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Guidebook How to develop a Sustainable Energy and Climate Action Plan in the Eastern Partnership Countries

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2018

Covenant of Mayors for Climate & Energy CoM East

Joint Research Centre

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The adaptation of this guidebook is to complement the new objectives of the Covenant of Mayors (CoM) initiative by updating the existing guidebook 2014 version [1], developed in the context of the CoM in the Eastern Partnership region. The revision is also based on the 2018 Covenant of Mayors methodology developed to address the European Union cities context [2], where a relevant contribution has been received from the European Commission Directorate-General Joint Research Centre (JRC): the project leader Jean François Dallemand and colleagues: Nadja Vetters, Paolo Zangheri, Tiago Serrenho, Nicola Labanca, Marco Follador, and Muntean Marilena.

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Special thanks to local authorities who make public their engagement in climate action planning through their participation in the Covenant of Mayors East.

Abstract

This guidebook is to support the implementation and to assist the participation of the Eastern Partnership (EaP region) cities and local authorities in the Covenant of Mayors (CoM) initiative in: Armenia, Azerbaijan, Belarus, Georgia, the Republic of Moldova and Ukraine.

The present outline aims to complement the new objectives of the CoM initiative by updating the 2014 version of the guidebook [1] for the preparation of the sustainable energy and climate action plans developed in the context of the CoM in the EaP region. The adaptation of guidebook is also based on the 2018 version of the CoM methodology developed to address the European Union cities context [2].

The current guidebook provides detailed step-by-step recommendations for the entire process of elaborating a local energy and climate strategy, from initial political commitment to implementation. It is divided into 3 parts:

- Part I relates to the description of the overall SECAP principles and reporting requirements and covers the strategic issues;
- Part II is related to municipality assessments, as pre-requisite to SECAP elaboration, as they will provide knowledge on the nature of the emitting entities, risk and vulnerabilities in the municipality territory:
    - Part 2.a: gives guidance on how to elaborate the Baseline Emission Inventory (BEI);
    - Part 2.b: gives guidance on how to perform a Climate Change Risk and Vulnerability Assessment (RVA).
- Part III is dedicated to the description of technical, measures and policies that can be implemented at local level by the local authority per sector of activity:
    - Part 3.a: focus on climate change mitigation;
    - Part 3.b: focus on adaptation to climate change;
    - Part 3.c: focus on financing sustainable energy and climate action plans.

The guidebook provides a flexible but coherent set of principles and recommendations. The flexibility will allow local authorities to develop a SECAP 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.

Introduction

This guidebook is to support the implementation of the Covenant of Mayors initiative (hereafter referred to as the "Covenant of Mayors (CoM)" in the Eastern European Partnership countries. The Eastern Partnership (EaP) is a joint initiative involving the European Union, its Member States and six Eastern European Partners: Armenia, Azerbaijan, Belarus, Georgia, the Republic of Moldova and Ukraine.

The Guidebook has been prepared by the European Commission Directorate-General Joint Research Centre (JRC), with the support and input of the Directorate-General for Neighbourhood and Enlargement Negotiations (DG NEAR), the Directorate-General for Energy (DG ENER), the Directorate-General for Climate Action (DG CLIMA), the European Covenant of Mayors Office (CoMO) and the Covenant of Mayors East Office (CoMO East).

- ***About the Covenant of Mayors for Climate & Energy***

The **Covenant of Mayors** ([1]) initiative was launched **in 2008** by the European Commission after the adoption of the 2007 EU Climate and Energy Package, to endorse and support the efforts deployed by local authorities in the implementation of sustainable energy policies towards a low carbon future. The initiative aimed to convene local and regional authorities' voluntary committing to achieving and exceeding the European Union **20 % CO_2 reduction objective by 2020**.

Since its launch, the initiative has progressively grown into a worldwide city movement, from East and South neighbouring countries of Europe (respectively in 2011 and 2012) and later to sub-Saharan African countries.

Initially, the CoM initiative in the Eastern Neighbourhood countries has come to involve six Eastern Partnership countries (Armenia, Azerbaijan, Belarus, Georgia, Republic of Moldova and Ukraine) and five central Asian countries (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan) in the implementation of local sustainable energy policies. Since 2017, the initiative in the region is tailored to the specific needs of the six Eastern Partnership countries**.**

In 2014, the European Commission launched the **Mayors Adapt** initiative. Based on the same principles as the Covenant of Mayors, this sister initiative was **focusing on adaptation** to climate change. Mayors Adapt invited local governments to demonstrate leadership in adaptation, and was supporting them in the development and implementation of local adaptation strategies.

In October 2015, both the Covenant of Mayors and Mayors Adapt initiatives officially merged on the occasion of a ceremony held in the European Parliament. The resulting **Covenant of Mayors for Climate & Energy** ([2]) - the goals and direction of which were defined with cities through a consultation process - is both more ambitious and broad-ranging.

CoM signatory cities in the EaP region now pledge to actively support the implementation of the **30 % CO_2 emission reduction target by 2030** and agree to adopt an integrated approach to **climate change mitigation and adaptation**

- ***About the Global Covenant of Mayors for Climate & Energy***

In January 2017, the Covenant entered a major new phase of its history when merging with the Compact of Mayors initiative. The resulting **Global Covenant of Mayors for Climate and Energy (GCoM)** ([3]) has become the largest movement of local governments committed to accelerating the transition to low-emission and climate resilient societies, while also addressing access to sustainable energy. It now also covers North America, Latin America and the Caribbean, and much of Asia including countries in the South-East as well as China, India and Japan. Thus far, a total of nine regional and national Covenant offices have been set up. These regional and national Covenants

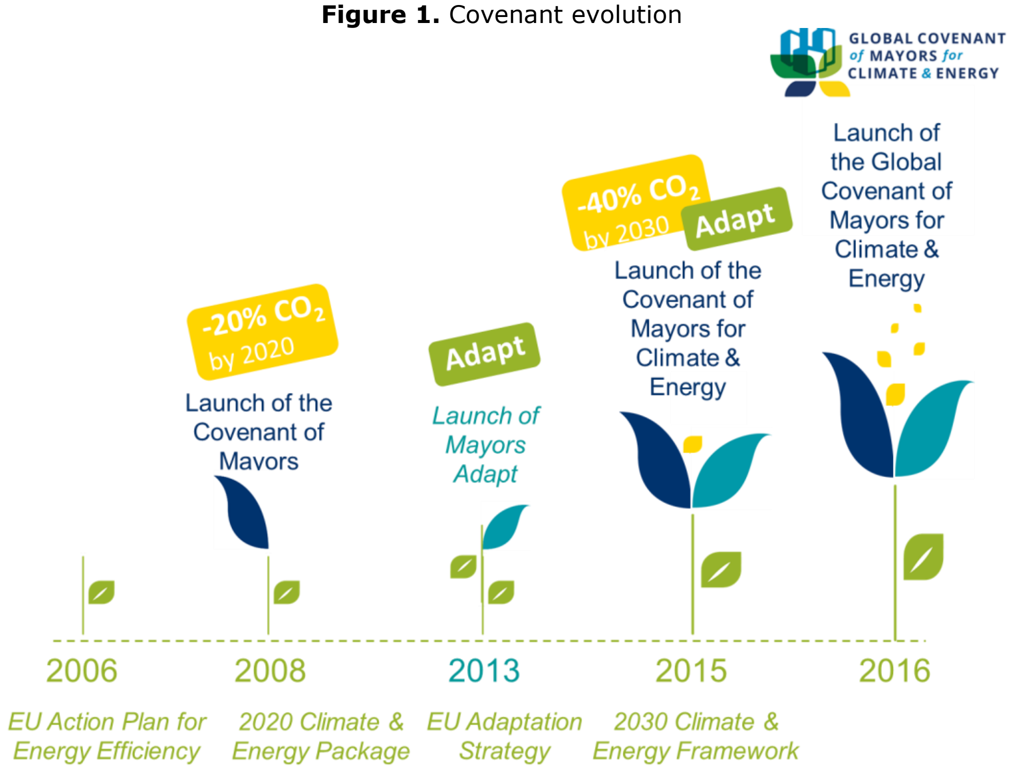
([1]) https://www.covenantofmayors.eu/about/covenant-initiative/origins-and-development.html
([2]) Speech/15/407.Paris Summit of Mayors of EU capitals and large cities
([3]) Official Global Covenant website : www.globalcovenantofmayors.org

operate as local chapters of a global alliance – allowing for adjustments to regional contexts and local realities, while enhancing global significance.

