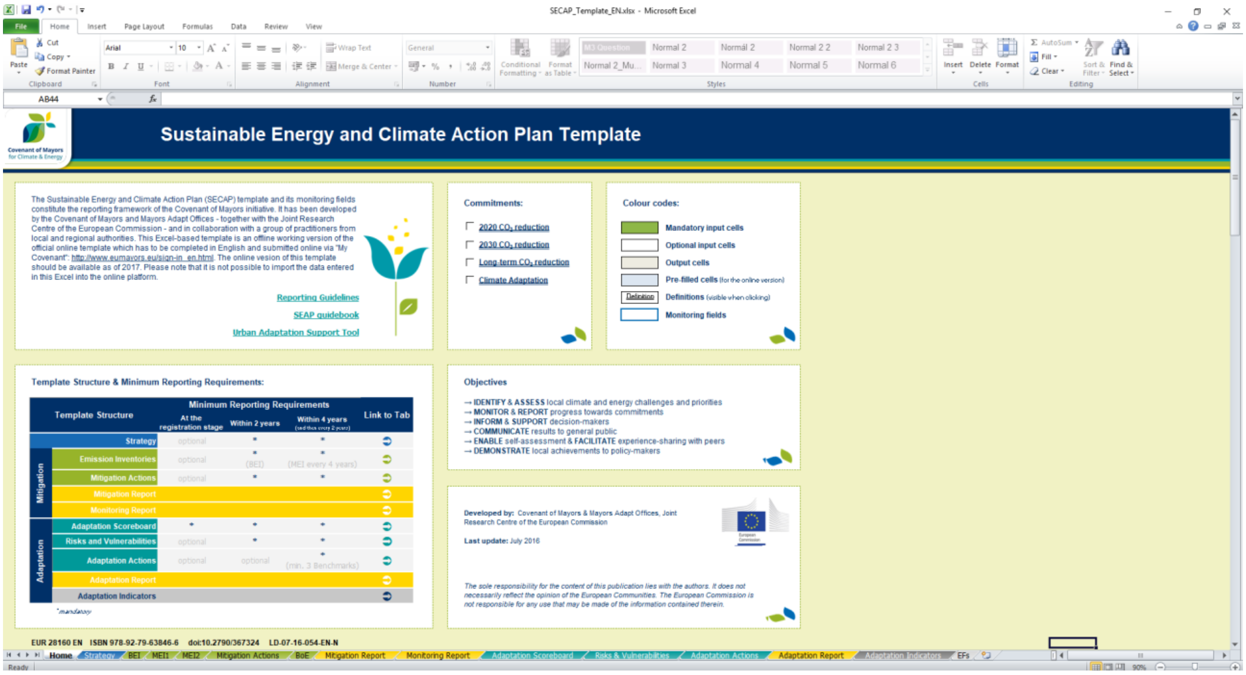


Source: http://mycovenant.eumayors.eu/capacity-sharing-corner/e-learning

6.4.2 EU Covenant of Mayors Reporting Template and Guidelines

An Excel copy of the Reporting Template (to be filled in every two years by signatories of the European Covenant of Mayors in the online reporting platform, the so-called "My Covenant") is downloadable in all EU languages. Moreover guidelines to support signatories of the European Covenant of Mayors throughout the online reporting process are available ([66]).

Figure 3. SECAP template



([66]) Neves A; Blondel L; Brand K; Hendel Blackford S; Rivas Calvete S; Iancu A; Melica G; Koffi B; Zancanella P; Kona A., (2016), The Covenant of Mayors for Climate and Energy Reporting Guidelines; EUR 28160 EN; doi:10.2790/586693, pp.68

PART 2 B
RISK AND VULNERABILITY ASSESSMENT (RVA)

7 Introduction

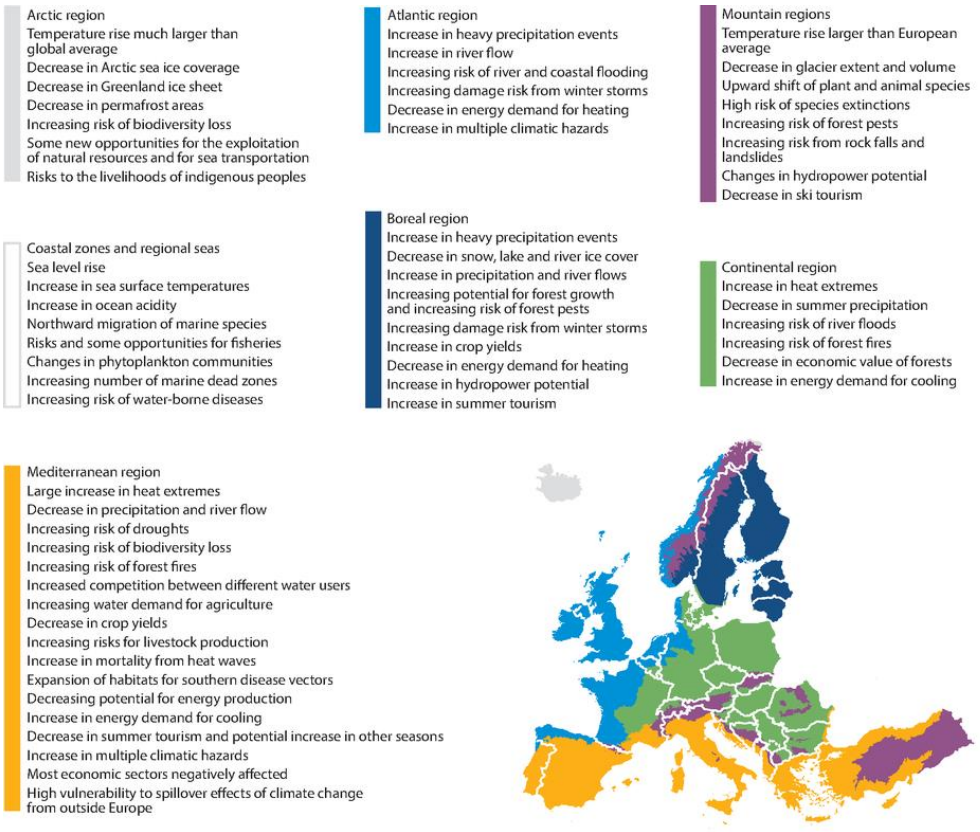
Assessing Climate Change Risk and Vulnerability (RVA) ([67]) has gained significance since 2010, given its central role in the Cancun Adaptation Framework ([68]), the EU Adaptation Strategy ([69]) and the countries development of National Adaptation Plans (European Commission, 2013) ([70]).

Even though most adaptation efforts are covered by public funds (EEA,2014), the private sector, particularly insurance companies, understands the importance of bringing climate change challenges clearly into their investment risk analysis in order to reduce potential losses associated with extreme events (Bank of England, 2015).

7.1 Climate impacts in Europe's cities

European cities are heavily vulnerable to the impacts of climate change. Heat, flooding, water scarcity and droughts (among others) can impact health, infrastructure, local economies, and quality of life of inhabitants. In the following figure (**Figure 4**) some examples of how climate change is impacting cities throughout Europe are shown. Effective climate action not only provides resilience in the face of climate impacts but also important benefits to urban areas in terms of quality of life, improved public health as well as job creation, for example.

Figure 4. Key observed and projected climate change and impacts for the main biogeographical regions in Europe (EEA, 2016) ([71])

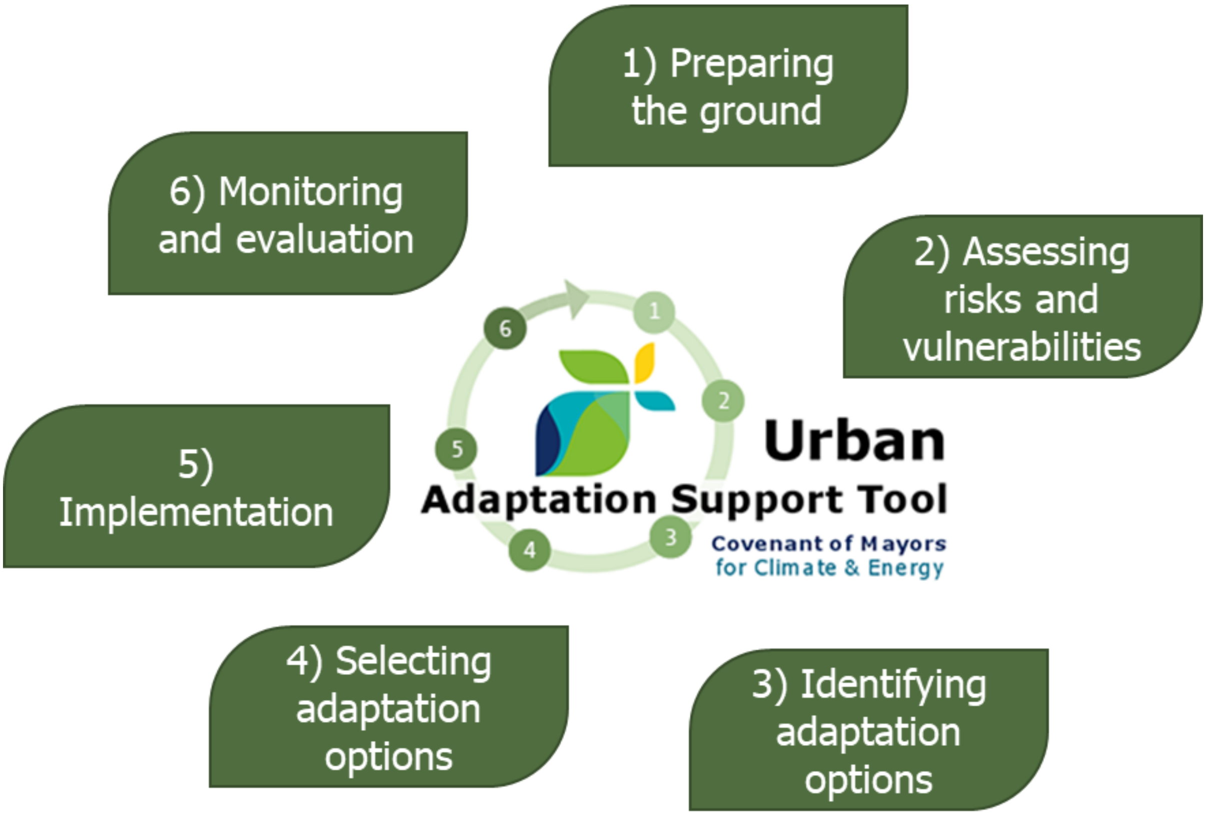


([67]) RVA: Risk and Vulnerability Assessment
([68]) UNFCCC (2010) CANCUN ADAPTATION FRAMEWORK (CAF) – Adopted at the 2010 Climate Change Conference in Cancun, Mexico (COP 16/ CMP 6). In the Agreements, Parties affirmed that adaptation must be addressed with the same level of priority as mitigation.
([69]) https://ec.europa.eu/clima/policies/adaptation/what_en
([70]) Ricardo, IEEP, Trinomics, and Alterra. Study to support the evaluation of the EU Adaptation Strategy, Ricardo/ED62885 Final Report, Study for the European Commission, 2018
([71]) https://www.eea.europa.eu/publications/climate-change-impacts-and-vulnerability-2016/key-findings

7.2 Assessing the climate risks and vulnerabilities at local level

Minimizing impacts in cities is a priority objective for both public and private sectors, since cities are centres of economic activity, and concentrate both population and assets (Swiss RE, 2014). All levels of government, including cities and regions, need a sound understanding of the climate risks and vulnerabilities on their territory to guide their decision making and policy shaping. Assessing climate risks and vulnerabilities is one of the first steps in the adaptation cycle (**Figure 5**), which provides the necessary information (What? Where? Why?) supporting tailored proactive measures for each site-specific context (How?).

Figure 5. Adaptation cycle steps



Source: Urban Adaptation Support Tool, CoMO/EEA

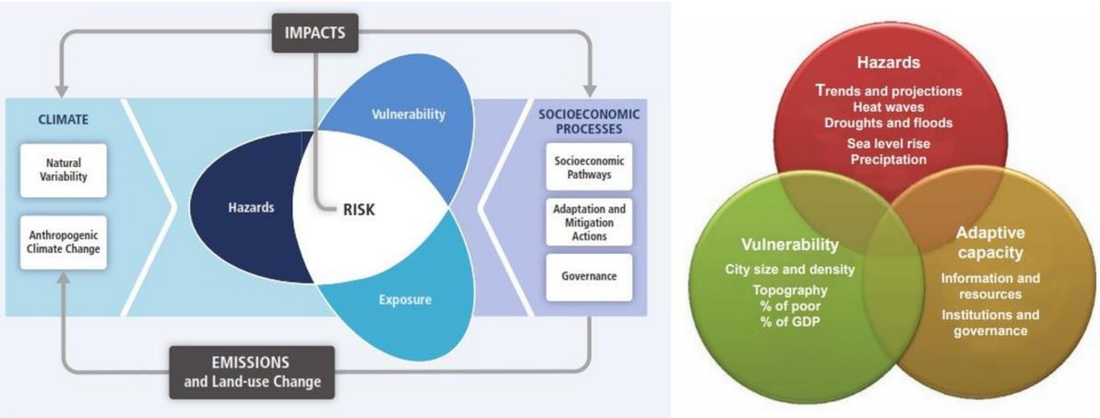
For each step of the adaptation cycle, signatories should go through a set of key actions, as illustrated in the following paragraphs. In particular the risk and vulnerability assessment is the second step of the cycle.

Not all issues that emerge from vulnerability assessments can be addressed, mainly due to budgetary limitations (World Bank, 2010). Therefore, the optimal level of adaptation faces a trade-off between the costs of investment in resilience and the expected benefits in terms of reduced losses and damages, versus a scenario of inaction. Even though this cost-benefit analysis is a crucial step in developing adaptation plans, the lack of robust estimations of costs, benefits and uncertainties still represents the main constraint in assessing vulnerability and risk for most countries and municipalities (EEA, 2014). Spatially explicit modelling of climate change risks can give an important contribution to a pragmatic cost-benefit estimation of different investment plans for adaptation (Loyd´s, 2014), promoting cost-effective solutions for each site-specific context. However, their implementation in small and mid-size cities still represents a challenge since local agencies usually do not have the necessary technical skills to use quantitative assessment tools, and georeferenced data with detailed resolution is often unavailable to feed the models (Revi et al., 2014). That said, the definition of a sound and easy to use RVA has to take into consideration the diverse panorama of skills, administrative capacities, and data availability and quality, at local level across European cities.

8 The necessity of a common approach

The EU strategy on Adaptation to climate change pursues the establishment of a common set of methods and indicators to assess the performance of adaptation projects and monitor the evolution of risk and vulnerabilities (see also Part 3). In the literature, there are very different definitions and ways to assess climate change risks and vulnerabilities. Scholars from different knowledge domains apply different approaches, often generating misunderstanding in interdisciplinary research on climate change (Füssel, 2007). The IPCC (2007) tried to propose a formal conceptualization of vulnerability as a function of a system's exposure and sensitivity to climate stressors and capacity to adapt and cope with their impacts. The Fifth Assessment Report (IPCC, 2014) introduced a slightly different terminology and moved from a climate change vulnerability to climate change risk framework by incorporating concepts from the disaster-risk community (IPCC, 2012). This risk framework differs, for example, from the one developed by the UCCRN (2011), as displayed in **Figure 5**, contributing to the confusion and lack of confidence of city climate practitioners about the correct way to assess climate change risks. Different RVA approaches - based on diverse explicative variables and ways of handling indicators - can make the comparison/benchmarking between cities' RVA scores unsound or invalid.