- ***About the Methodological & Reporting Frameworks***

The CoM helps local authorities to translate their commitments into reality, while taking into account the immense diversity on the ground. It provides signatories with a set of methodological principles (defined in the present guidebook) and a harmonised data compilation and reporting framework (consisting of a reporting template ([4]), and complemented by comprehensive reporting guidelines ([5])).

Figure 1. Covenant evolution



- ***About this Guidebook***

This guidebook is to support the implementation and to assist the participation of the Eastern Partnership cities in the Covenant of Mayors initiative in: Armenia, Azerbaijan, Belarus, Georgia, the Republic of Moldova and Ukraine.

The present outline aims to complement the above new objectives by updating the existing guidebook 2014 version [1] for the preparation of the sustainable energy action plans developed in the context of the CoM in the EaP region. The adaptation of guidebook is also based on the CoM methodology developed to address the European Union cities context [2].

The current guidebook provides detailed step-by-step recommendations for the entire process of elaborating a local energy and climate strategy, from initial political commitment to implementation. It is divided into 3 parts:

— Part I relates to the description of the overall SECAP principles and reporting requirements and covers the strategic issues;

— Part II is related to municipality assessments, as pre-requisite to SECAP elaboration, as they will provide knowledge on the nature of the emitting entities, risk and vulnerabilities in the municipality territory.

  - Part 2.a: gives guidance on how to elaborate the Baseline Emission

([4]) https://www.covenantofmayors.eu/index.php?option=com_attachments&task=download&id=142.
([5]) https://www.covenantofmayors.eu/index.php?option=com_attachments&task=download&id=172.

Inventory (BEI)
    - Part 2.b: gives guidance on how to perform a Climate Change Risk and Vulnerability Assessment (RVA)

- Part III is dedicated to the description of technical, measures and policies that can be implemented at local level by the local authority per sector of activity
    - Part 3.a: focus on climate change mitigation
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    - Part 3.c: focus on financing sustainable energy and climate action plans

The guidebook provides a flexible but coherent set of principles and recommendations. The flexibility will allow local authorities to develop a SECAP 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.

Further information and support:

If you do not find the desired information in the present guidebook, you can refer to the "Frequently Asked Questions" section, available on the Covenant website http://www.eumayors.eu/faq/index_en.htm or in the Russian version of the Covenant website www.com-east.eu. In addition, e-learning tool is available via the signatories' restricted area: "My Covenant" (Please note that a password is required).

In addition, a helpdesk has been set up to provide Covenant signatories with information and guidance on the preparation and implementation of both their BEI and their SEAP.

Signatories Helpdesk: info-east@eumayors.eu

For general or technical inquiries by phone, please call:

- Republic of Armenia- Yerevan office: +374 91 211 102; address: 1 Charents Street 2nd floor, 0025 Yerevan, Republic of Armenia
- Republic of Belarus - Minsk office: +375 296 324 872; address: 95/1 Niezaliezhnasci Av., Office 807, Minsk, 220043, Republic of Belarus
- Georgia & Azerbaijan - Tbilisi office: +995 599 974 003; address: 19th D. Gamrekeli Str. VI floor Office 611, Tbilisi 0160, Georgia
- Republic of Moldova – Chisinau office: +373 22 200 090; address: 66/1 Kogălniceanu Street, MD-2009, Chisinau, Republic of Moldova
- Ukraine – Kyiv Office: +38 044 278 03 1310; address: Prorizna Street, 4 floor, office 66, 01034 Kyiv, Ukraine

Part I. SECAP principles and reporting requirement

1. SECAP principles

The Sustainable Energy and Climate Action Plan (SECAP) is the key document that shows how the Covenant signatory will reach its commitments by 2030.

It uses the results of the Baseline Emission Inventory (BEI) to identify the best fields of action and opportunities for reaching the local authority's greenhouse gases (GHG) reduction target (of at least 30 % compared to the baseline emissions - more insights on this in Part III of this Guidebook).

It is also based on the Climate Change Risk and Vulnerability Assessment(s) (RVA(s)), which identifies the most relevant city climate hazards and vulnerabilities. The assessment will also identify the expected impacts on each policy sector, the adaptation strategy as well as the key adaptation actions.

The SECAP defines concrete measures for climate mitigation and adaptation, with timeframes and assigned responsibilities, which translate the long-term strategy into action. Signatories commit themselves to submitting their SECAPs within two years following adhesion.

The SECAP should not be regarded as a fixed but rather as a living document: as circumstances change and as the ongoing actions provide results and experience, it may be useful and necessary to revise the plan on a regular basis.

Opportunities to make cities more climate-resilient arise with every new development project to be approved by the local authority. Climate-related considerations should therefore be taken into account for all new developments, even if the SECAP has not yet been finalised or approved.

For cities who have already developed a Sustainable Energy Action Plan with an emission reduction target by 2020 (under the former version of the Covenant of Mayors) and/or an adaptation strategy (under Mayors Adapt) , their previous commitment(s) remain(s) valid. They are invited to renew and extend their commitments to the 2030 commitments (Covenant of Mayors for Climate & Energy) with a new council deliberation l, and to prepare a SECAP as a natural extension of their existing (mitigation and/or adaptation) plan.

1.1 Scope of the SECAP

The Covenant of Mayors concerns action at local and regional level within the competence of the local authority. The SECAP should concentrate on measures aimed at reducing the CO_2 emissions and the final energy consumption by end users and include adaptation actions in response to the impacts of climate change within the territory. The Covenant's commitments cover the whole geographical area/jurisdiction of the local authority (town, city, region). Therefore, the SECAP should include actions concerning both the public and private sectors. Moreover, the local authority is expected to play an exemplary role and therefore to take outstanding measures related to its own buildings and facilities, vehicle fleet, etc.

For climate change mitigation, the main target sectors are (municipal/residential/tertiary) buildings, equipment/facilities and urban transport [3] [4]. The SECAP may also include actions related to local electricity production (development of PV, wind power, CHP, improvement of local power generation), and local heating/cooling generation.

In addition, the SECAP should cover areas where local authorities can influence energy consumption on the long term (e.g. land use planning), encourage markets for energy efficient products and services (e.g. public procurement), as well as changes in consumption patterns (e.g. working with stakeholders and citizens) [5]. A detailed description of the sectors to be covered in the Baseline Emission Inventory is provided in Part II.a.

For climate change adaptation, the SECAP should include actions in the sectors and areas, which are likely to be most vulnerable to climate change in a local authority (hotspots). Vulnerable sectors can considerably vary within urban perimeters, from one city to another, from urban areas to more rural areas (e.g. buildings, transport, energy, water, waste, land use planning, environment & biodiversity, agriculture & forestry, health, civil protection & emergency, tourism): this is why gaining a deep understanding of the hazards and vulnerabilities of the local authority is of paramount importance.

Finally, mitigation and adaptation should complement each other, and should be mainstreamed into existing sectorial policies in order to foster synergies and optimize the use of available resources. A climate lens should be applied whenever a mitigation policy or action is formulated, planned and/or implemented, to see whether it works in favour of or against the adaptation goals and – if relevant - adjust it, and vice versa. Especially relevant is to avoid maladaptation (action taken ostensibly to avoid or reduce vulnerability to climate change that impacts adversely on, or increases the vulnerability of other systems, sectors or social groups [6].

Figure 2. The CoM main steps

1.2 Time horizon

The time horizon of the Covenant of Mayors is 2030. Therefore, the SECAP has to contain a clear outline of the strategic actions that the local authority intends to take in order to reach its commitments by 2030. The SECAP may cover a longer period, but in this case it should contain intermediate figures and objectives for the year 2030. For local authorities who joined the Covenant before November 2015, the 2020 target remains an important milestone towards the 2030 commitments.