Figure 6. Different climate change risk frameworks



Sources: on the left, IPCC (2014); on the right, UCCRN (2011)

Moreover, doubts remained on how to move from a conceptual framework to a quantitative assessment in a site-specific context. Judgements and approximations have to be made to translate the existing information about the city – such as climate parameters, biophysical and socioeconomic attributes, governance and institutional capacities, among others – into knowledge that triggers a realistic RVA. The method by which to select sound explicative variables, allocate them to specific RVA components – such as exposure, sensitivity, adaptation capacity - and weight and aggregate them into composite indicators, remains highly arbitrary and clouded.

This uncertainty and intricacy hinders and delays local authorities in understanding their climate change impacts, vulnerabilities and risks. This is particularly true in small and mid-size cities, which usually rely on limited technical skills and resources. To date, it is not possible to define a common pattern of RVA application across Europe. Several local authorities carry out a qualitative assessment based on collected information in literature reviews; others rely on quantitative climate-impact models and expert judgment (EEA, 2014). Mixed-method approaches, however, are used by most countries.

Therefore, there is a blatant demand for a harmonisation of the main concepts, methodologies and indicators for adaptation - as in the case of mitigation - to make RVAs easy to handle by non-expert users.

9 Risk and Vulnerability Assessment (RVA) – Main Concepts

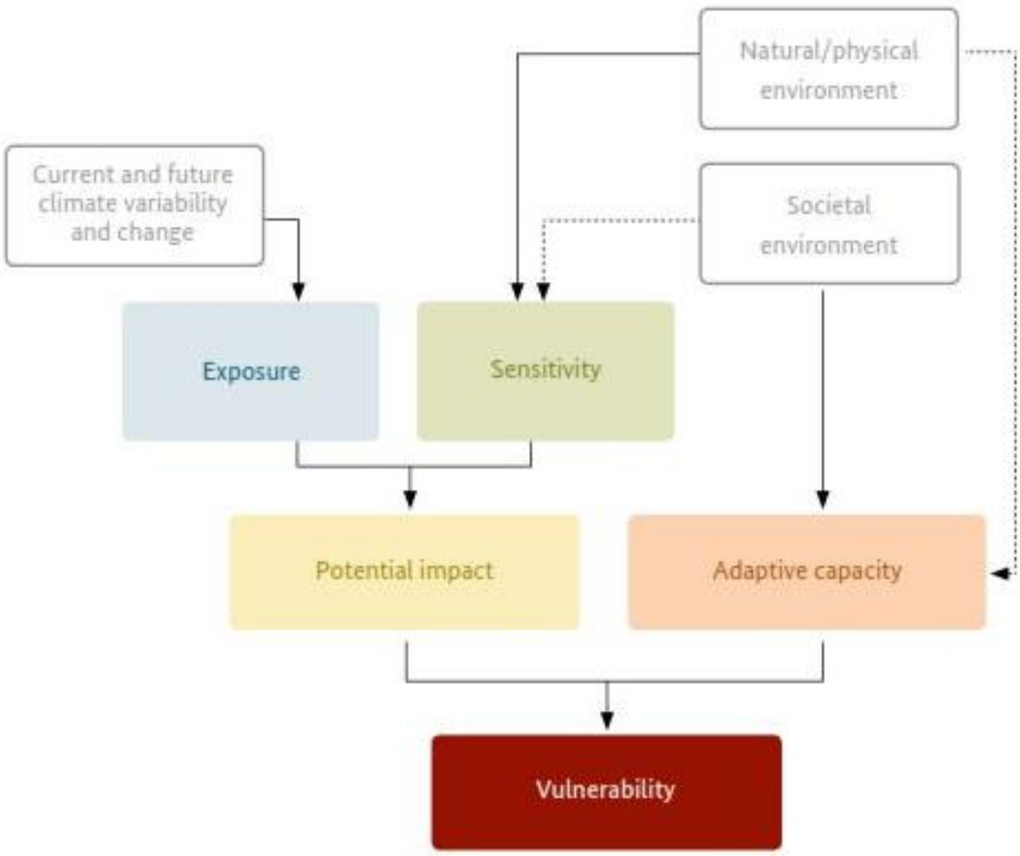
9.1 The evolution from the Fourth to the Fifth Assessment Report of the IPCC

As reported in the previous chapter, the concepts of vulnerability, risk and assessment have been progressively refined until the current framework was proposed. An insight of the evolution of the main concepts is crucial for the understanding of the current approach. The fourth assessment report framework is presented below only as an introduction to this chapter. The adopted framework to follow is however presented in section 9.1.2.

9.1.1 Fourth Assessment Report – Vulnerability Assessment (2007)

The fourth report of the IPCC (2007) describes vulnerability as a function of the indices of exposure, sensitivity and adaptation capacity (Füssel, 2009). **Figure 7** shows the main steps to aggregate these sub-components into a vulnerability assessment.

Figure 7. Vulnerability assessment framework



Source: GIZ, 2014

In this framework, Exposure includes information about the character, magnitude and variation in climate parameters and extremes.

Sensitivity determines the degree to which a system is adversely affected by a given climate stressor. It is generally composed of all environmental, social and physical attributes that can help explain the potential impact of a climate extreme.

The combination of Exposure and Sensitivity defines the Potential Impacts of Climate Change. For instance, a high mortality rate (Impact) during heat waves in cities is the result of prolonged high temperatures (Exposure) in combination with an elderly population living in improper housing condition (Sensitivity) (IPCC, 2007).

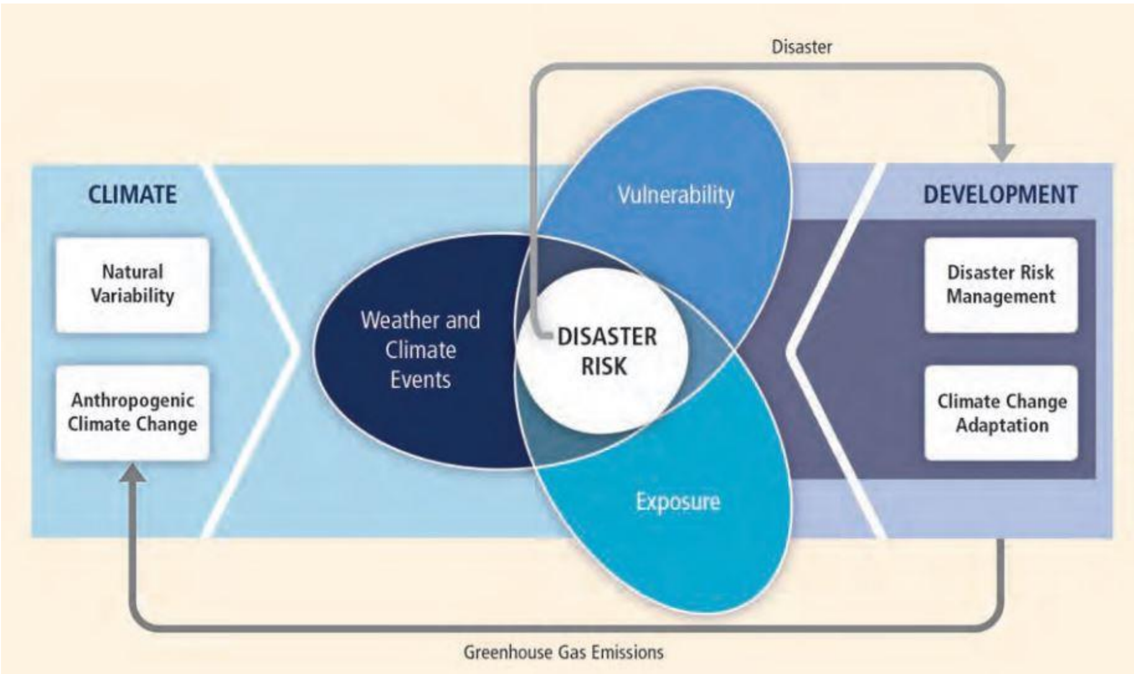
Adaptation Capacity describes the ability of a system to adjust to Climate Change to reduce possible damages, explore new opportunities, or cope with consequences (IPCC, 2007). There are various approaches to measuring the adaptive capacity of a local authority through proxy indicators: structural capacity, such as existing infrastructures and assets; institutional capacity, such as proper regulations, incentives, monitoring and information; and socioeconomic capacity, such as literacy levels, income diversification and gender-related inequalities (Qin et al., 2015; European Commission, 2013b; Rosenzweig et al., 2011; Dodman et al., 2009). The collection and quantification of this sub-component still represents an obstacle to vulnerability assessment due to the lack of reliable information.

9.1.2 Special report of the IPCC – SREX (2012)

This report introduces the concept of Disaster Risks as a function of climate extremes, system vulnerability, and exposure (**Figure 8**). In this context, exposure means "the presence of people, livelihoods, environmental services and resources, infrastructure, economic or cultural assets in place that could be adversely affected" (IPCC, 2012, pp. 4). Vulnerability quantifies the propensity to be adversely affected by a system, but the report does not clarify which kind of information should be used in the vulnerability index, though there are some references to levels of wealth, education, disability and health status, gender, age, class, etc. As such, it is assumed to include the main socioeconomic weaknesses of the systems.

Disaster Risk is defined as "the likelihood over a specified time period of severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic, or environmental effects that require immediate emergency response to satisfy critical human needs and that may require external support for recovery" (IPCC, 2012, pp.4).

Figure 8. Core concepts of SREX



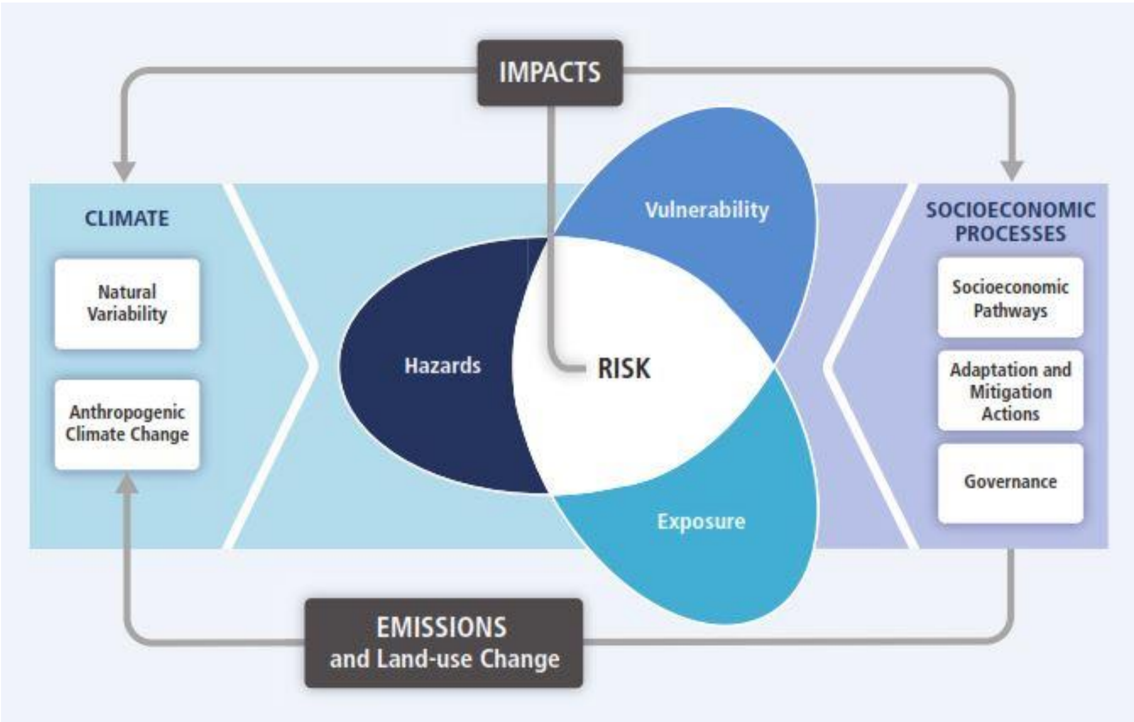
Source: IPCC, 2012

9.1.3 Fifth Assessment Report – Risk Assessment (2014)

The last Assessment Report of the IPCC (AR5) focuses on the concept of climate risk and proposes a new framework for its assessment (**Figure 9**). Risk is defined as a function of the expected potential impacts (hazards) of climate extremes, system vulnerability, and exposure. The latter maintains the same definition as in the SREX 2012 (see above). Hazard refers to climate-related physical events or impacts. Vulnerability includes sensitivity or susceptibility to harm, and the adaptive-capacity deficit of the system.

The term "risk" is used to define the risks of natural variability and climate change. Henceforth, we will adopt this definition and framework to propose a RVA for cities.

Figure 9. Climate Risk Assessment framework



Source: IPCC, 2014

9.2 RVA Terminology

A clear and common terminology is of great importance for developing a well-defined and accurate RVA in line with the conceptual evolution and the need of common framework stated in the previous chapters. The necessity of a common terminology within the EU has been arising in order to avoid misunderstandings among signatories and to have a clear set of indicators that can help estimate the vulnerability of their city.

Table 12 offers an example of the indicators proposed by the Climate-ADAPT platform to calculate city vulnerability to heat waves ([72]). The term "exposure" includes several information about lack of green areas, soil sealing, ventilation, etc., concepts far from the definition of "exposure" proposed by the IPCC (2014), described in 8.13. Therefore, for the sake of clarity and consistence, the main concepts and terms used in in any RVAs developed by Covenant signatories should be well defined.

([72]) http://climate-adapt.eea.europa.eu/knowledge/tools/urban-adaptation/climatic-threats/heat-waves

Table 12. Example of indicators to assess vulnerability to heat waves

Factors that tend to increase vulnerability to heat waves ...		Response capacity
Exposure	Sensitivity	
High thermal disomfort values	High share of vulnerable people	Increasing the share of green urban areas
Lack of green urban areas	High share of low-income households – socio-economic status	Decreasing soil sealing
High degree of soil sealing	High population number	Commitment to fight climate change – awareness of and trust in city governance
Increased background heat and heatwaves	High share of very young population	Trust in other people

Source: Climate-ADAPT platform, 2017

For the reason explained above, definitions of common terms have been excerpted from the Fifth Assessment Report of the IPCC (IPCC, 2014, pp.5) and reported in the Glossary. These will be used henceforth as references.

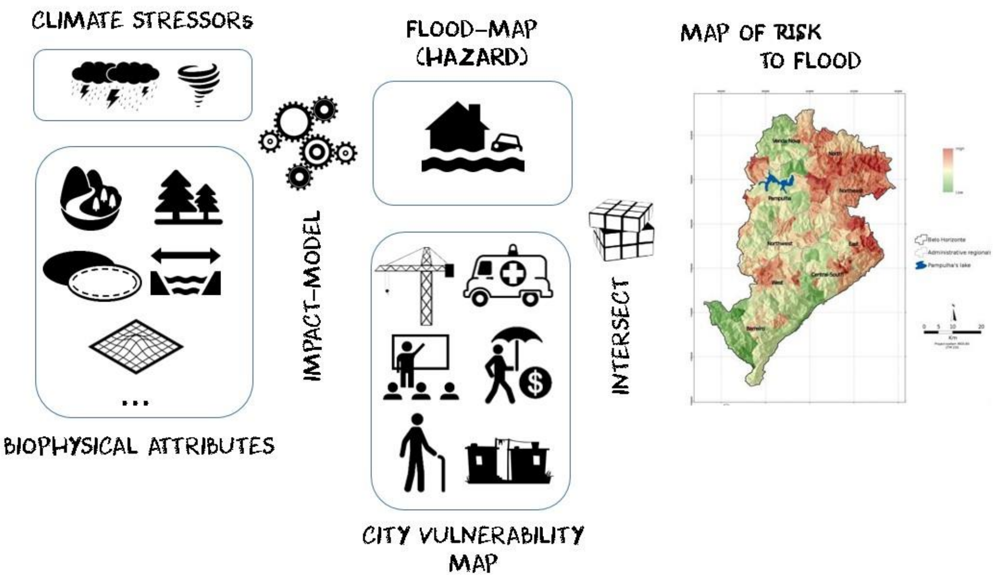
10 Methodological approaches for RVA

A Risk and Vulnerability Assessment (RVA) determines the nature and extent of a risk by analysing potential hazards and assessing the vulnerability that could pose a potential threat or harm to people, property, livelihoods and the environment on which they depend. This can take the form of a single assessment or various assessments undertaken per sector, for example.

According to the IPCC (2014), risk can be understood either qualitatively or quantitatively. Useful approaches for managing risk do not necessarily require an accurate assessment, unless the information is available.

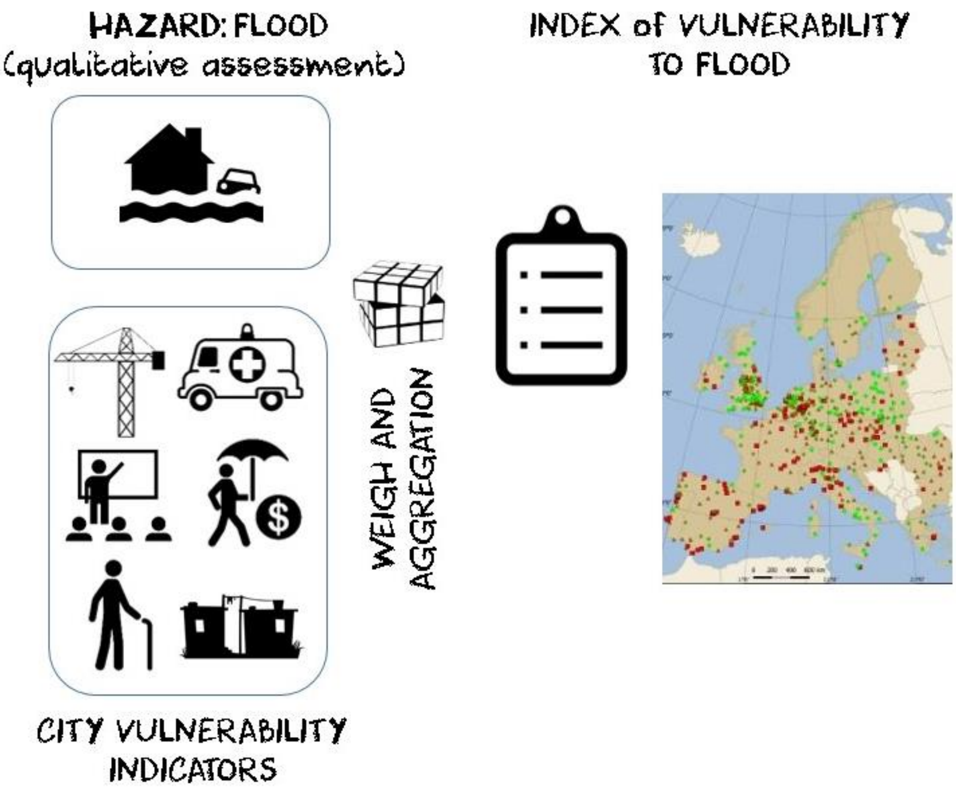
Two different approaches to help local authorities better understand climate change impacts, vulnerabilities and risks within their territory are proposed. They differ in the level of detail, required data, tools and technical skills needed to calculate the vulnerability to a specific hazard. A spatially explicit approach relies on climate impact-models (e.g. flood-model) to produce hazard maps (e.g. flood-map) according to specific climate stressor and city biophysical attributes (model´s input) (**Figure 10**). An Indicator-Based Assessment helps users to identify the factors that shape city vulnerability to climate threats through comparable composite indicators (**Figure 11**). The spatially explicit approach is most suited for greater local authorities that usually have the necessary resources and capacities to use the models and act on the main outcomes. The smaller local authorities might use a simpler qualitative approach based on the construction of composite indicators to assess their climate vulnerability and risk.

Figure 10. Vulnerability assessment based on spatially explicit climate impact-models (e.g. flood-model). The final map displays the vulnerability to flood of the city of Belo Horizonte in 2030 under RCP 8.5 (Bittencourt et al, 2017)



Source: JRC own elaboration

Figure 11. Indicator-based vulnerability assessment (e.g. to flood). Output comes in the form of a vulnerability index (often displayed by tables or simple GIS maps).The final map represents the comparison of vulnerability to flood of EU cities (Tapia et al., 2017)



Source: JRC own elaboration.

Local authorities could choose the most suitable option according to their available resources and skills to assess their risk. The scoreboard tool from the current reporting template could help the signatory to decide. However, the approach adopted in the reporting framework is qualitative and indicators should be provided for risk, vulnerability and impacts.

Further than the general approach, specific methodologies have been developed by Covenant Coordinators to best support their associated signatories in assessing their risks and vulnerabilities. As an example, the Province of Barcelona developed a specific excel file tool to make a simplified climate change vulnerability assessment. The tool includes information gathered from each municipality which can be related to climate change impacts and a check list that must be answered by the municipality. Once the check list is answered, the tool shows results on the vulnerability of the municipality to several climate change threats. However, this is a first preparatory approach, during SECAP drafting a more detailed assessment should be made ([73]).

10.1 RVA based on spatially explicit impact models

10.1.1 General considerations

Planning and implementing adaptation strategies to Climate Change takes place at a local level. Spatially explicit city-level assessment of risk of climate change impacts is essential to indicate adaptive measures at appropriate scales, taking into consideration the

([73]) http://mycovenant.eumayors.eu/capacity-sharing-corner/resources-library specificities of each context within the city. Detailed georeferenced analysis grants city authorities access to appropriate information for making decisions about the future development of physical and social infrastructure and for prioritizing adaptation investments.

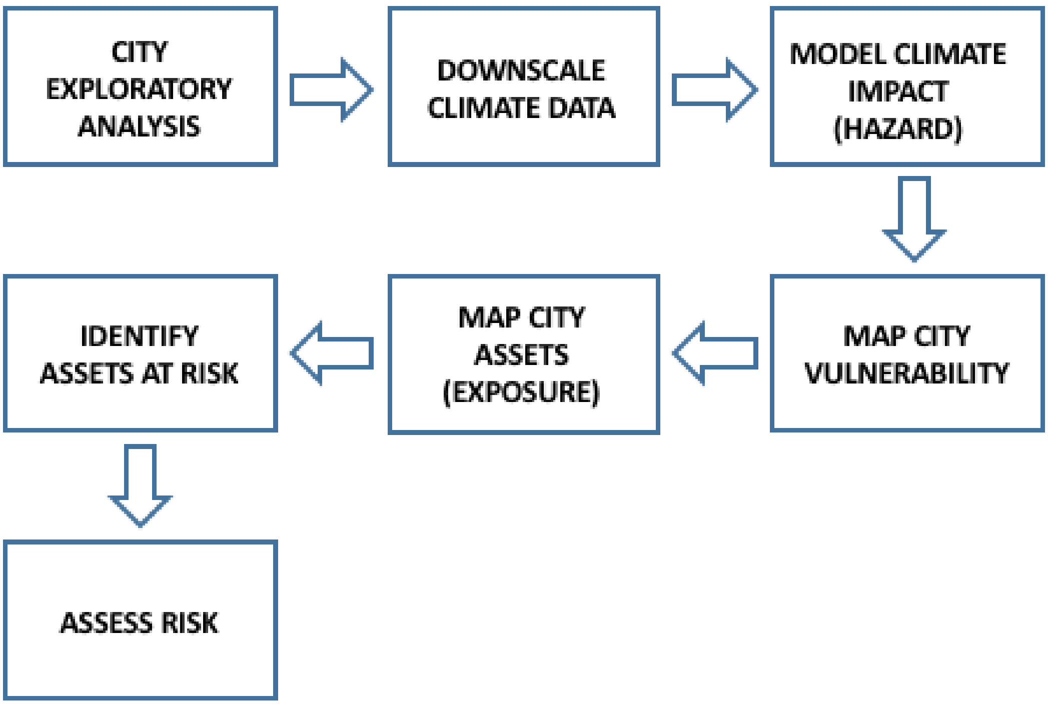
A spatially explicit approach is necessary to capture context-contingent processes varying across different scales, pointing out regions where climate change impacts and local characteristics are compounded creating hotspots of vulnerability (Oppenheimer et al., 2014). These hotspots are critical areas for policy action and their attributes have to be analysed with a higher degree of detail (European Commission, 2002). The variables that determine high vulnerability scores can highlight deficits in environment, governance, infrastructure, health, education or physical characteristics of the city.

Using spatially-explicit modelling demands technical skills and robust georeferenced datasets, not always available in small and mid-size cities. Data collection, validation and imputation, as well as processing and harmonization, are time consuming and require a good knowledge of GIS and statistical tools. Therefore, RVA could be conducted by an external consulting firm or through the assistance of city networks. The main objective of external consultancies is not training municipal officers to run models by themselves – rarely do they have the time and willingness to do that – but instead, guaranteeing the full uptake of the main research outcomes and their inclusion into urban decision-making processes.

10.1.2 Modelling framework

Several modelling steps shape the risk assessment framework, as displayed by **Figure 12**.

Figure 12. Modelling framework for risk assessment



Source: JRC own elaboration.

10.1.2.1 STEP 1: Exploratory analysis with key-stakeholders

This step usually includes a kick-off meeting with city stakeholders in order to contextualize the study, understand client needs and expectations, identify instances of Climate Change impacts, select a contact point in the local authority (i.e.an officer from Environmental department), and clearly explain the RVA approach and the required data. Weber et al., (2015) suggests creating an Advisory Group of relevant experts from academia, NGOs, city government and private sector, to help construct sound and policy-relevant indicators and selecting the best scale of analysis (e.g., neighbourhood). Input from city decision makers and local institutions steers the project towards actionable results.

The main sources of information – such as city agencies, civil protection, utility companies, and universities, among others – should be mapped. The contact point at the local authority should be entrusted with facilitating the communication between the parties and fostering data sharing.

Box 11. Main activities of the exploratory analysis of the city

— Stakeholder engagement

— Select a contact point to foster communication and data sharing and create an Advisory Group

— Qualitative understanding of city's specificities and climate change impacts

10.1.2.2 STEP 2: Downscale global climate data to regional context

Downscaling the results of global climate models (GCMs) to high resolution is necessary to capture the spatial and temporal variability of projected temperature, precipitation, wind, air humidity, and climate extremes (e.g., Cooling Degrees Day - CDD, number of consecutive dry days; Warm Spell Duration Index – WSDI heat waves, among others) at a sound scale for urban RVA. Downscaling is a complex issue and high resolution climate information has to be provided by regional or country research agencies to local authorities.

The EURO-CORDEX ([74]) - the European branch of the CORDEX initiative sponsored by the World Research Program - provides regional climate change projections for the EU domain from the CMIP5[75] experiments until 2100 with a grid resolution of about 12 km (0,11 degree).

Another EU-specific example could be found in the form of the regional climate adaptation strategies developed by national ministries or meteorological institutes as part of their National Adaptation Strategies.

Additionally, local data from city weather stations can be used to refine the calibration of the regional climate models, improving the accuracy of scenario projections. Urban climate maps can help to identify heat islands through the analysis of surface temperature and wind patterns according to building distribution and density (Katzschener, 2011).

Box 12. Main activities of downscaling climate data

— Regionalize results of global climate models to a proper resolution for applications at local level

([74]) http://www.euro-cordex.net
([75]) Coupled Model Intercomparison Project, Phase 5. https://pcmdi.llnl.gov/mips/cmip5/index.html

10.1.2.3 STEP 3: Climate-impact modelling - linking system attributes to climate projections

The Advisory Group defines the preliminary list of the climate impacts affecting the city, which drives the selection of the spatially explicit modelling tools.

In the literature, there are many examples of climate-impact models. The selection of the most suitable ones for the studied context depends on several factors, including data availability. Proxies can be used when desired data is unavailable (OECD and JRC, 2008); proxies introduce an additional uncertainty to the analysis but represent a valid tool to overcome the chronic lack of reliable or accessible information at local level. When data scarcity disables the use of detailed climate-impact models, GIS based tools (map algebra) can be used to link climate extremes to biophysical and socioeconomic data. The selection of the explicative variables has to be based on a deep literature review and expert judgement, and the means of aggregating them into composite indicators has to be well documented in order to guarantee scientific solidity and allow replication in similar contexts.

The model OUTPUT comes in the form of maps representing – for a specific time window and climate scenario ([76]) – the spatial variability within the urban perimeter of the potential impacts. The map is usually a raster file, whose resolution depends on the quality of INPUT data.

This STEP is commonly developed by consultancy firms, city networks or by regional/national research centres, due to its technical complexity.

Box 13. Main activities of modelling climate hazard

— Link Climate data with biophysical and socioeconomic data (Model INPUT) relevant to impact assessment

— Map climate related impacts (model OUTPUT) through spatially explicit impact-model (e.g. flood-model)

10.1.2.4 STEP 4: Map city vulnerabilities

Each hazard affects different areas within a city, and the consequences depend on specific socioeconomic and institutional weaknesses relevant to the impact at stake. Vulnerable communities affected by flooding instances have socioeconomic specificities and adaptation deficits different from the people impacted by heat waves, for example[77]. Therefore, the flood vulnerability map is different to the heat wave vulnerability map. It is important to correctly identify the factors that drive urban vulnerability to climate threats through literature review and consultation with the Advisory Group (see STEP 1).

Kaspersen and Halsnæs (2017) assessed the risk of urban flooding in the city of Odense, Denmark, by including socioeconomic data about population income, education, housing, behaviour, amongst others, to represent the system vulnerability. Wolf and McGregor (2013) pointed out the importance of including socio-economic drivers - such as health status, mobility, age, access to resources, among others - to correctly understand associated health outcomes in a vulnerability assessment for heat waves in London, UK.

Other European examples can also be cited. For example, in Lower Danube, a river restoration and rehabilitation action has been carried out against flood risks by means of green corridors, wetlands and floodplains ([78]). Trondheim has also implemented green infrastructure to mitigate flood risks through rain gardens and woodlands ([79]). However,

([76]) Global Climate Models provide information of temperature and precipitation, among others, according to RCPs scenarios.
([77]) The explicative variables are often the same for different vulnerabilities, since many factors such as housing or age are important to explain the consequences of different climate-related impacts.
([78]) http://climate-adapt.eea.europa.eu/metadata/case-studies/lower-danube-green-corridor-floodplain-restoration-for-flood-protection
([79]) https://www.ngu.no/en/topic/urban-groundwater

green infrastructure is not only useful for adaptation to flood risks, but also to heatwaves. Thus, green spaces and corridors have been built in urban areas such as Barcelona ([80]) and Stuttgart ([81]) for the purpose of minimising heat-related risks. Additional adaptation case studies per type of climate risk can be consulted in part 3b of this guidebook.