As it is not always possible to plan in detail concrete measures and budgets for such a long time span, the local authority may distinguish between:

- A vision, with long-term strategy and goals until 2030 and/or beyond, including firm commitments in areas like land-use planning, transport and mobility, public procurement, standards for new/renovated buildings etc.

- Detailed measures for the next 3-5 years, which translate the long-term strategy and goals into real actions.

Both the long-term vision and the detailed measures shall form an integral part of the SECAP.

Box 1 Example of long-term strategy on transport

A local authority decides that all the cars purchased for the municipal fleet should be electric. Of course, the municipality cannot vote the budget for all the cars that will be purchased up until 2030, but they can include this measure in the plan and evaluate its impact till 2030. For the duration of the local authority's political mandate, this measure should be presented in very practical terms, with budgets, identification of financing sources, etc.

This is particularly true for adaptation targets ([6]): local decision-makers often focus on the immediate benefits of a measure that fits into their political agenda, whilst adaptation is known to have long-term benefits. A robust planning of climate action must integrate short-term needs with long-term threats and consider the full range of interactions between sectors and policies in order to avoid maladaptation [7].

Box 2 Maladaptation

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.

Setting an emission reduction target to 2030 is mandatory for all signatories of the Covenant of Mayors for Climate & Energy. Nevertheless, signatories are warmly encouraged to set and to report on a longer-term target as well, to demonstrate that they have a vision towards decarbonised and resilient territories, providing universal access to secure, sustainable and affordable energy services for all. For this purpose, both the target year (beyond 2030) and the minimum emission reduction objective can be freely set by the local authority. It is also strongly recommended that measures related to the local authority's own buildings and facilities are implemented first, in order to set an example and motivate the stakeholders.

([6]) https://www.covenantofmayors.eu/support/adaptation-resources.html

1.3 The SECAP process: Ten key elements

As a summary of what is presented in this Guidebook, here are the 10 essential principles (**Table 1**) that should keep in mind when elaborating a SECAP. These principles are linked to the commitments taken by the Covenant signatories and constitute key ingredients of success.

Table 1. The SECAP process: Ten key elements

Phase	Requirements	Steps	Description
Initiation	Committing to address climate change mitigation and adaptation	1. Political commitment and signing of the Covenant	Formal adoption of the plan by the municipal council (or equivalent decision-making body) Strong political support is essential to ensure the success of the process, from SECAP design to implementation and monitoring. This is why the SECAP document must be approved by the municipal council (or equivalent decision-making body).
		2. Mobilization of all municipal departments involved	The SECAP process should not be conceived by the different departments of the local administration as an external issue, but it has to be integrated in their everyday life. The SECAP should outline which structures are in place or will be organised in order to implement the actions and follow the results. It should also specify the human resources made available. A coordinated (inter)action between mitigation and adaptation through the mobilisation of all municipal departments involved should be ensured. This implies strong horizontal cooperation among policy sectors that are used to working in separate silos to comply only with their sectoral agenda.
		3 Build support from stakeholders: Engagement of citizens and stakeholders	In order to develop successful mitigation and adaptation planning, multiple stakeholder engagement is required. Stakeholder engagement should be carried out since the very first steps of the planning process until the end of it, in order to have a successful planning. The plan has to describe how the citizens and stakeholders have been involved in its elaboration, and how they will be involved in implementation and follow up. Advisory Groups should be created to ensure an exhaustive understanding of city specificities and problems, meet end-user expectations, guarantee a common agreement about selected indicators, and ensure a full uptake of the main outcomes and their inclusion into decision-making.
Planning phase	Completing a baseline emission inventory (BEI) and risk and vulnerability assessment (RVA)	4. Assessment of the current framework: Where are we?	Sound assessment of the local situation (BEI) and (RVA) outputs: The SECAP should be elaborated based on a sound knowledge of the local baseline situation in terms of energy consumption and greenhouse gas emissions, as well as of climate hazards, vulnerabilities and impacted policy sectors. Therefore, an assessment of the current framework should be carried out.

Phase	Requirements	Steps	Description
			This includes elaborating a BEI and preparing a RVA – in line with the CoM commitments. The results of both the BEI and the RVA have to be included in the SECAP document.
	Setting a mitigation target for 2030 and adaptation goals	5. Establishment of the vision: Where do we want to go?	The SECAP document must contain a clear reference to the core emission reduction commitment taken by the local authority when signing the Covenant of Mayors. The overall CO_2 reduction commitment has to be translated into concrete actions and measures together with the CO2 reduction estimates in tons/year by 2030. For the local authorities that have a longer term CO_2 reduction target (for example by 2050) they should set an intermediary target by 2030 (30% as a minimum) for the reasons of comparability. In addition to the mitigation commitment, adaptation goals have to be specified coherently with the main outcomes of the vulnerability and risk assessment.
	Redaction of a sustainable energy and climate action plan (SECAP)	6. Elaboration of the plan: How do we get there? Strategies and set of actions until 2030	The plan must contain a clear outline of the strategic actions that the local authority intends to take in order to reach its commitments by 2030. It has to contain: ● The strategy and goals until 2030, including firm commitments in areas like land-use planning, transport and mobility, public procurement, standards for new/renovated buildings etc. ● Detailed measures for the coming years, which translate the long-term strategy and goals into actions. For each measure/action, it is important to provide a general description, the responsible body, the timing (start-end, major milestones), the cost estimation and financing/source, the indicators for monitoring. In addition, for mitigation actions the following should also be indicated: estimated energy saving/increased renewable energy production and associated estimated CO2 reduction.
		7. Comprehensive measures addressing the key sectors of activity – as identified in the signatory's assessments (BEI & RVA)	The commitment taken by the signatories concerns the reduction of the CO_2 emissions in their respective territories. Therefore, the SECAP has to contain a coherent set of mitigation measures covering possibly all the Covenant key sectors of activity: not only the buildings and facilities that are managed by the local authority, but also the sectors of activity in the territory of the local authority: residential sector, tertiary sector, public and private transport. Before starting the elaboration of actions and measures, the establishment of a long-term vision with clear objectives is highly recommended. The adaptation strategy should be part of a stand-alone document (e.g. the so-called SECAP) and/or mainstreamed in separate documents. Based on recognised local risks and vulnerabilities, the local authority should identify actions aimed at

Phase	Requirements	Steps	Description
			enhancing local adaptive capacity to respond to climate change impact or/and reducing city sensitivity to climate extremes.
Implementation phase	Implementation of the SECAP	8. Implementation of the SECAP	Provide long-term political support to the SECAP process. Make sure that the energy and climate policy is integrated in the everyday life of the local administration. Show interest in the plan implementation, encourage stakeholders to act, show by example. Networking with other CoM signatories, exchanging experience and best practices, establishing synergies and encouraging their involvement in the Covenant of Mayors. Human and financial resources: SECAP elaboration and implementation require human and financial resources. Local authorities may adopt different approaches: Using internal (in-house) resources, for example by integrating the tasks in (an) existing department(s) of the local authority involved in energy- and climate-related topics (e.g. local Agenda 21 office, environmental and/or energy department).Setting up a new unit within the local administration (approx. 1 person/100,000 inhabitants).Outsourcing (e.g., private consultants, city-networks, universities …). Getting support from national, local and regional energy agencies or Covenant Territorial Coordinators ([7]) (CTCs).
Monitoring and reporting phase	Monitoring and reporting the progress	9. Monitoring	Regular monitoring using relevant indicators followed by adequate revisions of the SECAP allows to evaluate whether the local authority is achieving its targets, and to adopt corrective measures if necessary. The CoM signatories are therefore committed to submit a "Monitoring Report" every second year following the submission of the SECAP. The SECAP should contain a brief outline on how the local authority intends to ensure the follow-up of the actions and monitor the results. Signatories who had already committed to 2020 targets should continue to monitor and report on the progress to achieve them while starting to report on 2030 targets.
		10. Reporting requirements	The Covenant Signatories commit to submitting their SECAPs within two years following adhesion. The SECAP document must be uploaded in national language (or in English) via the Covenant of Mayors' website. Signatories are required, at the same time, to fill in an online SECAP template in English. This will allow them to summarise the results of their BEIs and of the Climate Change Risk and Vulnerability Assessment as well as the key elements of their SECAP. Dedicated monitoring templates are available to report on the SECAP implementation. The template has to be filled carefully with sufficient level of detail, and should reflect the content of the SECAP.