Box 14. Main activities of mapping city vulnerability

— Understand city specificities that could contribute to aggravating the consequences of a specific climate hazard

— Map socioeconomic, institutional, biophysical etc. characteristics associated with sensitivity and capacity of adaptation to specific hazards

— Repeat vulnerability mapping for each hazard

From a global perspective, to cite the study of Belo Horizonte, Brazil (Bettencourt et al, 2016), the vulnerability to flood included data about i) population residing in slums in relation to total population of the sub-basin; ii) low-income population level; iii) existence of rain-alert systems; iv) existing (or planned) drainage infrastructure, among others. The vulnerability to dengue included information on i) share of population with regular access to basic sanitation; ii) low-income population rate; iii) ongoing educational projects (NGOs and Municipality) for a proper management of land and garbage; iv) share of population with regular access to basic health care, among others.

10.1.2.5 STEP 5: Define Exposure by mapping important assets within the city

Information about the location and properties of relevant city assets, such as buildings, roads, historical monuments, and population density, has to be included into an assets inventory map. This map represents the exposure of the system. Information about population density can be extracted from local or national census databases. Assets can be georeferenced and characterized by mean of GIS software or the Google Earth platform. Useful information layers about trends in urbanization, population distribution and built-up areas can be downloaded from the Global Human Settlement (GHSL) dataset ([82]). The GHSL European Settlement Map is a spatial raster dataset mapping human settlements in Europe as derived from remote sensing image processing.

Box 15. Main activities of mapping city assets

— Map and characterize important buildings, economic, productive, infrastructure, historical, etc. assets and people that could be adversely affected.

10.1.2.6 STEP 6: Overlay hazard, vulnerability and asset maps (exposure) to assess the number of assets at risk

The hazard map (e.g., flood map) is combined with the vulnerability map and the assets map (exposure) to quantify the number of assets and vulnerable communities at risk. This step has to be replicated for each climate-related impact.

All the explanatory variables of risk have to be geo-referenced and normalized to become spatially comparable (pixel by pixel, or mapping unit by mapping unit, in a GIS based approach) and aggregable in a weighted index. The normalization can be made by subtracting the minimum value and dividing by the range of the indicator values ([83])

([80]) http://climate-adapt.eea.europa.eu/metadata/case-studies/barcelona-trees-tempering-the-mediterranean-city-climate
([81]) http://climate-adapt.eea.europa.eu/metadata/case-studies/stuttgart-combating-the-heat-island-effect-and-poor-air-quality-with-green-ventilation-corridors

([82]) http://ghsl.jrc.ec.europa.eu/data.php
([83]) Min-Max normalization: $\frac{x_i - x_{min}}{x_{max} - x_{min}}$

(Naumann et al., 2014). This method normalises indicators to have an identical range [0,1].

Finally, the urban risk map is computed by integrating its determinants - i.e. hazard, vulnerability and exposure – through a spatially explicit approach, as suggested by Neumann et al. (2015):

$$Risk = Hazard\ x\ Exposure\ x\ Vulnerability \quad \text{Eq.(1)}$$

Box 16. Main activities of mapping assets at risk

— Intersect hazard, vulnerability and assets maps (exposure)

— Identify assets within hotspots of risk

— Repeat this step for each hazard

10.1.2.7 STEP 7: Assess the risk (potential loss and damage)

The IPCC (2014) defines risk as the potential consequences of something valuable at stake when the outcome is uncertain, recognizing the diversity of values. Monetizing historical or cultural assets or health issues can be extremely arbitrary and not always accepted by scholars from different academic fields. Adding monetary value in terms of expected losses and damage costs for each asset is not always possible due to data scarcity. Insurance companies can provide useful information about the value of most urban assets and damage costs; but their databases are hardly accessible and proxies often have to be used to overcome the lack of data. For example, Kaspersen and Halsnes (2017) used information from Danish Insurance Company to define a damage function and unit damage costs according to inundation thresholds for different buildings in the city of Odense caused by flooding during extreme precipitation. Health costs have been calculated based on the number of people exposed to mixed rain-sewage water, which contributes to causing infections. They assessed the range of expected costs for different rain patterns, pointing out the relationship between climate extremes and expected risks at city level. Risks are calculated by adding monetary values in terms of damage costs and welfare losses for each asset. The damage function has been based on the general assumption that the unit damage cost for each asset remains constant beyond an inundation threshold (water level required to cause damage) and increases with the intensity of rainfall events. Naumann et al., (2015) described the relationship between the severity of drought periods and expected damages in two economic sectors – i.e., cereal production and hydropower generation – through a power-law damage function for 21 countries in Europe. They pointed out that the different shape of the damage function – which defines the expected risk - can be explained by the site-specific vulnerability to drought of each sector.

Impacts on non-market assets – such as social or environmental welfare – that cannot be easily translated into a monetary dimension, can be evaluated and compared through a Multicriteria Assessment (MCA) to support urban adaptation planning (EEA, 2016).

Box 17. Main activities of assessing risks

— Approximate unit damage costs and damage functions for each asset

— MCA for invaluable ($) assets

— Quantify expected losses and damages

10.2 Indicator-based vulnerability assessment

Indicator-Based Vulnerability Assessment (IBVA) has been widely used to assess climate change vulnerability in urban contexts (Tapia et al., 2017; Weber et al., 2015; Wolf and McGregor, 2013). This approach is particularly suitable for smaller and mid-size cities since it doesn’t demand particularly technical skills or modelling tools and can be fed by using public available datasets. Moreover, defining common assumptions, methodology, sets of indicators and climate threats, will allow comparability of results and the possibility of benchmarking European cities in terms of vulnerability to climate change.

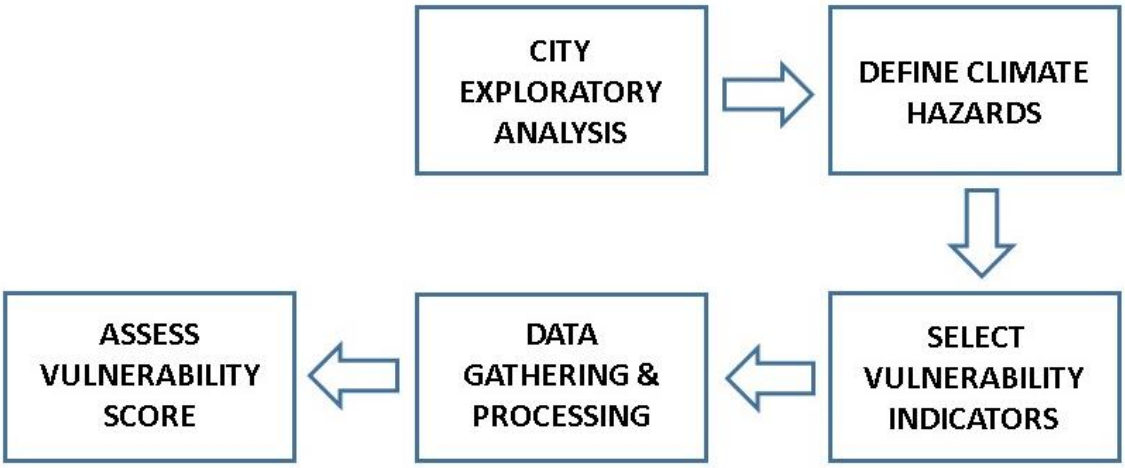
According to the IPCC (2014), vulnerability is described by non-climatic factors covering a system´s biophysical and socioeconomic attributes. As highlighted in Chapter 4.1.2.4, different climate hazards affect different vulnerabilities in the city.

The level of aggregation of IBVA depends on the general objectives of the study, the technical skills of local authorities, and data availability. An assessment of the urban area as a whole aggregates information about the city attributes and provides an overview about the potential vulnerability of the city to particular climate threats. The results offer a useful base for benchmarking cities across Europe and for defining proper allocation of funding to the most critical contexts. Capturing the spatial variability of the indicators within the urban perimeter demands a spatially explicit approach. The spatial unit for aggregating data can be defined according to administrative borders, such as neighbourhoods or districts. This approach allows decision makers to better understand which are the problematic areas and possible weaknesses within the city and to properly allocate local investments in adaptation. The handling and visualization of vulnerability indicators can be based on GIS map algebra and doesn´t require particular technical capacities or tools.

10.2.1 IBVA framework

Figure 13 displays the main steps that shape the IBVA framework:

Figure 13. Sequence of steps for indicator-based vulnerability assessment



Source: JRC own elaboration

10.2.2 STEP1: City exploratory analysis

This step is common for the two approaches: spatially explicit impact models and Indicator based assessment. As a consequence, the description of this step can be found in Chapter 9.1.2.1 of Part 2 B.

Box 18. Main activities of the exploratory analysis of the city

— Stakeholder engagement

— Select a contact point to foster communication and data sharing and create an Advisory Group

— Qualitative understanding of city's specificities and climate change impacts

10.2.3 STEP 2: Identify climate hazards for the city

A coarse assessment as the one reported in **Figure 4** can help drive the discussion with key-stakeholders (STEP 1) about expected climate hazards by localizing the city within a specific risk zone. The macro-scale information should be calibrated through observed instances of climate-related impacts within the city.

Tapia et al. (2017) conducted a deep literature review to identify the most relevant climate threats faced by European cities. It points out that most urban areas are affected by more than one hazard, and the most recurrent impacts are:

- Heat waves on human health;
- Droughts on water management;
- Inland floods and coastal floods - due to storm surge and heavy rainfalls - on city infrastructure, buildings, socioeconomic tissues and services.

Revi et al. (2014) highlight that these hazards will be recurrent in urban areas due to increased frequency, intensity and duration of extreme weather events, such as heavier precipitations, longer droughts, warmer spells and storm surges. The Urban Vulnerability Map Book of the Climate-ADAPT platform also includes forest fires among the climatic threats for EU cities ([84]).

Even though the exposure to climate change and weather extremes can vary a lot across Europe, a common list of climate change-related indicators and related impacts should be defined, at least within the same climate risk zone (**Figure 4**) by crossing macro-scale information with local observed instances. For example, London is included in the North-Western (NW) zone, characterized by an increase of winter precipitation and risk of flooding. Recently, the city had also to face health impacts due to heat waves (Wolf and McGregor, 2013), a hazard not listed in NW zone.

A qualitative description of time-scales (short, mid and long term) of the expected impacts should be provided in order to correctly prioritize investments. There are many easily accessible sources of information about climate change projections and data in Europe, such as:

— Technical reports by European and multilateral agencies: i) EEA, (2016); ii) Kovats et al., 2014; iii) Revi et al., 2014; among others; iv) PESETA II and PESETA III projects ([85]).

— Data Sharing Platforms: i) Climate-ADAPT ([86]); ii) IPCC data Distribution Centre ([87]); iii) JPI Climate ([88]); iv) Climate Change Knowledge Portal ([89]), among others;

([84]) http://climate-adapt.eea.europa.eu/knowledge/tools/urban-adaptation/climatic-threats/forest-fires
([85]) https://ec.europa.eu/jrc/en/peseta
([86]) http://climate-adapt.eea.europa.eu/knowledge/tools/urban-adaptation/introduction
([87]) http://www.ipcc-data.org/
([88]) http://www.jpi-climate.eu/publications

— National and international meteorological centres, such as the Met Office ([90]) and the European Centre for Medium Range Weather Forecasts[91], among others.

Box 19. Main activities of defining climate hazards for the city
— Gather data about current climate related impacts
— Identify climate threats for the city (short, mid and long term)

10.2.4 STEP 3: Select vulnerability indicators

Each impact affects different areas within a city, and the consequences depend on specific socioeconomic and institutional weaknesses relevant to the impact at stake. It is important to correctly identify the indicators that drive urban vulnerability to the selected climate hazards, through literature review and consultation with the Advisory Group[92]. Weber et al. (2015), for example, modified the Social Vulnerability Index - developed by Cutter et al. (2003) - to focus specifically on population characteristics associated with sensitivity to extreme heat in cities. Non-climatic indicators have to be grouped into the vulnerability components, i.e., Sensitivity and Adaptation Capacity. They include information about human capital, socioeconomic conditions, infrastructure and built environment, natural capital, governance and institutions, among others (Tapia et al, 2017). Indicators should be selected on the basis of their analytical soundness, measurability, relevance and coverage (OECD and JRC, 2008). The final list should be validated by the Advisory Group.

Box 20. Main activities of selecting vulnerability indicators for the city
— Focus on socioeconomic, institutional, biophysical, etc. characteristics associated with sensitivity and capacity of adaptation to specific hazard
— Repeat the selection for each hazard

10.2.5 STEP 4: Data gathering and processing

City socioeconomic indicators and information about the built environment and biophysical attributes can be extracted from existing databases at local, regional and national level. The Urban Audit database (Eurostat, 2016) provides a comparable set of indicators – mainly socioeconomic data - with European coverage ([93]).

The Urban Vulnerability Map Book of the Climate-ADAPT platform provides useful maps and data at city-level about urban capacity for response, governance, resources and economic status, among others. It produces maps per climatic threat including heat waves, water scarcity and droughts, flooding and forest fires. Factors that tend to increase vulnerability to specific climate impacts have been grouped into vulnerability dimensions, namely exposure, sensitivity and response capacity ([94]).

The National Census Bureaux and National Statistical Institutes ([95]) also provide useful information about the demographics and socioeconomic status of the urban population.

The construction of composite indicators should be based on a step-by-step approach aimed at reducing data manipulation and misrepresentation. It includes: i) imputation of missing data and deep analysis of outliers (with eventual removal of anomalous values); ii) multivariate analysis to study the overall structure of dataset and internal consistency

([89]) http://sdwebx.worldbank.org/climateportal
([90]) http://www.metoffice.gov.uk/services/data-provision
([91]) https://www.ecmwf.int/en/forecasts
([92]) Advisory groups and working groups include relevant experts from academia, NGOs, city government and private sector.
([93]) EU28 wide plus Norway and Switzerland
([94]) Please refer to chapter 3.2.2
([95]) The Census Hub of EUROSTAT facilitates data gathering and sharing across EU Census bureaux https://ec.europa.eu/CensusHub2/query.do?step=selectHyperCube&qhc=false

check; iii) normalization to render the variables comparable; iv) weighting and aggregation, respecting the data properties and project theoretical framework; v) assess possible sources of uncertainty (OECD & JRC, 2008). The selection of the weights is a delicate issue and should be based on deep literature review, expert judgement or manual calibration towards observed instances.

Box 21. Main activities of data gathering and processing

— Identify and access data sources

— Data preparation to construct a composite indicator: imputation of missing data and outlier removal; MVA and consistency check; normalization; weighting and aggregation; uncertainty assessment

10.2.6 STEP 5: Assess vulnerability score

Sensitivity to and adaptation capacity for specific climate threats can be calculated through different equations and aggregation approaches (e.g. linear, geometric, non-compensatory Multi-Criteria Analysis).

Using GIS map algebra is a common and simple way to combine explicative variables of city sensitivity and adaptation capacity into the vulnerability indicator (Heltberg and Bonch-Osmolovsky, 2011). Data is aggregated and displayed at the scale of analysis (e.g., neighbourhood, census unit or district), providing a useful information about the spatial variability of vulnerability components within the urban perimeter (Weber et al., 2015; Follador et al., 2013).

Tapia et al. (2017) calculate sensitivity and adaptation capacity under different hazards (i.e., heat wave, flood and drought) at city level, without considering their variability within the urban perimeter. In this case, data is presented as tables, and each variable represents the value for the city as a whole. The vulnerability components have been estimated through a geometric aggregation, and the vulnerability score has been used to compare and benchmark 571 cities across Europe. They point out that the most vulnerable cities should be studied in detail through a fine-grained vulnerability assessment in order to improve the understanding of urban risks and support adaptation planning.

Box 22. Main activities of vulnerability assessment

— Aggregate the explicative variables into the vulnerability components: sensitivity and capacity of adaptation to a specific hazard

— Assess the city vulnerability score

— Repeat the assessment for each hazard

11 Final considerations

Adaptation is a relatively new topic for most cities worldwide. Among the main obstacles to commitment to adaptation, local authorities and Climate Change practitioners indicate the lack of a common and transparent approach to assess climate-related impacts, vulnerabilities and risks in their territory. They point out that many examples of methods and indicators exist for calculating RVA, making the selection of the best approach arbitrary and often unsupported by sound technical motivations. Using different methodologies for the same city can lead to different results and consequently different adaptation planning. To reduce the possibility of data misrepresentation and to foster comparability among European cities, the standardization of indicators and methods to assess climate impacts, vulnerability and risk is needed. This calls for common and agreed semantics, terms, indicators and equations to manage RVA in Europe (and among European Agencies).

A spatially-explicit approach based on detailed climate-impact models offers a clear picture of city vulnerability and risk, addressing important questions such as the *what*, *where*, *why* and *how* of investing in adaptation within urban perimeters. It allows the identification of the regions where climate change impacts are concentrated, pointing out vulnerability hotspots. Mapping the main assets within the hotspots provides an approximation of potential losses and damages; monetizing the risk represents an effective way to capture the attention of decision makers and foster the discussion about adaptation costs versus the costs of inaction. Multi-Criteria Analysis can be used to evaluate and compare climate change risk on intangible factors – i.e., non-market assets which value cannot be accurately quantify in economic terms, such as the social or environmental welfare. This information is necessary to allow the optimal allocation of resources for adaptation and climate-proof investments. Unfortunately, this kind of analysis demands technical skills and data resources hardly available in small and mid-size cities. For them, an easier approach based on indicator construction should be proposed.

Engaging key stakeholders and creating local Advisory Groups are fundamental steps to: i) guarantee the correct understanding of the urban system from multiple perspectives (and data sources) and meet end-user expectations; ii) develop policy-relevant indicators and select a proper level of data aggregation (spatial support); iii) guarantee a common agreement and a full uptake of the main outcomes; iv) and, finally, to foster local actions. The participatory process with key-stakeholders ensures a pragmatic assessment of Risk and Vulnerability focused on real city needs. The city Advisory Group (see step 1) offers a powerful tool to discover urban specificities and to maximize the utility and inclusion of results into local decision-making. It facilitates the mainstreaming of adaptation into existing sectoral strategies, promoting more holistic measures to address short, mid and long-term climate risks, avoiding policy trade-offs, spill-over effects, and subsequent maladaptation.

References

PART 2A

Banja M., Monforti-Ferrario, F., Bódis K., Kona, A., Jäger-Waldau, A., Taylor, N., Dallemand, J.F., (2017), *Mitigating climate change: renewables in the EU – cutting greenhouse gas emissions through renewables*, *Volume 2*, EUR 28677 EN, ISBN 978-92-79-70478-9, doi:10.2760/722355, Luxembourg: Publications Office of the European Union, 2017

Berndes G., Abt B., Asikainnen A., Cowie A., Dale V., Egnell G., Lindner M., Marelli Luisa, Pare' D., Pingoud K., Yeh S. (2016), Forest biomass, carbon neutrality and climate change mitigation, From Science to Policy, European Forest Institute, ISBN 978-952-5980-27-1, ISSN 2343-1237

Bertoldi, P., Cayuela, D. B., Monni, S., & de Raveschoot, R. P. (2010a). How to develop a Sustainable Energy Action Plan (SEAP). Joint Research Centre Scientific and Technical reports, EUR 24360 EN, ISBN 978-92-79-15782-0

Bertoldi, P., Bornás Cayuela, D., Monni, S., and Piers de Raveschoot, R.,2010b, Existing Methodologies and Tools for The Development And Implementation of Sustainable Energy Action Plans (SEAP), EUR 24309 EN – Scientific and Technical Research series – ISSN 1018-5593, ISBN 978-92-79-14852-1, doi:10.2788/81771, Luxembourg: Publication Office of the European Union, pp.68

Cerutti, A.K., A. Iancu, G. Janssens-Maenhout, G. Melica, F. Paina, and P. Bertoldi (2013), The Covenant of Mayors in Figures 5-Year Assessment, EUR 25992. Luxembourg: Publications Office of the European Union

Data4Action (2016), Data Access Guidebook for Sustainable Energy Action Plans**,** co-funded by the Intelligent Energy Europe Programme of the European Union (Grant agreement no. IEE/13/368/SI2.675578). http://data4action.eu/wp-content/uploads/2014/05/576 -Data-Access-Guidebook-Ireland-rx2a.pdf

Dünnebeil, F., Knörr, W., Heidt, C., Heuer, C., Lambrecht, U. (2012), Balancing Transport Greenhouse Gas Emissions in Cities – A Review of Practices in Germany", Gesellschaft für Internationale Zusammenarbeit (GIZ), Beijing Transportation Research Center

EEA (2016), EMEP/EEA air pollutant emission inventory guidebook — 2016. EEA, Copenhagen. Available at http://www.eea.europa.eu/publications/emep-eea-guidebook-2016

ELCD (2015), European Reference Life Cycle Database (ELCD) Release 3.2. LCA data sets of key energy carriers, materials, waste and transport services of European scope. Available at http://eplca.jrc.ec.europa.eu/ELCD3/index.xhtml

Giuntoli J., Agostini A., Edwards R., Marelli L. (2017), Solid and gaseous bioenergy pathways: input values and GHG emissions. Calculated according to the methodology set in COM(2016) 767, EUR 27215 EN, doi:10.2790/27486

Global Protocol for Community-Scale GHG Emissions (GPC), 2014. Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC). December, 2014. Available at: http://www.wri.org/publication/global-protocol-community-scale-greenhouse-gas-emission-inventories

IEA (2016), "Extended World Energy Balances, Edition 2015", *IEA World Energy Statistics and Balances* (database). http://dx.doi.org/10.1787/95e22f23-en

IEA (2017), Coal Information (2017 edition), ISBN 978-92-64-27817-2 ISSN 1683-4275, ISSN 1012-9324 (print), http://dx.doi.org/10.1787/16834275, August 2017

IPCC (1995), Contribution of Working Group I to the Second Assessment of the Intergovernmental Panel on Climate Change, Houghton, J.T., Meira Filho, L.G., Callender, B.A., Harris, N., Kattenberg, A. and K Maskell (Eds). Cambridge University Press, UK. pp.572

IPCC (2003). Report on Good Practice Guidance for Land Use, Land-Use Change, and Forestry (GPG-LULUCF), http://www.ipccnggip.iges.or.jp/public/gpglulucf/gpglulucf_contents.html

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

IPCC (2007), Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp.996

IPCC (2012), Renewable Energy Sources and Climate Change Mitigation, Special Report of the Intergovernmental Panel on Climate Change (SRREN, Edenhofer et al. (eds), ISBN 978-1-107-02340-6 H), http://www.ipcc.ch/pdf/specialreports/srren/SRREN_Full_Report.pdf

Kennedy, C., Steinberger, J., Gasson, B., Hansen, Y., Hillman, T., Havranek, M., Pataki, D., Phdungsilp, A., Ramaswami, A., Villalba Mendez, G. 2009. Methodology for inventorying greenhouse gas emissions from global cities. Energy Policy (2009), doi:10.1016/j.enpol.2009.08.050

Koffi B, Cerutti, A.K., Duerr M., Iancu A., Kona A., Janssens-Maenhout G. (2017b), Covenant of Mayors: Default Emission Factors - Version 2017. European Commission, Joint Research Centre (JRC) [Dataset] PID: http://data.europa.eu/89h/jrc-com-def-comw-ef-2017

Koffi, B., Cerutti, A., Duerr, M., Iancu, A., Kona, A. and Janssens-Maenhout, G. (2017a), Covenant of Mayors for Climate and Energy: Default emission factors for local emission inventories – Version 2017, EUR 28718 EN, Publications Office of the European Union, Luxembourg, 2017, ISBN 978-92-79-71478-8 (print); 978-92-79-71479-5 (online), doi:10.2760/28586 (print), 10.2760/290197 (online), JRC107518

Kona A., Melica G., Bertoldi P., Rivas Calvete S., Zancanella P., Koffi B., Iancu A., Janssens-Maenhout G., Dallemand J.-F., (2017), Covenant of Mayors: 8- Year Assessment, EUR 28723 EN, Publications Office of the European Union, Luxembourg, 2017, ISBN 978-92-79-71624-9, doi:10.2760/64731, JRC106725

Meshartility (2015), Summary Report on Good Data Sharing Practices, Deliverable number D2.9, ICLEI European Secretariat GmbH, April 2015, pp.32,

Neves, A., Blondel L., Brand K., Hendel Blackford S., Rivas Calvete S., Iancu A., Melica G., Koffi B., Zancanella P., Kona A., (2016). The Covenant of Mayors for Climate and Energy Reporting Guidelines; EUR 28160 EN; doi:10.2790/586693, pp.68

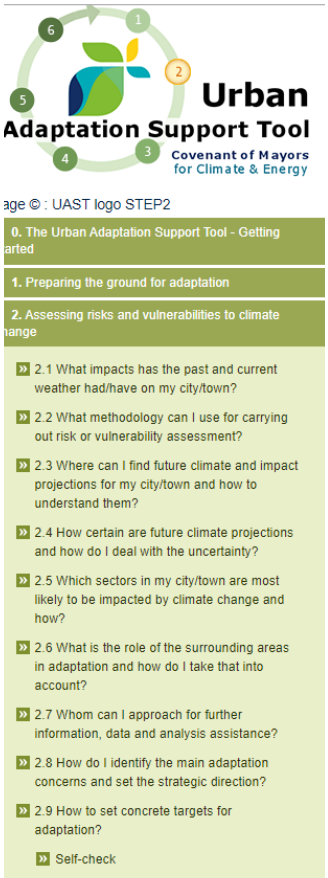
UNFCCC (2013), Reporting guidelines on annual inventories for Annex I Parties, http://unfccc.int/resource/docs/2013/cop19/eng/10a03.pdf#page=2

UNFCCC (2017), Interim National Determined Contributions Registry. Internet: http://www4.unfccc.int/ndcregistry/Pages/All.aspx

Wolf M.-A., Pant R., Chomkhamsri K., Sala S., Pennington D. (2012), The International Reference Life Cycle Data System (ILCD) Handbook - Towards more sustainable production and consumption for a resource-efficient Europe, ISBN 978-92-79-21640-4, doi:10.2788/85727

PART 2B

The Urban Adaptation Tool - The Reference Tool for Covenant Signatories



The Urban Adaptation Support Tool (UAST) complements the present guidebook with further practical guidance and relevant links. It is of special importance for local authorities, in particular in countries where national level tools and support are currently lacking or under development. It was developed by the Covenant of Mayors team specifically to support Covenant and Mayors Adapt signatory cities in their day-to-day adaptation work and is regularly updated. It is hosted on the EEA's Climate-ADAPT portal.

For more information on assessing risks and vulnerabilities to climate change (Step 2: https://climate-adapt.eea.europa.eu/knowledge/tools/urban-ast/step-2-0)

Note: Besides, and on the same portal, The Urban Vulnerability Map Book provides maps on potential impacts of climate change, vulnerabilities and adaptation actions of European cities.

https://climate-adapt.eea.europa.eu/knowledge/tools/urban-adaptation/introduction

<u>Other References</u>

Bank of England, (2015), The impact of climate change on UK insurance sector. A climate change adaptation report by the Prudential Regulatory Authority, pp.87. Prudential Regulatory Authority press

Bittencourt, F., Follador, M., Pereira, V., Rocha, A., Vaz, C., Vieira, T., Amoni, M., Bicalho, F., (2018), Climate vulnerability index: a case study for the city of Belo Horizonte, Brazil. Climate Change Adaptation in Latin America: managing vulnerability, fostering resilience - Climate Change Management series – Springer International Publishing AG

Breil, M. and Swart, R. (2015), National action supporting urban adaptation in EEA Member States. Eionet Report ETC/CCA 2015/3, pp.45

C40 (2017), Infrastructure interdependencies and climate risk report, pp.56

COR, (2016), Regional and local adaptation in the EU since the adaption of the EU Adaptation Strategy in 2013. Report by European Committee of the Regions, pp.114

COR (2017), Towards a new EU climate change adaptation strategy – taking an integrated approach. OPINION by European Committee of the Regions, ENVE VI/015, pp.11. Plenary session, 8-9 February 2017

Cutter, S., Boruff, B. and Shirley, W. (2003), Social vulnerability to environmental hazards. Social Science Quarterly 84(2), pp.241-261

DG CLIMA (2017), Mainstreaming of adaptation into the ESIF 2014-2020. European Commission report, pp.130

EEA (2012), Urban adaptation to climate change in Europe. Challenges and opportunities for cities together with supportive national and European policies. European Environmental Agency report No 2/2012

EEA (2014), National Adaptation policy processes in European countries. European Environmental Agency report, No 4/2014, pp.136

EEA (2016), Urban adaptation to climate change in Europe 2016. Transforming cities in a changing climate. European Environmental Agency report, No 12/2016, pp.140

European Commission (2013), COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS: An EU Strategy on adaptation to climate change. COM (2013) 0216 final, Brussels, 16.04.2013

European Commission (2014), Multiannual Financial Framework 2014-2020 and EU budget 2014. DG for Budget

European Commission (2017), Horizon 2020, working programme 2016-2017. Climate Change action, environment, resource efficiency and raw materials. European Commission Decision C(2017) 2468 of 24 April 2017, pp.108

Follador, M., Pereira, H., Abreu, A. (2013), Analise de vulnerabilidade as mudanças climáticas na cidade de Goiania, Goias. InterAmerican Development Bank report

Füssel, H.M. (2007), Vulnerability: a generally applicable conceptual framework for climate change research. Global environmental change, 17, pp.155-167

Füssel, H.M. (2009), Review and quantitative analysis of indices of climate change exposure, adaptave capacity, sensitivity and impacts. World Development report 2010 – background note, pp.35

Giordano, F., Rizzitiello, F., Ndong, C. and Scaramella, A. (2014), 'Adattamento ai Cambiamenti Climatici nelle Città Italiane: Risultati del Questionario ISPRA', in: Focus sulle città e la sfida dei cambiamenti climatici, ISPRA — Istituto Superiore per la Protezione e la Ricerca Ambientale, Rome, Italy

GIZ (2014), The vulnerability sourcebook. Concept and guidelines for standardized vulnerability assessments. GIZ press, pp.180