([7]) Covenant Coordinators (roles, list): https://www.covenantofmayors.eu/about/covenant-community/coordinators.html

1.4 Joint SECAPs

Should a group of adjoining Covenant of Mayors´ cities want to elaborate a common SECAP and Baseline Emissions Inventory (BEI), they are allowed to do so, preferably under the aegis of a Covenant Territorial Coordinator. Two options of joint SECAP are allowed:

— Joint SECAP Option 1, recommended for two or more cities willing to implement one or several joint actions, but remaining individually committed to the 2030 target. In this case cities can submit only one SECAP document approved by the municipal council (or equivalent decision-making body) of each of the municipalities, but each city has to fill-in its own SECAP template. The objective of reducing 30% of the CO_2 emissions by 2030 is not shared by the group of cities as it remains an individual objective of each city participating in the joint SECAP. The emissions´ reductions corresponding to the common measures proposed in the SECAP will be divided among each city sharing these measures.

— Joint SECAP Option 2, recommended for:

- a group of small- and medium-sized municipalities within the same territorial area (indicatively with less than 10,000 inhabitants each);
- an urban agglomeration, like a metropolis with its suburbs. In this case, the group is registered as one signatory and has to submit only one SECAP document, approved by the municipal council (or equivalent decision-making body) of each of the municipalities and to fill-in only one SECAP template. The objective of reducing 30 % of the CO_2 emissions by 2030 is shared by the group of cities. In the SECAP document, the specific contribution to the overall plan of each of the municipalities needs to be defined.

More information can be found in the Quick Reference Guide 'Joint Sustainable Energy Action Plan' by the Covenant of Mayors Office http://www.eumayors.eu/IMG/pdf/Joint_SECAP_guide-2.pdf. If municipalities are interested in joining the CoM as a 'group of signatories', please contact the Covenant of Mayors East Office.

Table 2. Summary of the two options for joint SECAPs

Covenant Steps	Option 1	Option 2
30 % CO_2 reduction target:	Individual target	Shared target
Submission of the SECAP template:	Individual	1 for the group
Submission of the SECAP document:	>> 1 joint SECAP <<	
Publication of the results in the online catalogue:	1 per Signatory	1 for the group

1.5 Covenant Territorial and National Coordinators

Local authorities, which do not have sufficient skills or resources to draft and implement their own SECAP, should be supported by public administrations with such capacities.

There are two types of Supporting Structures — Territorial and National Coordinators.

- Covenant Territorial Coordinators (CTCs) are sub-national decentralised authorities — including provinces, regions and public groupings of municipalities.
- Covenant National Coordinators (CNCs) are national public bodies — including national energy agencies and ministries dealing with energy.

Provinces, regions, national public bodies, metropolitan areas, groupings of local authorities which officially commit to provide strategic guidance, financial and technical support to Covenant signatories will be officially recognized as Covenant Coordinator by the European Commission.

Supporting structures can also maintain close contact with the European Commission and the CoM East Office to ensure the best possible implementation of the Covenant. Thus, supporting structures are officially recognised by the Commission as key allies in conveying the message and increasing the impact of the Covenant. CTCs and CNCs are in a position to provide strategic guidance and financial and technical support to local authorities with political will to sign up to the Covenant of Mayors.

Supporting Structures can offer direct technical and financial assistance such as:

— Supporting structures willing to take on the role of CTCs and CNCs commit to:

— Promoting accession to the Covenant of Mayors among municipalities in their territory and providing support and coordination to those municipalities signing up;

— Providing technical and strategic assistance to those municipalities willing to join the Covenant but lacking the necessary resources to prepare a SECAP;

— Facilitating access to funding to the municipalities for the development and implementation of their SECAP;

— Mobilising technical expertise in order to help Covenant signatories preparing their BEI or SECAP;

— Developing or adapting methodological aids for preparing the SECAPs, taking into account the national or regional context;

— Assisting in the organisation of local energy days to raise awareness;

— Reporting regularly to the Commission on the results obtained and participating in the strategic implementation of the Covenant.

— Training local officials, who will be the final SECAP owners.

Box 3. Examples of Covenant Territorial/National Coordinators

The **Province of Flemish Brabant** in Belgium has made efforts in guiding municipalities throughout all the steps of the SECAP process, from generating interest in the Covenant of Mayors initiative to the preparation of the emission inventories and to planning actions. In particular they have proposed a number of tools ranging from communication material to technical documents and templates, which represent a practical help for Covenant signatories.

The **Province of Barcelona** in Spain, while directly financing the development of SECAPs of the signatories it supports, has applied for funding under the ELENA facility and signed a contract with the European Investment Bank in 2010. The Province has received a grant of 2 million euros which allowed the financing of 190 feasibility studies for energy efficiency in buildings, public lighting, renewable energies and legal studies and resulted in 122.5 million euros of investments. The CTC has also helped the municipalities in the organization of low cost actions: one example is the project Euronet 50/50, supported by Intelligent Energy Europe, aiming at achieving energy savings at school through behavioural changes.

2. SECAP process and reporting requirements

2.1 Initiation phase

2.1.1 Political commitment and signing of the Covenant

Strong political support is essential to ensure the success of the process, from SECAP design to implementation and monitoring. This is why the SECAP **must be approved by the municipal council** (or equivalent decision-making body).

The key decision-makers of the local authority should further support the process by allocating adequate human resources with clear mandate and sufficient time and budget to prepare and implement the SECAP. It is essential that they are involved in the SECAP elaboration process so that it is accepted and backed up by them. Adequate training should be provided to municipal officers dealing with the SECAP. Political commitment and leadership are driving forces that stimulate the management cycle. Therefore, they should be sought from the very beginning. The formal approval of the SECAP by the municipal council (or equivalent decision making body), along with the necessary budgets for the first year(s) of implementation is another key step.

As the highest responsible entity and authority, the municipal council must be closely informed of the follow-up of the implementation process. An implementation report should be produced and discussed periodically. In the context of the Covenant, a monitoring report has to be submitted every second year for evaluation, monitoring and verification purposes. If necessary, the SECAP should be updated accordingly.

Finally, the key decision-makers of the local authority could also play a role in:

- Integrating the SECAP vision with the other actions and initiatives of the relevant municipality departments and making sure it becomes part of the overall planning
- Assuring the long-term commitment to implementation and monitoring, along the full duration of the SECAP
- Seek and support citizens' participation and stakeholders' involvement
- Ensure that the SECAP process is 'owned' by the local authority and the residents
- Sharing their vision, results, experience and know-how with fellow local and regional authorities within the EU and beyond through direct cooperation and peer-to-peer exchange

There is no single route leading to political commitment. Administrative structures, patterns of political approval and political cultures vary from country to country. For such reason, the local authority itself is best suited to know how to proceed to raise the political commitment needed for the SECAP process.

2.1.2 Mobilize all municipal departments involved

It is key to the success of the whole process beginning with the design of a SECAP and resulting in its implementation, that a narrow collaboration amongst the different local administrative departments is established and that the SECAP process is taken into account when relevant administrative decisions are made. A SECAP should not be regarded as a standalone document. On the contrary, it should be interlinked with the signatory's energy policy and should be integrated into the everyday life of the different departments of the local administration.

Therefore, the SECAP document itself should indicate which working groups are in place or will be organised for preparing the Baseline Emission Inventory, planning the SECAP actions, implementing them and monitoring the results. Particular reference should be made to the management structure steered by a skilled energy manager and to the allocation of adequate human resources. Where organisational structures have already been created for other related policies (energy management unit, local Agenda 21 coordination, etc.), they may be used in the context of the Covenant of Mayors, as described in the example of the City of Lviv ([8]).

At the beginning of the SECAP elaboration process, a 'Covenant coordinator' should be appointed within the city administration. She/he must have full support of the local political authorities and from the hierarchy, as well as the necessary time availability, and the budgetary means to carry out his/her tasks. In large cities, he/she could even have a dedicated unit or a team at his/her disposal, with several staff. Depending on the size of the local authority, one person dedicated to data collection and CO2 emissions inventory may also be necessary.

In other cases, organisational change in a municipal administration may be required, establishing a department or a unit for energy efficiency, renewable energy and other sectors. This unit can, at a later stage (after a SECAP has been prepared), undertake the responsibility for overall energy management of the public buildings owned by the city. As an example of simple organisation structure, two groups may be constituted:

- A climate policy steering committee, constituted by politicians and senior managers. Its mission would be to provide strategic direction and the necessary political support to the process and to mainstream climate change mitigation and adaptation policy across different departments.
- One or several working group(s), constituted by the energy planning manager, key persons from various departments of the local authority, public agencies, etc. Their task would be to coordinate the actual SECAP elaboration and follow-up work, to ensure stakeholders' participation, to organise monitoring, to produce reports, and undertake other relevant activities around specific issues, possibly with contributions from non-municipal key actors directly involved in SECAP actions.

Both the steering committee and the working group(s) need a distinct leader, although they should be able to work together. Moreover, the objectives and functions of each one of these groups must be clearly specified. A well-defined meeting agenda and a project-reporting strategy are recommendable in order to have a good command over the SECAP process.

It is essential that both sustainable energy management and climate adaptation are integrated with the other actions and initiatives of the relevant municipality departments, and it must be ensured that they become part of the overall planning of the local authority. Multi-departmental and cross-sectoral involvement is required, and organisational targets need to be in line and integrated with the SECAP. The establishment of a flow chart, indicating the various interactions between departments and actors, would be useful to identify the adjustments that may be necessary to the local authority's organisation. As many key municipal players as possible should be assigned responsible roles to ensure strong ownership of the process in the organisation. A specific communication campaign may help reach and convince the municipal workers in different departments.

Moreover, adequate training should not be neglected in different fields, such as technical competencies (energy efficiency, renewable energies, efficient transport, vulnerability and adaptation assessment, climate science, public health, emergency management, cultural heritage…), project management, data management, financial management, development of investment projects, and communication (how to promote behavioural changes, etc.). Linking with local universities can be useful for this purpose.

([8])https://www.esmap.org/sites/default/files/esmap-files/Lviv%20Buildings%20Case%20final%20edited%20042611.pdf

The SECAP process should not be conceived by the different departments of the local administration as an external issue, but it has to be integrated in their everyday life. The SECAP should outline which structures are in place or will be organised in order to implement the actions and follow the results. It should also specify the human resources made available. A coordinated (inter)action between mitigation and adaptation through the mobilisation of all municipal departments involved should be ensured.

Depending on their size and human resources availability, local authorities may benefit from the assistance of Covenant Territorial Coordinators or energy agencies. It is even possible for them to subcontract some specific tasks (e.g. compilation of a BEI or of a RVA) or to use interns (Masters or PhD students can do much of the work associated with the collection of data and entry into a GHG calculation tool to produce the BEI).

2.1.3 Building support from stakeholders

To implement and achieve the objectives of the SECAP, the adhesion and participation of the civil society is essential. This is the reason why the mobilisation of the civil society is part of the CoM commitments. It is highly recommended that the local authority includes in its communication strategy arguments that can be particularly appealing to citizens/stakeholders and that it highlights which benefits an effective SECAP implementation can bring (e.g. lower energy bills, better living conditions etc. See also section 5 of the present document).

This is because a SECAP is not a plan for the municipality (or the local administrative body) itself but for the whole local community. It should serve as a long term platform for coordinating the major stakeholders, especially in the energy field. The identification of such stakeholders and their involvement in the development of both local energy policy and of the SECAP itself are key preconditions for the plan's successful implementation. As a result, the SECAP document should describe how the civil society has been involved in the elaboration of the plan, and how it will be involved in its implementation.

2.1.3.1 Building support from stakeholders

In order to develop successful mitigation and adaptation planning, multiple stakeholder engagement is required. Stakeholder engagement should be carried out since the very first steps of the planning process until the end of it. The plan has to describe how the citizens and stakeholders have been involved in its elaboration, and how they will be involved in implementation and follow up.

All members of society have a key role in addressing the energy and climate challenge with their local authorities. Together, they have to establish a common vision for the future, define the paths that will make this vision come true, and invest the necessary human and financial resources. Stakeholders' involvement is the starting point for stimulating the behavioural changes that are needed to complement the technical actions embodied in the SECAP.

This is the key to a concerted and co-ordinated way to implement the SECAP. Citizens and stakeholders – given their activities and their impact on the environment - are likely to be influenced by the solutions devised but they can also help reach the targets. The views of citizens and stakeholders should be known before detailed plans are developed. Therefore, citizens and other stakeholders should be involved and be offered the opportunity to take part in the key stages the SECAP elaboration process: building the vision, defining the objectives and targets, setting the priorities, etc.

There are various degrees of involvement: 'informing' is at one extreme whilst 'empowering' is at the other. To make a successful SECAP, it is highly recommended to seek the highest level of participation of stakeholders and citizens in the process. Stakeholder engagement should be carried out since the very first steps of the planning process until the end of it.

Box 4. Stakeholders' participation is important for various reasons

- Participatory policy-making is more transparent and democratic
- A decision taken together with many stakeholders is based on more extensive knowledge
- Broad consensus improves the quality, acceptance, effectiveness and legitimacy of the plan
- Sense of participation in planning ensures the long-term acceptance, viability and support of strategies and measures
- SECAPs may sometimes get stronger support from external stakeholders than from the internal management or staff of the local authority

For these reasons, to mobilise the civil society to take part in developing the action plan is a formal commitment of those signing the CoM. The first step is to identify the main stakeholders. **Table 3** shows the potential roles that the local authority and the stakeholders can play in the SECAP process. The stakeholders are those:

- whose interests are affected by the issue
- whose activities affect the issue
- who possess/control information, resources and expertise needed for strategy formulation and implementation
- whose participation/involvement is needed for successful implementation.

Here is a list of potentially important stakeholders in the context of a SECAP:

- Local administration: relevant municipal departments and companies (municipal energy utilities, transport companies, etc)
- Local and regional energy agencies
- Financial partners such as banks, private funds, ESCOs ([9]);
- Institutional stakeholders: chambers of commerce, chambers of architects and engineers;
- Energy suppliers, utilities;
- Transport/mobility players: private/public transport companies, etc.;
- The building sector: building companies, developers, housing authorities;
- Businesses and industries;
- Supporting Structures and energy agencies and media
- NGOs and other civil society representatives including students, workers, etc.
- Representatives of Existing structures (Local Agenda 21, etc.);
- Universities and research centers;
- Hospitals
- Knowledgeable persons (consultants, etc.);

([9]) ESCO is the acronym for Energy Services Companies.