Heidrich, O., Reckien, D., Olazabal, M., Foley, A., Salvia, M., da Gragorio Hurtado, S., Orru, H., Flacke, J., Geneletti, D., Prietrapertosa, F. Hamann, J., Tiwary, A., Feliu, E., Dawson, R.J. (2016), National climate policies across Europe and their impacts on cities strategies. Journal of environmental management, 168, pp.36-45

Heltberg, R. and Bonch-Osmolovskiy, M. (2011). Mapping vulnerability to Climate Change. Policy research working paper No 5554. The World Bank

IPCC (2007). Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J., Hanson, C.E. (Eds.)]. Cambridge University Press, Cambridge, UK, pp.976

IPCC (2012), Special Report on managing the risks of extreme events and disasters to advance climate change adaptation (SREX). Summary for policymakers. [Field, C.B., Barros, V., Stocker, T.F., Qin, D., Dokken, D.J., Ebi, K.L., Mastrandrea, M.D., Mach, K.J., Plattner, G.-K., Allen, S.K., Tignor, M., Midgley, P.M. (Eds.). Cambridge University Press, Cambridge, UK and NY, pp.1-19

IPCC (2014), Climate Change 2014. Impacts, Adaptation and Vulnerability. Summary for policymakers. Part A: Global and Sectoral Aspects. Contribution of WG II to the Fifth Assessment Report of IPCC. [Field, C.B., et al.]. Cambridge University Press, Cambridge, UK and NY, pp.34

Kaspersen, P.S. and Halsnæs K. (2017), Integrated climate change risk assessment: a practical application for urban flooding during extreme precipitation. Climate services 6, pp.55-64

Katzschener, L. (2011), Urban Climate Maps. Available at: http://www-docs.b-tu.de/megacity-hcmc/public/02_Urban_Expansion/2_DPA_Roundtable_Katzschner_EN_lores.pdf

Kovats, R.S., Valentini, R., Bouwer, L.M., Georgopoulou, E., Jacob, D., Martin, E., Rounsevell, M., and Soussana J.-F. (2014), Europe. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp.1267-1326

Loyd' s (2014), Catastrophe modelling and climate change. Loyd's press, pp.41

Naumann, G., Barbosa, P., Iglesias, A. and Vogt, J. (2014), Exploring drought vulnerability in Africa: na indicator based analysis to be used in early warning systems. Hydrology and Earth System Sciences, 18, pp.1591-1604

Naumann, G., Spinoni, J., Vogt J.V., Barbosa, P. (2015), Assessment of drought damages and their uncertainties in Europe. IOP Publishing, Environmental Research Letters, 10

Neumann, S., Crick, F., Harman, B. Schuch, G. and Choy, D.L. (2015), Maximizing synergies between disaster risk reduction and climate change adaptation: potential enablers for improved planning outcomes. Environmental science and policy, 50, pp.46-61

OECD and JRC (2008), Handbook on constructing composite indicators. OECD press, pp.158

Oppenheimer, M., Campos, M., Warren, R., Birkmann, J., Luber, G., O'Neill, B. and Takahashi K. (2014), Emergent risks and key vulnerabilities. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Cambridge University press, Cambridge, United Kingdom and New York, NY, USA, pp.1039-1099

Revi, A., Satterthwaite, D.E., Aragón-Durand, F., Corfee-Morlot, J., Kiunsi, R.B.R., Pelling, M., Roberts, D.C., and Solecki, W. (2014), Chapter 8: Urban areas. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp.535-612

Ricardo AEA ltd (2013a), Adaptation strategies for European Cities. Final Report for DG Clima, pp.148

Ricardo AEA ltd, (2013b), State of Play –Impacts vulnerability and adaptation in European cities. Appendix 7 to Adaptation strategies for European Cities - Final Report for DG Clima. pp.70

Swiss RE (2014), Mind the Risk. A global ranking of cities under threat from natural disasters, pp.39. Swiss RE press

Tapia, C., Abajo, B., Feliu, E., et al. (2017), Profiling urban vulnerabilities to climate change: An indicator-based vulnerability assessment for European cities. Ecological Indicators, 78, pp.142-155

The Word Bank (2010), The economics of Adaptation to climate change. A synthesis report. The WB Group, pp.84

UCCRN (2011), Climate change and Cities: First Assessment report ARC3. Urban Climate Change Research Network. Cambridge press, pp.28

Weber, S., Sadoff, N., Zell, E., Sherbinin, A. (2015), Policy relevant indicators for mapping the vulnerability of urban populations to extreme heat events: a case study of Philadelphia. Applied geography 63, pp.231-243

WHO (2012), The new European policy for health – Health 2020. World Health Organization, regional office for Europe. Draft 2, pp.174

Wolf, T. and McGregor, G. (2013), The development of a heat wave vulnerability index for London, United Kingdom. Weather and Climate Extremes 1, pp.59-68

List of abbreviations and definitions

AFOLU	Agriculture Forestry and Other Land Use
BEI	Baseline Emission Inventory
CCS	carbon capture and storage
CH_4	methane
CHP	combined heat and power
CO_2	carbon dioxide
CO2EH	CO_2 emissions related to heat that is exported outside of the territory of the LA
CO_2-eq	CO_2-equivalents
CO2GEP	CO_2 emissions due to the production of certified green electricity purchased by the LA
CO2IH	CO_2 emissions related to imported heat from outside the territory of the LA
$CO2_{LPE}$	CO_2 emissions due to the local production of electricity
$CO2_{LPH}$	CO_2 emissions due to the local production of heat
CoM	Covenant of Mayors for Energy and Climate
COM-EF	CoM default Emission Factors data collection
$CO2_{CHPE}$	CO_2 emissions from electricity production in a CHP plant
$CO2_{CHPH}$	CO_2 emissions from heat production in a CHP plant
$CO2_{CHPT}$	total CO_2 emissions of the CHP plant
DSO	Distribution system operator
EC	European Commission
EF	Emission Factor
EFE	local emission factor for electricity
EFDB	Emission Factor Database
EFH	emission factor for heat
ELCD	European Reference Life Cycle Database
EMEP	European Monitoring and Evaluation Programme
ENEL	Ente Nazionale per l'Energia Elettrica
EPLCA	European Platform on Life Cycle Assessment
ETS	European Union Greenhouse Gas Emission Trading System
EU	European Union
EUROSTAT	The European Union's Statistical Office, providing statistical information to the institutions and Member States of the EU
EU-28	European Union 28 Member States
GEP	green electricity purchases by the local authority
GHG	greenhouse gas (only refers to N_2O, CH_4, CO_2 in this report, if no explicit list)
GPC	Global Protocol for Community-Scale Greenhouse Gas Emission Inventory
GPG	good practice guidance
GWP	global warming potential
HDD	heating degree days
HDD_{AVG}	heating degree days in an average year
EEA	European environment agency
ICLEI	Local Governments for Sustainability

IEA	International Energy Agency
ILCD	International Reference Life Cycle Data System
IPCC	Intergovernmental Panel on Climate Change
JRC	Joint Research Centre of the European Commission
LA	Local Authority
LAU	Local administrative unit
LCA	life cycle assessment
LEP	local energy production
LHC	local heat consumption
LHC_TC	temperature corrected local heat consumption
LPE	local production of electricity
LULUCF	Land Use Land Use Change and Forestry
MEI	Monitoring Emission Inventory
MESHARTILITY	Measure and share data with utilities for the Covenant of Mayors
N_2O	nitrous oxide
NACE	Statistical classification of economic activities in the European Community
NCV	Net calorific value
NEEFE	National or European Emission Factor for Electricity consumption
NUTS	Nomenclature of territorial units for statistics
OECD	Organisation for Economic Co-operation and Development
PV	solar photovoltaic installation
RES	Renewable energy sources
RVA	Risk and vulnerability assessment
SECAP	Sustainable Energy Action Plan
toe	tonne of oil equivalent
TCE	total electricity consumption in the territory of the local authority
UNFCCC	United Nations Framework Convention on Climate Change
VKT	Vehicle-Kilometres Travelled

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Annex 1. How estimating the emission reduction needed to achieve the 2030 target

A) UNKNOWN OR NO EXPECTED CHANGE IN POPULATION

The targeted 2030 maximum absolute emissions Em_{2030} are calculated as follows:

$$Em_{2030} = Em_{BEI} * (1 - T_{ab}) \quad \text{(a)}$$

CO_2 emission reduction needed to achieve the absolute $Red_{ab}(T_{ab})$ or per capita $Red_{ab}(T_{pc})$ target:

$$Red_{ab}(T_{ab}) = Red_{ab}(T_{pc}) = Em_{BEI} * T_{ab} = Em_{BEI} - Em_{2030} \quad \text{(b)}$$

B) EXPECTED CHANGE IN POPULATION

CO_2 emission reduction needed, using the per capita target (recommended)

The BEI emissions per capita (t CO_2/capita) are calculated as follows:

$$Em_{BEIpc} = \frac{Em_{BEI}}{Pop_{BEI}} \quad \text{(c)}$$

The 2030 per capita emissions (t CO_2/capita) are calculated as follows:

$$Em_{2030pc} = Em_{BEIpc} * (1 - T_{pc}) = \left(\frac{Em_{BEI}}{Pop_{BEI}}\right) * (1 - T_{pc}) \quad \text{(d)}$$

The targeted maximum 2030 absolute emissions are calculated as follows:

$$Em_{2030} = Em_{2030pc} * Pop_{2030} \quad \text{(e)}$$

The per capita CO_2 emission reduction needed to achieve the per capita target is given by:

$$Red_{pc}(T_{pc}) = (Em_{BEIpc} - Em_{2030pc}) \quad \text{(f)}$$

CO_2 emission reduction needed to achieve the per capita target is calculated by accounting for the change in population as follows:

$$Red_{ab}(T_{pc}) = (Em_{BEIpc} - Em_{2030pc}) * Pop_{2030} \quad \text{(g)}$$

CO_2 emission reduction needed, using the absolute target (not recommended)

CO_2 emission reduction needed to achieve the absolute target is calculated by accounting for the change in population as follows:

$$Red_{ab}(T_{ab}) = Em_{BEI} * T_{ab} + \frac{Em_{BEI}}{Pop_{BEI}} * (Pop_{2030} - Pop_{BEI}) \quad \text{(h)}$$

Where:

Em_{BEI} and Em_{2030}: absolute CO_2 emissions (t CO_2) for the BEI and 2030 years, respectively

Em_{BEIpc} and EM_{2030pc}: per capita emissions (t CO_2/capita) for the BEI and 2030 years, respectively

T_{ab} (in %): absolute reduction target (at least 40%)

T_{pc} (in %): per capita reduction target (at least 40%)

$Red_{pc}(T_{pc})$: per capita CO_2 emission reduction (t CO_2/capita) needed to achieve the per capita target

$Red_{ab}(T_{ab})$: absolute CO_2 emission reduction (t CO_2) needed to achieve the absolute target

$Red_{ab}(T_{pc})$: absolute CO_2 emission reduction (t CO_2) needed to achieve the per capita target

Pop_{BEI} and Pop_{2030}: population of the city (inhabitants) in the BEI and 2030 years, respectively

Annex 2. Recalculation examples

In general, once the BEI is completed, there is no need to change the numbers later on. However, there are a few occasions when recalculation of BEI is needed to ensure consistency between the emission estimates of BEI and MEI. Examples of recalculation provided in this annex are:

- industry delocalisation
- new information on emission factors
- exclusion of a local power plant
- new aspect of local generation definition and the calculation of the Local Emission Factor for Electricity (EFE)
- temperature correction

2.1. Recalculation due to industry delocalization

Emission reductions due to industry delocalisation are explicitly excluded from the Covenant of Mayors. In these guidelines, industry delocalisation means a full and permanent closure of an industrial plant, the emissions of which represented more than 1% of the baseline emissions. An example of recalculation due to industry delocalisation is presented below.

The local authority decided to include emissions from industrial plants not included in EU ETS in the BEI, because the SEAP included measures to improve energy efficiency in the plants. However, one of the plants (Plant A), the emissions of which were 45 kt CO_2 in the baseline year (1.4% of the baseline emissions), closed down before the monitoring year. Inclusion of this emission source in BEI but excluding it from MEI would mean that the local authority would gain benefit due to industry delocalisation. Therefore, the local authority has to recalculate the baseline year emissions so that the emissions of Plant A are excluded.

Table 14: Example of recalculation due to industry delocalization:

Subsector	**CO_2 emissions (kt)** Plant A is present	**CO_2 emissions (kt)** Plant A have been removed
Residential buildings	2 000	2 000
…	…	…
Industries (excluding industry part of an ETS)	70	25
Subtotal buildings, facilities and industry	**2 735**	**2 690**
…		
Subtotal transport	500	500
Total	**3 235**	**3 190**

2.2. Recalculation due to new information on the emission factors

Recalculation due to new information on emission factors or methodological changes has to be carried out only in the case that the new information reflects the situation in the baseline year more accurately than the information used in compilation of BEI. If real changes in emission factors have occurred between the baseline year and the monitoring year - for instance due to the use of different fuel types - then different emission factors will correctly reflect the changed circumstances, and recalculation is not needed ([96]).

> **Example of Recalculation due to new information on the emission factor**
>
> The local authority had used the *standard* emission factor provided in 2010 guidebook (Bertoldi et al., 2010) to estimate the base year emissions from coal combustion in a local district heating plant. The emission factor was 0.341 t CO_2/MWh. In the monitoring year, the local authority asked the coal provider to give information on the carbon content and thus the emission factor, of the coal type provided. The coal provider informed the local authority that the emission factor of that coal type is 0.335 t CO_2/MWh, and that the same coal type has been provided to the city since many years.
>
> If the local authority started to use the new emission factor only since the MEI, it would gain benefit, as estimated emissions would be lower than in BEI even if the same amount of fuel would be used. Therefore, the local authority has to recalculate the BEI using the same emission factor that will be used in the MEI.

2.3. Recalculation due to the exclusion of a local power plant

Electricity produced locally within the local territory can be included in the Local Production of Electricity (LPE) for all plants that fulfil the criteria as defined in section 4.4.1. In case a small power plant using fossil fuel and initially included in LPE would become bigger than 20 MW during the implementation process, then the eligibility criteria would not be fulfilled anymore and the signatory would have to exclude it from the LPE calculation. In this case, the corresponding GHG emissions ($CO2_{LPE}$) would have to be recalculated for the BEI and previous MEIs.

2.4. Recalculation due to updated criteria of defining local energy generation units and the calculation of the Local Emission Factor for Electricity (EFE)

Units added to the definition of LPE from the previous edition:

- Combined Heat and Power (CHP) larger than 20 MW fuel input
- Renewable Energy Source (RES) Units larger than 20 MW fuel
- Units outside the local territory (co-)owned by the local authority (optional to be included)

<u>New parameters included in the calculation of Local Emission Factor for Electricity:</u>

- Municipal certified electricity purchase was replaced by a more extended parameter called certified electricity purchase and sale (regardless of the sector). The certified electricity accounted in the inventory is the difference between the certified energy purchased from outside the local territory and the certified energy produced within the territory and sold to third parties outside the administrative boundaries (see point 5.2.3).
- Combined Heat and Power (CHP) larger than 20 MW fuel input
- Renewable Energy Source (RES) Units larger than 20 MW fuel

([96]) Extensive guidance for recalculation is given in the chapter "Time series consistency" of IPCC (2006), available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/1_Volume1/V1_5_Ch5_Timeseries.pdf

— Units outside the local territory (co-)owned by the local authority (optional to be included)

Electricity produced locally within the local territory can be included in the Local Production of Electricity (LPE) for all plants that fulfil the criteria as defined in section 4.4.1.

In case a power plant initially excluded in LPE of the SEAP 2020 (because of the selection criteria on local energy generation defined in 2010 version of the guidebook), would become eligible with the new definition of LPE, then the signatory would have to include it in the LPE calculation. In this case, the corresponding local emission factor and $CO2_{LPE}$ would have to be recalculated for the BEI and previous MEIs.

2.5. Correction of heat consumption for outside temperature

The local authority may choose to use temperature correction for emissions from space heating when reporting the emissions and monitoring the progress towards target. Temperature corrected emissions can be calculated using the following equation:

— $LHC\_TC = LHC * HDD_{AVG} / HDD$

— LHC_TC = temperature corrected heat consumption in year x [MWh]

— LHC = actual heat consumption in the year x [MWh]

— HDD_{AVG} = heating degree days in an average year (defined over a certain time period) [K · d]

— HDD = heating degree days in the year x [K · d]

Heating degree days (HDD) denote the heating demand in a specific year. HDD is derived from daily temperature observations, and defined relative to a base temperature - the outside temperature above which a building needs no heating. For each day, during which the temperature is below the base temperature, the HDD is the difference of the base temperature and actual temperature. In some Member States, meteorological offices provide HDD data for different parts of the country. HDD_{AVG} denotes a long-term average of heating degree days, which may also be available from the meteorological office. If a long-term average is not available, the local authority may keep the BEI emissions uncorrected, and correct the emissions in MEI using the HDD of baseline year instead of average. Similar approach can also be used to correct the emissions from cooling based on cooling demand.

Calculation of heating degree days (HDD)

Heating of buildings in the territory of local authority usually begins when the outside temperature is less than 15 degrees Celsius. The LA collects the data for each of the days of the year in the table below, and as a sum of the results; the local authority gets the annual HDD.

Day	Temperature	Difference to base temperature (when smaller than base temperature)	HDD_day
Day 1	12	3	3
Day 2	9	6	6
Day 3	5	10	10
Day 4	-2	17	17
...	...	...	...

Day 365	17	0	0
HDD (total of the year)			700

Annex 3. Projects related to activity data collection

3.1. MeShaRtility project

Name of the project	**MeShaRtility project** (Measure and SHARe data with uTILITies for the Covenant of MaYors)
Website:	
Duration	April 2012- April 2015
Geographical coverage	EU in general, Specifically addressing 12 countries: Bulgaria, Croatia, Cyprus, Estonia, Germany, Italy, Latvia, Malta, Poland, Romania, Slovenia, Spain.
Main aims	The project explored challenges and barriers relevant for data accessibility for the local authorities in the process of developing local GHG emission inventories as baseline for the development of the GHG mitigation plans through sustainable energy management. Based on the findings, it proposed solutions and developed tools facilitating the exchange of energy data between energy utilities and local authorities.
Relevant deliverables	
Summary report about good data sharing practices at EU level Analysis report on EU and National legal frameworks on data, 2015. The report may be downloaded from: The publication includes a collection of good practices developed in different project countries which improve municipalities' access to local, sectored energy data and thus help them to make the process of energy planning more efficient. The examples include both favourable legal solutions implemented by national authorities and a number of voluntary initiatives launched by energy utilities and/or different organisations working with local authorities (energy agencies, NGOs and others). The examples quoted include development of national and regional data sharing platforms (e.g. Dutch klimaatmonitor), voluntary data sharing mechanisms implemented by energy providers or distribution service companies and bilateral memorandums of cooperation signed between local authorities and energy suppliers.	
MESHARTILITY website () The website is the main source of information on the MESHARTILITY project and on its results. It gives insight into the data challenges encountered by municipalities compiling local emission inventories and developing Sustainable Energy Action Plans, as well as possible ways of overcoming these challenges identified by the project partners. The "Library" section contains links to many publications that include tips and recommendations where to get bottom-up energy data and how to develop a successful SEAP and implement local energy actions. The website is available in 12 languages: English, Bulgarian, Croatian, Estonian, German, Greek, Italian, Latvian, Polish, Romanian, Slovenian and Spanish.	
Memorandum of cooperation It is a template for a memorandum of cooperation, drafted based on the experiences in the target countries, with the main purpose of structuring and regulating the data	

exchange between local authorities and energy utilities providers, as a guarantee of the quality and continuity of the data sharing. Both parties can adapt and further develop the text, e.g. adding other common goals that they wish to achieve on the local level.

Improving access to local energy data – Lessons learnt and recommendations from MESHARTILITY

The publication describes the main lessons learnt, achievements and recommendations developed within the MESHARTILITY project, which addressed data challenges faced by local governments when compiling their GHG inventories and developing Sustainable Energy Action Plans, especially the ones related to the access to reliable, bottom up energy data.

3.2. Data4Action

Name of the project	**Data4Action**
Website:	http://data4action.eu
Duration	March 2014- February 2017
Geographical coverage	EU-28
Objectives	Data4Action, aims to foster win-win energy data exchange collaboration models between public authorities and energy data providers and focused especially from moving from bilateral data exchange cooperation agreements **to regional « one-stop shop» data centres («Observatories»).**
Relevant deliverables	

Data Access Guidebook for Sustainable Energy Actions Plans, 2016

http://www.fedarene.org/wp-content/uploads/2017/01/576-Data-Access-Guidebook-rx15.pdf

Of interest for the Local Authorities:

Contains a list of the Regional Data Centres/ Regional Energy and GHG Emissions Observatories for EU-28 countries. The list contains the contact details and a brief description of the services provided (Appendix 2). In addition, the Guidebook has 10 versions translated into the national languages for Bulgaria, Czech Republic, France, Greece, Ireland, Italy, Romania, Spain, Sweden and United Kingdom. Each version contains a description of the national framework that underpins the energy data sharing structures and requirements in the respective country (Chapter 3).

Bulgaria: http://data4action.eu/bg/

Czech Republic: http://data4action.eu/cs/

France : http://data4action.eu/fr/

Greece: http://data4action.eu/el/

Ireland: http://data4action.eu/en/?cd=ir

Italy: http://data4action.eu/it

Romania: http://data4action.eu/ro/

Spain: http://data4action.eu/es/

Sweden: http://energikontornorr.se/data4action-guide/

United Kingdom: http://data4action.eu/uk/

Of interest for Covenant Coordinators and Supporters:

Contains the description of the collaboration model for local data sharing called Regional Energy and GHG Emissions Observatories which is a multilateral agreement in which a third party provides on-stop shop services and is responsible for brokering all collaboration agreement and the data exchange process between the Energy Data Providers and Local Authorities.

Annex 4. Examples of methods, tools and data for the road transport

4.1. Common methodologies to assess energy consumption from road transport

Several approaches and methods for accounting the energy consumption from transport have been developed, which differ greatly in their level of effort required to collect and analyse data and in their level of information they provide, but can be distinguished with two main Top down and Bottom up approaches (see for instance Dünnebeil et al., 2012; EEA, 2016).

The top-down approach (fuel sales method)

The top down approach to assess transport activity sector greenhouse gas emissions is primarily relevant for the national level and only offers very basic information for the local level. It is commonly based on the so-called "*Fuel sales method*". This territorial method calculates on-road transportation emissions based on the total fuel sold within the city boundary. The fuel sold on the territory is used as a proxy for transportation activity occurring in the same territory.

The bottom up approaches

Bottom-up methodologies to assess emissions from transport require more data collection and analysis, but also provide far more useful information to guide local policy and planning. According to the way energy consumption/emission is allocated to the local territory, three main methods exist:

Territorial method (also called geographic method): This method, which is the one recommended in the frame of the Covenant (see Annex 4), quantifies emissions from transportation activity occurring solely within local boundaries, regardless of the trip's origin or destination and whatever the driver is a resident of the municipality or not. Basic traffic counts are required to estimate the number of vehicles traveling, including the average trip length and potentially also the type of vehicle.

Resident activity method: This method quantifies emissions from transportation activity undertaken by city residents only, considering all their trips, within or across the city borders. It requires information on resident Vehicle Kilometre Travelled (VKT) from vehicle registration records and surveys on travel behaviour of residents. Modest efforts are required to get relatively solid estimates with a combination of vehicle fleet registration data and surveys among residents and basic travel behaviour.

Induced activity method: With regard to urban planning and future projections this approach is the most sophisticated methodology as it identifies the underlying travel dynamics in the region, which can be relevant for local, regional and national policy making. It requires a substantial amount of data from 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. Computer modelling allows analysing the effects/trade-off of various scenarios in transport policy and urban planning.

Unlike the *fuel sales method*, these bottom-up methods, based on travel patterns, can help identifying priority areas for policy intervention. For many cities, the method is indeed already integrated into the local plans (e.g. Sustainable Urban Mobility Plans, Air and Noise Pollution Mitigation Plans). The main disadvantage of these methods is that they might require significant resources with regard to data collection and analysis.

4.2. Pros and cons of common methodologies for road transportation

Type of approach	Method	Advantage	Disadvantages
Top Down	*Fuel sales method*	Relatively simple apply Does not require many resources Consistent with the national inventories (IPCC methodology)	Source of inaccuracy: the quantity of fuel sold could vary substantially from the energy consumed within the city borders. Poor instrument for planning and monitoring a sustainable urban transport system because so the lack detailed information (intensity of the traffic, routes, modal shift, vehicle efficiency changes) which prevents identifying and acting on the source of emissions.
Bottom up	*Territorial method* To be used in the Covenant	Only relatively basic traffic counts are required (number of vehicles traveling within a city, average trip length, type of vehicles). Provides information on interventions related to vehicle use and modal choice within a city; Provides information on other local effects of the road transport (e.g. for air and noise pollution).	Traffic counts at key points around the city, whatever the drivers are resident of the municipality or not.
	Resident activity method	Modest efforts required to get relatively solid estimates with a combination of vehicle fleet registration data and surveys among residents and basic travel behaviour.	It requires information on the resident Vehicle Kilometre Travelled.
	Induced activity method (recommended by GPC[1])	With regard to urban planning and future projections this approach is the most sophisticated methodology as it identifies the underlying travel dynamics in the region, which can be relevant for local, regional and national policy making.	This methodology requires a substantial amount of data from city residents, but also from other travellers, which could be gathered through different sources, incl. data collection at major routes, Big Data (e.g. from smart phones) and satellite data.

Sources: Dünnebeil et al. (2012); EEA (2016)

[1] "The Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) is a joint project by ICLEI-Local Governments for Sustainability (ICLEI), the World Resources Institute (WRI) and C40 Cities Climate Leadership Group (C40), with additional collaboration by the World Bank, UNEP, and UN-Habitat". Info available at http://www.iclei.org/activities/agendas/low-carbon-city/gpc.html

4.3. Examples of tools for estimating the CO2 emissions from the road transport sector

To develop a CO_2 emission inventory for the transport sector and to assess the direct and indirect CO_2 emission reduction potential from bottom up methods, there are a number of tools that require only minimal data and no modelling efforts, as the ones provided below (see also section 3.3.1).

Tool	Link
COPERT4 road transport emissions model (European Environment Agency and EMISIA)	http://emisia.com/products/copert/copert-5
Greenhouse Gas Protocol Tools (GHG Emissions from Transport)	http://www.ghgprotocol.org/calculation-tools
Transport Emissions Evaluation Model (TEEMP) Clean Air Asia/ITDP	http://cleanairasia.org/transport-emissions-evaluation-model-for-projects-teemp/

4.4. Average specific consumption per car engine technology in the EU-28 [l/km], 2000-2015 (Source: Odyssee)

Year	Total Average	Gasoline	Diesel
2000	0.078075	0.0813	0.0691
2001	0.077082	0.0806	0.0680
2002	0.076451	0.0803	0.0677
2003	0.075565	0.0794	0.0674
2004	0.074704	0.0788	0.0670
2005	0.073875	0.0781	0.0663
2006	0.072778	0.0773	0.0659
2007	0.072008	0.0766	0.0656
2008	0.071159	0.0757	0.0651
2009	0.070547	0.0750	0.0648
2010	0.07009	0.0746	0.0646
2011	0.069446	0.0742	0.0641
2012	0.068715	0.0741	0.0639
2013	0.067921	0.0734	0.0636
2014	0.069346	0.0731	0.0635
2015	0.069016	n.a.	n.a.
Average specific consumption	0.0723	0.0768	0.0658

4.5. Average specific consumption of road transport of goods in the EU-28 [Wh/tkm], 2000-2015 (Source: Odyssee)

	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
European Union	819	806	794	812	775	768	763	752	751	798	778	771	757	747	736	734
Austria	413	408	402	395	394	393	387	372	371	386	381	378	378	352	345	357
Belgium	658	636	620	621	618	609	577	527	522	538	519	551	543	545	551	562
Bulgaria	522	442	419	478	455	423	576	479	475	407	376	354	337	267	301	301
Croatia	628	630	638	645	647	648	645	636	637	644	641	636	594	592	602	586
Cyprus	2,340	2,378	2,264	2,149	2,676	2,063	2,452	2,432	2,131	2,707	2,432	2,723	2,650	3,391	3,416	3,609
Czech Republic	279	315	302	338	364	430	406	426	415	462	383	363	380	355	376	356
Denmark	281	312	292	286	274	266	272	278	274	267	315	314	287	256	276	290
Estonia	457	606	629	569	531	487	545	475	415	491	497	500	523	495	470	490
Finland	543	573	556	592	600	588	655	673	625	649	663	739	766	839	847	809
Germany	466	465	448	407	398	392	386	380	379	398	380	366	377	377	363	380
Greece	851	827	818	1,408	722	1,120	821	1,033	971	1,173	1,000	1,269	1,007	1,199	1,218	1,218
Hungary	739	800	890	904	840	765	687	588	612	608	586	522	505	433	466	505
Ireland	768	764	748	755	735	726	722	712	976	1,106	1,094	1,126	1,094	1,130	1,112	1,100
Italy	688	741	757	857	807	755	886	956	880	857	800	1,021	1,098	1,059	1,201	1,210

Latvia	672	688	602	555	525	475	411	387	377	485	421	286	280	290	288	279
Lithuania	500	535	416	381	392	328	342	336	337	331	299	287	251	212	245	283
Luxembourg	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Malta	2,992	3,317	3,303	3,312	3,009	2,924	3,370	3,274	3,191	3,196	3,134	2,966	2,938	2,925	2,998	3,139
Netherlands	704	713	728	705	680	698	699	722	729	751	720	705	737	665	649	666
Poland	459	463	440	520	486	544	495	471	449	421	408	406	352	284	286	291
Portugal	933	883	865	927	637	604	576	548	601	627	613	568	769	599	665	762
Romania	930	1,051	786	652	536	385	356	347	421	708	892	836	n.a.	n.a.	n.a.	n.a.
Slovakia	408	431	506	394	391	368	407	378	391	370	459	421	411	401	381	347
Slovenia	409	461	523	513	475	444	408	398	361	333	337	315	309	293	302	288
Spain	578	561	598	593	620	621	633	606	609	626	614	584	529	555	529	509
Sweden	426	449	442	455	454	457	448	450	431	486	493	492	518	487	n.a.	n.a.
United Kingdom	851	851	869	868	882	898	907	894	904	982	914	870	846	916	1,053	983

Annex 5. How to allocate the energy input between electricity and heat produced by CHP plants

Part or all of the heat used in the territory of the local authority may be generated in a combined heat and power (CHP) plant. It is essential to divide the emissions of a CHP plant between heat and electricity when filling the B online templates. The fuel use - and consequently, the associated emissions - can be allocated between heat and electricity generation by using the following method is proposed:

The method allocates the emissions based on the energy inputs required to produce separately (non in cogeneration) the same amount of outputs of heat and electricity (as in the CHP power plant output) as follows([97]):

$$CO2_{CHPH} = \frac{\frac{P_{CHPH}}{\eta_h}}{\frac{P_{CHPH}}{\eta_h}+\frac{P_{CHPE}}{\eta_e}} * CO2_{CHPT} \quad \text{(a)}$$

$$CO2_{CHPE} = CO2_{CHPT} - CO2_{CHPH} \quad \text{(b)}$$

Where:

$CO2_{CHPT:}$ total amount of CO_2 emissions in the CHP power plant [tCO_2]

$CO2_{CHPH}$: amount of CO_2 emissions from heat production [tCO_2]

$CO2_{CHPE}$: amount of CO_2 emissions from electricity production [tCO_2]

$P_{CHPE:}$ amount of electricity produced [MWh]

$P_{CHPH:}$ amount of heat produced [MWh]

η_e typical efficiency of separate electricity production. The recommended value to be used is set in the national efficiency factor for electricity generation and/or the average of EU regularly published by Eurostat (46 %).

http://ec.europa.eu/eurostat/web/energy/data/shares

η_h: typical efficiency of separate heat production. The recommended value to be used is 90 %.