Table 3. The SECAP process: the main steps - role of the key actors

The SECAP process : the main steps - role of the key actors				
PHASE	**STEP**	**Municipal council or equivalent body**	**Local administration**	**Stakeholders**
Initiation	Political commitment and signing of the Covenant	Make the initial commitment. Sign the Covenant of Mayors. Provide the necessary impulse to the local administration to start the process.	Encourage the political authorities to take action. Inform them about the multiple benefits (and about the necessary resources).	Make pressure on political authorities to take action (if necessary).
	Mobilize all municipal departments involved	Allocate sufficient human resources and make sure adequate administrative structures are in place (e.g. horizontal offices ensuring collaboration amongst different departments of the administration) to ensure a coordinated action between mitigation and adaptation.		
	Build support from stakeholders	Provide the necessary impulse for stakeholders' participation. Show that you consider their participation and support as important.	Prepare an inventory of the relevant stakeholders, decide what channels of communication/participation you want to use, establish collaboration practices. Inform them about the process that is going to start, and collect their views.	Express their views, explain their potential role in SECAPs development and implementation.
Planning phase	Assessment of the current framework: Where are we?	Make sure the necessary resources are in place for the planning phase.	Conduct the initial assessment, collect the necessary data, and elaborate the CO_2 baseline emission inventory and the climate risks and vulnerabilities assessment. Make sure the stakeholders are properly involved.	Provide valuable inputs and data, share the knowledge.
	Establishment of the vision: Where do we want to go?	Support the elaboration of the vision. Make sure it is ambitious enough. Approve the vision (if applicable).	Establish a long-term vision and objectives that support the vision. Make sure it is shared by the main stakeholders and endorsed by the political authorities.	Participate in the definition of the vision, express their view on the city's future.
	Elaboration of the plan: How do we get there?	Support the elaboration of the plan. Define the priorities, in line with the vision previously defined.	Elaborate the plan: define policies and measures in line with the vision and the objectives, establish budget and financing sources and mechanisms, timing, indicators, responsibilities. Keep the political authorities informed, and involve stakeholders. Make partnerships with key stakeholders.	Participate in the elaboration of the plan. Provide input, feedback. Contribute to initiating and designing the processes.
	Plan approval and submission	Approve the plan and the necessary budgets, at least for the first year(s).	Submit the SECAP via the CoM website. Communicate about the plan.	Make pressure on political authorities to approve the plan (if necessary)
Implementation phase	Implementation	Provide long-term political support to the SECAP process.	Coordinate the implementation. Make sure each stakeholder is aware of its role in the implementation.	Each stakeholder implements the measures that are under its responsibility and shares the results.
		Make sure that the energy and climate policy is integrated in the everyday life of the local administration.	Implement the measures that are under responsibility of the local authority. Be exemplary. Communicate about your actions.	Make pressure / encourage the local administration to implement the measures under its responsibility (if necessary).
		Show interest in the plan implementation, encourage stakeholders to act, show the example.	Motivate the stakeholders to act (information campaigns). Inform them properly about the resources available for EE, RES and adaptation.	Changes in behaviour, EE, RES and adaptation action, general support to SECAP implementation.
		Networking with other CoM signatories, exchanging experience and best practices, establishing synergies and encouraging their involvement in the Covenant of Mayors.		Encourage other stakeholders to act
Monitoring and reporting phase	Monitoring	Ask to be informed regularly about the advancement of the plan.	Proceed to a regular monitoring of the plan: advancement of the actions and evaluation of their impact.	Provide the necessary inputs and data.
	Reporting and submission of the implementation report and review	Approve the report (if applicable). Ensure that plan updates occur at regular intervals.	Periodically update the plan and report periodically to the political authorities and to the stakeholders about the advancement of the plan. Communicate about the results. Every second year, submit an implementation report via the CoM website. Involve political authorities and stakeholders.	Provide comments on the report and report on the measures under their responsibility. Participate in plan update.

Box 5. Awareness raising examples in Georgia and Belarus

The Energy Efficiency Centre in Georgia (EECG) in partnership with the self-governing Rustavi city organised the awareness raising event 'Let's save Energy', through the organisation of Intelligent Energy Days in Rustavi city as part of the project 'Energy Saving Initiative in the Building sector in Eastern Europe and the central Asian Countries' financed by the European Commission. This event had a non-formal educational character and included seminars at five public schools and the replacement of light bulbs in kindergartens.

In the City of Polotsk, Belarus, the annual Sustainable Energy Days were supported by the “City Lights” project which aims at transitioning the whole city to modern, energy efficient street-lighting. The project is supported by the Polotsk Regional Committee, and the “Interaction” Fund supported by the European Commission. The outreach events included city runs, treasure hunts and quizzes on energy efficiency among schoolchildren, implemented architectural summer-school with applied green architecture initiatives, carried out an on-line energy efficiency marathon, implemented an intellectual-athletic contest “Together – to energy efficiency!”, set up a photo-wall for specially for Polotsk Energy Days, which got broadly featured on Instagram.

- national/regional/provincial administrations and/or neighbouring municipalities, to ensure coordination and consistency with plans and actions that take place at other levels of decision
- Tourists and tourist industry, where appropriate
- Agricultural community, where appropriate
- Port authority and/or coast guard, where appropriate

To meet the challenge of adaptation to climate change, traditional models of stakeholders' involvement might not be sufficient, while integrated solutions in the urban planning and design process are required. Innovative ways to support the efforts and the commitments and to consolidate the knowledge of different groups and individuals need to be found. An innovative tool could be a Private-Public Partnership, which allow the community to "be part of" instead of "taking part in" the change. In this context, each partner is asked to play a specific role for reaching the climate related goal and accepts to be accountable. This mechanism allows partners to enjoy shared benefits (such as increased knowledge and skills, creation of new methods and solutions, strengthened credibility and trust, etc.), while providing benefits to the external community (e.g. satisfying collective needs, strengthening civil society, sustainable territorial development, creation of wellbeing, etc.). The Partnership must be formalised through a Protocol Agreement specifying:

— The goals and partnership models

— The categories and roles to be carried out

— The governance mechanisms of the partnership

Enforcing the partnership requires support actions, which can vary considerably depending on the resources the partnership can count on and range from networking, facilitating awareness and access to credit, possibilities for funding, until technical planning and co-financing investments. The partnership must be regularly monitored not only in terms of results, but also of relations, communication, transparency and management.

2.1.3.2 Communication

Communication is an essential means to keep the stakeholders informed and motivated. Therefore, a clear communication strategy should be integrated in the SECAP.

Communication should also give visibility to the commitments of the partners and acknowledge the results achieved.

- Before initiating a communication campaign, some information should be specified in order to maximise the impact of the action.
- Specify the message to be transmitted and the effect to be produced (desired outcome).
- Identify the key audience.
- Establish a set of indicators to evaluate the impact of the communication (head count at a seminar, surveys – quantitative/qualitative, hits on website, feedback, e.g. e-mails, …)
- Specify the most appropriate communication channel(s) (face to face – most effective form of communication, advertising, mail, e-mail, internet, blogs, talks/meetings, brochures, posters, newsletters, printed publications, media releases, sponsorship ...).
- Specify planning and budget.

Communication can also be internal to the local authority: setting up internal communication means may be necessary to improve collaboration between the departments involved within the local authority. A horizontal office coordinating different departments of the local administration may serve this purpose.

2.1.3.3 Public awareness

Public awareness and social engaging play a pivotal role for successful climate action. Measures to induce behaviour change and to provide education significantly contribute to the decrease of energy consumption through social and non-technological approaches that must be included in policies that support energy efficiency and energy savings.

In the CoM framework, local governments are integrating policies aiming at increasing public awareness (such as information and benefit campaigns) towards a behavioural change in energy use in their territories.

This chapter aims at guiding local authorities in the preparation and successful implementation of this kind of measures that allow improving the impact of their information and training campaigns.

Measures targeting different groups and covering several sectors are frequently selected from municipalities in Sustainable energy and climate actions plans. Table 4 shows exemplary measures implemented in seven municipalities. At European level, measures under the heading "Information campaigns" are one of the most favoured areas of intervention.

The most common tools which the measures rely on include:

— the lately developed: *web based* platforms are the most popular selected way of communication. Several EU MS describe the added value of unifying the topics under one umbrella web. It is also recommended to keep the messages as simple and funny as it can be *(see Austrian Klimaaktiv or the Finnish MOTIVA platforms)*

— the classic: *mass info campaigns*. In general the scope and messages to be communicated are extremely varied. There is a need to tailor-made targeted messages for specific audiences. However, they must target specific areas of society, and the message need to be repeated to be effective. *(see German EnergiEffizienz, or the French "j'éco-réenove, j'économise)*

— based on active communication *on-line tools*: to calculate CO_2 reduction or energy savings estimations.*(see the Belgian "Energy guzzlers tool")*

— *database* containing examples of energy efficiency applications: illustrated examples of energy renovated houses, energy efficient expert list. These kinds of measures targeting users with previous knowledge on the topic may be very effective. (see *the Danish illustrated catalogues)*

— energy days, dedicated moments and spots to specific topics enable to raise the attention of public on themes that may be daily neglected (helpdesk and *info points*).