([97]) See for instance Annex II of the European Energy Efficiency Directive (2012/27/EU)

Annex 6. Default Net calorific values (IPCC, 2006)

Fuel type	Net calorific value [TJ/Gg]	Net calorific value [MWh/t]
Crude Oil	42.3	11.8
Orimulsion	27.5	7.6
Natural Gas Liquids	44.2	12.3
Motor Gasoline	44.3	12.3
Aviation Gasoline	44.3	12.3
Jet Gasoline	44.3	12.3
Jet Kerosene	44.1	12.3
Other Kerosene	43.8	12.2
Shale Oil	38.1	10.6
Gas/Diesel Oil	43.0	11.9
Residual Fuel Oil	40.4	11.2
Liquefied Petroleum Gases	47.3	13.1
Ethane	46.4	12.9
Naphtha	44.5	12.4
Bitumen	40.2	11.2
Lubricants	40.2	11.2
Petroleum Coke	32.5	9.0
Refinery Feedstocks	43.0	11.9
Refinery Gas 2	49.5	13.8
Paraffin Waxes	40.2	11.2
White Spirit and SBP	40.2	11.2
Other Petroleum Products	40.2	11.2
Anthracite	26.7	7.4
Coking Coal	28.2	7.8
Other Bituminous Coal	25.8	7.2
Sub-Bituminous Coal	18.9	5.3

Fuel type	**Net calorific value [TJ/Gg]**	**Net calorific value [MWh/t]**
Lignite	11.9	3.3
Oil Shale and Tar Sands	8.9	2.5
Brown Coal Briquettes	20.7	5.8
Patent Fuel	20.7	5.8
Coke Oven Coke and Lignite Coke	28.2	7.8
Gas Coke	28.2	7.8
Coal Tar	28.0	7.8
Gas Works Gas	38.7	10.8
Coke Oven Gas	38.7	10.8
Blast Furnace Gas	2.47	0.7
Oxygen Steel Furnace Gas	7.06	2.0
Natural Gas	48.0	13.3
Municipal Wastes (non-biomass fraction)	10	2.8
Waste Oil	40.2	11.2
Peat*	9.76	2.7

These IPCC default Net calorific values (NCV) may be used for both stationary sources and road transport (see fuels in bold) when country-specific data are unavailable.

*Although peat is not strictly speaking a fossil fuel, its greenhouse gas emission characteristics have been shown in life cycle studies to be comparable to that of fossil fuels and CO_2 emissions from combustion are included in the national emissions as for fossil fuels.

Annex 7. CO_2 emission factors for fuels (IPCC, 2006)

Fuel type	CO_2 emission factor [kg/TJ]	CO_2 emission factor [t/MWh]
Crude Oil	73300	0.264
Orimulsion	77000	0.277
Natural Gas Liquids	64200	0.231
Motor Gasoline	69300	0.249
Aviation Gasoline	70000	0.252
Jet Gasoline	70000	0.252
Jet Kerosene	71500	0.257
Other Kerosene	71900	0.259
Shale Oil	73300	0.264
Gas oil / diesel	74100	0.267
Residual Fuel Oil	77400	0.279
Liquefied Petroleum Gases	63100	0.227
Ethane	61600	0.222
Naphtha	73300	0.264
Bitumen	80700	0.291
Lubricants	**73300**	0.264
Petroleum Coke	97500	0.351
Refinery Feedstocks	73300	0.264
Refinery Gas	57600	0.207
Paraffin Waxes	73300	0.264
White Spirit & SBP	73300	0.264
Other Petroleum Products	73300	0.264
Anthracite	98300	0.354
Coking Coal	94600	0.341
Other Bituminous Coal	94600	0.341
Sub-Bituminous Coal	96100	0.346

Fuel type	CO_2 emission factor [kg/TJ]	CO_2 emission factor [t/MWh]
Lignite	101000	0.364
Oil Shale and Tar Sands	107000	0.385
Brown Coal Briquettes	97500	0.351
Patent Fuel	97500	0.351
Coke oven coke and lignite Coke	107000	0.385
Gas Coke	107000	0.385
Coal Tar	80700	0.291
Gas Works Gas	44400	0.160
Coke Oven Gas	44400	0.160
Blast Furnace Gas	260000	0.936
Oxygen Steel Furnace Gas	182000	0.655
Natural Gas	56100	0.202
Municipal Wastes (non-biomass fraction)	91700	0.330
Industrial Wastes	143000	0.515
Waste Oil	73300	0.264
Peat*	106000	0.382

These IPCC default CO_2 emission factors may be used for both stationary sources and road transport (see fuels in bold) when country-specific data are unavailable. It is recommended to ensure that default emission factors, if selected, are appropriate to local fuel quality and composition.

*Although peat is not strictly speaking a fossil fuel, its greenhouse gas emission characteristics have been shown in life cycle studies to be comparable to that of fossil fuels and CO_2 emissions from combustion are included in the national emissions as for fossil fuels.

Annex 8. Glossary

This document provides a glossary with some specific but most recurrent terms within the CoM documents and informative materials. The definitions are consistent with the IPCC terminology and with official documents.

Adaptation

The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects.

Albedo

The fraction of solar radiation reflected by a surface or object, often expressed as a percentage. Snow-covered surfaces have a high albedo, the albedo of soils ranges from high to low, and vegetation covered surfaces and oceans have a low albedo. The Earth's planetary albedo varies mainly through varying cloudiness, snow, ice, leaf area and land cover changes.

Baseline Emission Inventory

The Baseline Emission Inventory (BEI) quantifies the amount of CO2 emitted in the key sectors and other activity sectors in the territory of the Covenant signatory for the baseline year. It allows identifying the principal anthropogenic sources of CO_2 (and other GHGs) emissions and to prioritise the reduction measures accordingly.

Behavioural change

The alteration of human decisions and actions in ways that mitigate/reduce negative consequences of Climate Change impacts.

Carbon dioxide (CO2)

A naturally occurring gas, also a by-product of burning fossil fuels from fossil carbon deposits, of burning biomass, of land use changes (LUC) and of industrial processes. It is the principal anthropogenic greenhouse gas (GHG) that affects the earth's radiative balance. It is the reference gas against which other GHGs are measured and therefore has a Global Warming Potential (GWP) of 1.

Carbon sequestration

The uptake of carbon containing substances, in particular carbon dioxide (CO_2), in terrestrial or marine reservoirs. Biological sequestration includes direct removal of CO_2 from the atmosphere through land-use change (LUC), afforestation, reforestation, revegetation, carbon storage in landfills, and practices that enhance soil carbon in agriculture (cropland management, grazing land management). In parts of the literature, carbon sequestration is used to refer to Carbon Dioxide Capture and Storage (CCS).

Climate change

Climate change refers to a change in the state of the climate that can be identified by changes in the mean and the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the United Nations Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods'. The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes.

CO2-equivalent emission

CO2-equivalent emission is a common scale for comparing emissions of different GHGs. It is the amount of carbon dioxide (CO_2) emission that would cause the same integrated radiative forcing, over a given time horizon, as an emitted amount of a greenhouse gas (GHG) or a mixture of GHGs. The CO_2-equivalent emission is obtained by multiplying the emission of a GHG by its Global Warming Potential (GWP) for the given time horizon. For a mix of GHGs it is obtained by summing the CO_2-equivalent emissions of each gas.

Co-benefits

The positive effects that a policy or measure aimed at one objective might have on other objectives. Co-benefits are often subject to uncertainty and depend on, among others, local circumstances and implementation practices.

Decarbonisation

The process by which countries or other entities aim to achieve a low-carbon economy, or by which individuals aim to reduce their carbon consumption.

Ecosystem

A functional unit consisting of living organisms, their non-living environment, and the interactions within and between them. The components included in a given ecosystem and its spatial boundaries depend on the purpose for which the ecosystem is defined. Ecosystem boundaries can change over time. Ecosystems are nested within other ecosystems, and their scale can range from very small to the entire biosphere. In the current era, most ecosystems either contain people as key organisms, or are influenced by the effects of human activities in their environment.

Emission factors

The emissions released per unit of activity.

Emissions

(Anthropogenic) Emissions of greenhouse gases (GHGs), aerosols, and precursors of a GHG or aerosol caused by human activities. These activities include the burning of fossil fuels, deforestation, land use changes (LUC), livestock production, fertilization, waste management, and industrial processes. Emissions are usually classified in direct emissions that physically arise from activities within well-defined boundaries and indirect emissions that are a consequence of the activities within well-defined boundaries.

Exposure

The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.

Global warming

Global warming refers to the gradual increase in global surface temperature, as one of the consequences of radiative forcing caused by anthropogenic emissions.

Global warming potential (GWP)

An index, based on radiative properties of greenhouse gases (GHGs), measuring the radiative forcing following a pulse emission of a unit mass of a given GHG in the present-day atmosphere integrated over a chosen time horizon, relative to that of carbon dioxide (CO2). The GWP represents the combined effect of the differing times these gases remain in the atmosphere and their relative effectiveness in causing radiative forcing. The Kyoto Protocol is based on GWPs from pulse emissions over a 100-year time frame.

Governance

A comprehensive and inclusive concept of the full range of means for deciding, managing, and implementing policies and measures. The concept of governance recognizes the contributions of various levels of government (global, international, regional, local) and the contributing roles of the private sector, of nongovernmental actors, and of civil society to addressing the many types of issues facing the global community.

Greenhouse Gas (GHG)

Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of terrestrial radiation emitted by the earth's surface, the atmosphere itself, and by clouds. This property causes the greenhouse effect. Water vapour (H2O), carbon dioxide (CO2), nitrous oxide (N2O), methane (CH4) and ozone (O3) are the primary GHGs in the earth's atmosphere. Moreover, there are a number of entirely human-made GHGs in the atmosphere, such as the halocarbons and other chlorine- and bromine containing substances, dealt with under the Montreal Protocol. Beside CO2, N2O and CH4, the Kyoto Protocol deals with the GHGs sulphur hexafluoride (SF6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs).

Hazard

The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources. In this report, the term hazard usually refers to climate-related physical events or trends or their physical impacts.

Heat Island

The heat island effect is the phenomenon whereby atmospheric and surface temperatures are higher in urban areas than in the surrounding rural areas associated with the change in runoff, effects on heat retention and changes in surface albedo.

Impacts

Effects on natural and human systems. In this report, the term impact is used primarily to refer to the effects on natural and human systems of extreme weather and climate events and of climate change. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. Impacts are also referred to as consequences and outcomes. The impacts of climate change on geophysical systems, including floods, droughts, and sea level rise, are a subset of impacts called physical impacts.

Lifecycle assessment

A widely used technique defined by ISO 14040 as a "compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle". The results of LCA studies are strongly dependent on the system boundaries within which they are conducted. The technique is intended for relative comparison of two similar means to complete a product.
The approach considers the overall life cycle of the fuels/electricity. This includes all emissions of the energy chain that also take place outside the territory (such as transport losses, refinery emissions or energy conversion losses).

Maladaptation

Interventions and investments in a specific location or sector that could increase the vulnerability of another location or sector, or increase the vulnerability of the target group to future climate change. Maladaptation arises not only from inadvertent badly planned actions, but also from deliberate decisions focused on short-term benefits ahead of longer-term threats, or that fail to consider the full range of interactions, feedbacks and trade-offs between systems and sectors arising from planned actions.

Mitigation

Human interventions to reduce the sources or enhance the sinks of greenhouse gases (GHGs) and of other substances which may contribute directly or indirectly to limiting climate change.

Primary energy

It is defined in several alternative ways. Primary energy is the energy stored in natural resources (e. g., coal, crude oil, natural gas, uranium, and renewable sources). According to the International Energy Agency (IEA) definition, "primary energy is the energy that has not undergone any anthropogenic conversion". Primary energy is transformed into secondary energy by cleaning (natural gas), refining (crude oil to oil products) or by conversion into electricity or heat. When the secondary energy is delivered at the end-use facilities it is called final energy.

Renewable energy (RE)

Renewable energy sources, also called renewables, are energy sources that are replenished by natural processes at a rate that equals or exceeds its rate of use. Renewable energy sources include the following:

— Hydropower: the electricity generated from the potential and kinetic energy of water in hydroelectric plants;

— Geothermal energy: the energy available as heat from within the earth's crust, usually in the form of hot water or steam;

— Wind energy: the kinetic energy of wind converted into electricity in wind turbines;

— Solar energy: solar thermal energy (radiation exploited for solar heat) and solar photo-voltaic for electricity production.

Rebound effect

Phenomena whereby the reduction in energy consumption or emissions (relative to a baseline) associated with the implementation of mitigation measures in a jurisdiction is offset to some degree through induced changes in consumption, production, and prices within the same jurisdiction.

Resilience

The capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance; responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation.

Risk

The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazard. In this report, the term risk is used primarily to refer to the risks of climate-change impacts.

Risk and vulnerability assessment (RVA)

The Risk and Vulnerability Assessment is an analysis that determines the nature and extent of risk, by analysing potential hazards and assessing vulnerability that could pose a potential threat or harm to people, property, livelihoods and the environment on which they depend. It allows the identification of areas of critical concern and therefore provides information for decision-making. The Risk and Vulnerability Assessment serves, along with the Baseline Emission Inventory, as the point of departure for the development of the Sustainable Energy and Climate Action Plan (SECAP).

Sustainable Development

Development that meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987).

Transit Oriented Development

Urban development within walking distance of a transit station, usually dense and mixed with the character of a walkable environment.

Vulnerability

The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

Resources and websites:

IPCC (Intergovernmental Panel on Climate Change) (2014). Working Group III - AR5 – Climate Change 2014: Mitigation of Climate Change

IPCC (Intergovernmental Panel on Climate Change) (2014). Working Group II - AR5 – Climate Change 2014: Impacts, Adaptation, and Vulnerability

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