"Training measures" may have a great impact on community since they target more enthusiastic or empathic audience (students, energy related workers).However, these measures are not very common, because they are more difficult to set and organize, requiring specific skills. Three most common training measures are:

— General training to adults, targeting sectors or general ones

— Education and awareness raising at schools

— Ecodriving, general (adults, students) or professional (drivers, energy related workers) ones.

Table 4. Exemplary information actions at local level

City	**Measure**
Pilea Hortiaris	Pilot demonstrative project on Energy efficiency Measures and RES technologies at a Municipal Schools
Turin	Yearly training courses targeting citizens and municipal employees on energy behaviour
Dublin	Mobility manager & eco driving campaign
Tallinn	Working with citizens and stakeholders program. Advices for the renovation of the residential, tertiary buildings, includes additional thermal insulation and heat and ventilations systems
Larnaka	Bicycle motion day (yearly)
Sonderborg	Network of energy advisors from the construction industry which spreading information about the benefits of the energy renovation through marketing methods which involve direct contact with the homeowner such as: "tupperware" method (small/medium gatherings organized for example in a private home involving the neighbours) and consultancy caravan.
Burgas	Behavioural change for use of private cars; Expanding of parking "blue zone"; Traffic lights "green wave"

- *Source: Rivas et al, 2015* [5] *([10])*

([10]) Rivas et al 2016 "Effective information measures to promote energy use reduction in EU Member States" JRC 100661

2.2 Planning phase

2.2.1 Assessment of the current framework: BEI and RVA outputs

The SECAP should be elaborated based on a sound knowledge of the local situation in terms of energy and greenhouse gas emissions, as well as of climate hazards, vulnerabilities and impacted policy sectors. Therefore, an assessment of the current framework should be carried out.

This includes calculating a CO_2 baseline emission inventory (BEI) and preparing a climate change risk and vulnerability assessment (RVA), which are key CoM commitments. Both the BEI and the RVA have to be included in the SECAP document.

i) The BEI and subsequent inventories are essential instruments that allow the local authority to have a clear vision of the priorities for action, to evaluate the impact of the measures and determine the progress towards the objective. It allows maintaining the motivation of all parties involved, as they can see the result of their efforts. Here are some specific points of attention:

- The BEI has to be relevant to the local situation, i.e. based on energy consumption/production data, mobility data etc. within the territory of the local authority. Estimates based on national /regional averages would not be appropriate in most cases, as they do not allow capturing the efforts made by the local authority to reach its CO_2 targets.
- The methodology and data sources should be consistent through the years.
- The BEI must cover at least the sectors in which the local authority intends to take action to meet the emission reduction target. The following are considered key Covenant sectors as they represent significant CO_2 emission sources in urban environment and can be influenced by the local authority: residential, municipal and tertiary buildings and facilities, and transport.
- The BEI should be accurate, or at least represent a reasonable vision of the reality.
- The data collection process, data sources and methodology for calculating the BEI should be well documented (if not in the SECAP then at least in the local authority's records).

ii) The RVA allows to identify the climate hazard risks which are relevant to your local authority (at present or in the future), to analyse the vulnerabilities (socio-economic and/or physical & environmental) and evaluate the expected impacts by policy sector. Similar to the BEI, the RVA defines the basis for setting the priorities and monitoring progress on adaptation to climate change. To this end indicators related to risks, vulnerability and impact should be calculated using input data which can be available also in future years.

The definition of the emissions inventories and knowledge of the local situation as well as of the future perspectives of the territory are essential for identification of the priority areas of intervention and the selection of relevant measures aimed at reducing CO_2 emissions within the territory. In principle, it is anticipated that most SECAPs will cover the so-called 'key sectors' that are taken into account within the inventory:

- municipal buildings, equipment/facilities;
- tertiary buildings, equipment/facilities;
- residential buildings;
- transport.

Nevertheless, the recommendation is to include all the sectors mentioned above and as many other relevant fields of action as possible, namely:

- local energy production and district heating;
- municipal landfills, waste & wastewater treatment facilities (when present within the territory);
- public lighting;
- land-use planning and urban green spaces;
- industry (if present within the territory);
- public procurement of products and services;
- working with citizens and stakeholders.

In particular, addressing district heating and waste & wastewater treatment facilities (within the territory) is considered important for Eastern Pacific signatories. District heating and cogeneration reduce more emissions of particulates and other local or regional pollutants such as nitrogen oxides and sulphur dioxide compared to individual heating units because the former tend to be much more efficient ([11]). In addition, it is usually much less expensive and more practical to reduce or capture emissions at central heating plants than in small boilers in individual homes. ([12]). Emissions from the decomposition of organic waste (including sewage and residual waters) involve the release of biogas that contains highly emitting gas — methane (CH_4). Therefore, biogas recovery is a good opportunity to contribute to the reduction of GHG emissions. Further information on technical measures can be found in Part III of this Guidebook.

Box 6. Detailed steps for conducting the baseline review

- Select the review team — preferably the inter-sectoral working group.

At this stage you should decide what degree of stakeholder involvement you prefer for this process. As stakeholders generally possess a lot of valuable information, their involvement is highly recommended (see Chapter 2 of this Guidebook on Adapting administrative structures).

- Assign tasks to team members.

- Consider the competencies as well as the availability of each member of the group in order to assign them tasks that they will be able to perform.

- Establish review schedule.

- Indicate realistic start and end date of all data collection activities.

- Identify the most important indicators to be included in the assessment. The following elements should be covered:

- What is the energy consumption and CO_2 emissions of the different sectors and actors present in the territory of the local authority, and what are the trends? (See Part II).

- Who produces energy and how much? Which are the most important sources of energy? (See Part II).

- What are the drivers that influence energy consumption?

- What are the impacts associated with energy consumption in the city (air pollution, traffic congestion, etc.)?

([11]) See *COMING IN FROM THE COLD: Improving District Heating Policy in Transition Economies*, published by the International Energy Agency (http://www.iea.org/.

- What efforts have already been made in terms of energy management and what results have they produced? Which barriers need to be removed?

- Which barriers need to be removed?

- What is the degree of awareness of officials, citizens and other stakeholders in terms of energy conservation and climate protection?

In Annex, we provide a table with more detailed specifications of the aspects that could be covered in the assessment.

- Collect the baseline data.

This requires the collection and processing of quantitative data, the establishment of indicators, and the gathering of qualitative information using document review and interviews/workshops with stakeholders. The selection of datasets needs to be based on criteria that are agreed on with stakeholders, who will be actively involved in contributing data. Part II of this Guidebook provides guidance for the collection of data related to energy consumption.

- Compile the CO_2 Baseline Emission Inventory based on energy data.

Based on energy data, the CO_2 BEI can be compiled (see Part II of this Guidebook). - Analyse the data in order to inform policy. It is not enough just to collect data: data needs to be analysed and interpreted in order to inform policy. For example, if the baseline review shows that energy consumption is increasing in a specific sector, try to understand why it is so: population increase, increased activity, increased usage of some electrical devices, etc. - Write the self-assessment report — be honest and truthful; a report that does not reflect reality serves no purpose. The baseline review can be carried out internally within the local authority as a self-assessment process, but combining the self-assessment with an external peer review can add additional value to the process. Peer review offers an objective third-party review of achievements and future prospects. Peer reviews can be carried out by external experts who work in other cities or organisations in similar fields of expertise. It is a cost-effective method and often a more politically acceptable alternative to consultants.

Table 5. Suggestion of aspects to be covered in BEIs and in the RVA

SCOPE	KEY ASPECTS FOR ASSESSMENT
Energy structure and CO_2 emissions	Level and evolution of energy consumption and CO_2 emissions by sector and by energy carrier (see part II). Global and per capita.
Renewable energies	Typology of existing facilities of production of renewable energies Renewable energy production and trends Use of agricultural and forest biomass as renewable energy sources Existence of bio-energetic crops Degree of self-supplying with renewable energies Potentialities for renewable energy production: solar thermal and photovoltaic, wind, mini-hydraulics, biomass, others

SCOPE	KEY ASPECTS FOR ASSESSMENT
Energy consumption and energy management in the local administration	Level and change in the energy consumption of the local administration by sector (buildings and equipment, public lighting, waste management, waste water treatment, etc.) and by energy carrier (see Part II) Assessment of the energy efficiency of buildings and equipment using efficiency indexes of energy consumption (for example: kWh/m^2, kWh/m^2 • user, kWh/m^2 hours of use). This allows identifying the buildings where there are more improvement potentialities. Characterisation of the largest energy consumers among municipal buildings and equipment/facilities. Analysis of key variables (for instance: type of construction, heating, cooling, ventilation, lighting, kitchen, maintenance, solar hot water, implementation of best practices …) Assessing the types of lamps, lighting and energy-related issues in public lighting. Assessment of energy efficiency using efficiency indexes of energy consumption. Degree and adequacy of energy management in public buildings/equipment and public lighting (including energy accounting and audits) Established initiatives for improving energy saving and efficiency and results obtained to date Identification of potentialities for improvement in energy savings and efficiency in buildings, equipment/facilities and public lighting.
Energy consumption of the municipal fleet	Evaluation of the composition of the municipal fleet (own vehicles and of externalised services), annual energy consumption (see Part II) Composition of the urban public transport fleet, annual energy consumption Degree of the energy management of the municipal fleet and public transport Established initiatives for improving reducing energy consumption and results obtained to date Identification of potentialities for improvement in energy efficiency
Energy infrastructures	Existence of electricity production plants, as well as district heating/cooling plants Characteristics of the electricity and gas distribution networks, as well as any district heat/cold distribution network Established initiatives for improving energy efficiency of the pants and of the distribution network and results obtained to date Identification of potentialities for improvement in energy efficiency

SCOPE	KEY ASPECTS FOR ASSESSMENT
Buildings	Typology of the existing building stock: usage (residential, commerce, services, social…), age, thermal insulation and other energy-related characteristics, energy consumption and trends (if available, see Part II), protection status, rate of renovation, tenancy, … Characteristics and energy performance of new constructions and major renovations What are the minimal legal energy requirements for new constructions and major renovations? Are they met in practice? Existence of initiatives for the promotion of energy efficiency and renewables in the various categories of buildings What results have been achieved? What are the opportunities?
Industry	Importance of industry sector in the energy balance and CO_2 emissions. Is it a target sector for our SECAP? Existence of public and private initiatives address to promote energy saving and efficiency in industry. Key results achieved. Degree of integration of energy/carbon management in industry businesses? Opportunities and potentialities on energy saving and efficiency in industry
Transport and mobility	Characteristics of the demand of mobility and modes of transport. Benchmarking and major trends. What are the main characteristics of the public transportation network? Degree of development and adequacy? How is the use of public transportation developing? Are there problems with congestion and/or air quality? Adequacy of public space for pedestrians and bicycles. Management initiatives and mobility planning. Initiatives to promote public transport, bicycle and pedestrian.
Urban planning	Characteristics of existing and projected "urban spaces", linked to mobility: urban density, diversity of uses (residential, economic activity, shopping, ...) and building profiles. Degree of dispersion and compactness of urban development. Availability and location of the main services and facilities (educational, health, cultural, commercial, green space, ...) and proximity to the population. Degree and adequacy of integration of energy-efficiency criteria in urban development planning Degree and adequacy of integration of sustainable mobility criteria in urban planning.

SCOPE	KEY ASPECTS FOR ASSESSMENT
Public procurement	Existence of a specific policy commitment on green public procurement. Degree of implementation of energy and climate change criteria in public procurement. Existence of specific procedures, usage of specific tools (carbon footprint or others).
Awareness	Development and adequacy of the activities of communication and awareness to the population and stakeholders with reference to energy efficiency. Level of awareness of the population and stakeholders with reference to energy efficiency and potential savings. Existence of initiatives and tools to facilitate the participation of citizens and stakeholders in the SECAP process and the energy and climate change policies of the local authority.
Skills and expertise	Existence of adequate skills and expertise among the municipal staff: technical expertise (energy efficiency, renewable energies, efficient transport …), project management, data management (lack of skills in this field can be a real barrier!), financial management and development of investment projects, communication skills (how to promote behavioral changes etc), green public procurement...? Is there a plan for training staff in those fields?

Source: Methodology Guide for the revision of the Local Agenda 21 Action Plans in the Basque Country – UDALSAREA21 (Basque Network of Municipalities for Sustainability)

2.2.2 Establishment of the vision - setting mitigation target and indication of adaptation goals

The SECAP document must contain a clear reference to the core emission reduction commitment taken by the local authority when signing the Covenant of Mayors. Contrary to the recommendation indicated in the SECAP Guidebook for the European countries, in the case of the Eastern Partnership signatories the use of a recent baseline year is highly recommended.

The main reason is that local authorities often have difficulties in retrieving reliable data to compile an inventory for 1990. Also, in the light of continued market transition and dynamic evolution in the Eastern European counties, 1990 is often non-reflective of the recent energy consumption trends or economic indicators. An additional reason for avoiding the choice of an early year as the baseline might appear for signatories who want to include industries in their SECAPs, as most of the post-Soviet countries have experienced an economic downturn in the 1990s. Hence, those industrialisation levels cannot be related to the current ones.

The local authority should choose the closest year for which the most comprehensive and reliable data can be collected. The overall CO_2 reduction commitment has to be translated into concrete actions and measures together with the CO_2 reduction estimates in tons/year by 2030. For the local authorities that have a longer term CO_2 reduction target (for example by 2050) they should set an intermediary target by 2030 (30% as a minimum) for the reasons of comparability. In addition to the mitigation commitment, adaptation goals should be specified and should be coherent with the identified risks and hazards.

The SECAP must contain a clear reference to the signatory's own core commitment for a reduction of CO_2 emissions by 2030. This commitment needs to be at least 30 % and based on reference levels, which are defined on the basis of a BEI.

The use of a BAU scenario was the main customized provision envisaged for the Eastern Pacific signatories of the CoM. It aims to allow those municipalities that are on a rapid economic growth path to develop their economies in a sustainable manner. It is therefore foreseen that such signatories will see their GHG emissions increase over the years, but it is expected that they will limit such increase as much as possible through the implementation of adequate energy policies and climate protection measures.

The signatories from the Eastern Partnership and central Asian countries have three options to set their GHG emissions reductions target, in a fixed level target (i.e. BEI it can be set as absolute and/or per capita) while in BAU projection (only absolute target).

— Setting the target on the basis of the BEI:

  - as an absolute reduction, compared to the overall emissions accounted in the BEI (referring to tonnes of CO_2 or tonnes of CO_2-equivalent (CO_2-eq.));
  - as a per capita reduction, compared to the total per capita emissions accounted in the BEI (referring to tonnes of CO_2 per capita or tonnes of CO_2-eq. per capita). The per capita option allows signatories to take into account both a sharp decrease and a sharp increase in population within their territory. In case of a strong decrease in population over the years, the signatory is highly recommended to choose a per capita objective.

— Setting the target on the basis of a BAU scenario, calculated starting from the results of the BEI and foreseeing CO_2 emissions for the territory of the local authority in 2030 (referring to tonnes of CO_2 or tonnes of CO_2-eq.). When preparing a BAU scenario, Eastern Partnership signatories have two options:

  - Develop their own approach, whose technical and scientific soundness will be analysed by the Joint Research Centre (JRC).
  - From open source information, several emissions projection tools and instruments for energy policy analysis and climate mitigation assessments are available. For example, the city of Tbilisi has developed its BAU scenario using the LEAP tool (Long range Energy Alternatives Planning System) ([13]). However, each municipality is free to develop its own approach if human resources, and financial and technical capabilities allow for it.
  - Use the national coefficients developed by the JRC, and provided in the Part II of this Guidebook. These were developed using the Emission Database for Global Atmospheric Research (EDGAR) within the CIRCE project [8] [9]. The POLES method (Prospective Outlook for the Long term Energy Systems) [10]) that considers energy consumption increase due to population and economic growth was also employed. Starting from present data, the BAU scenario projects the evolution of energy and emissions levels until 2030, under the hypothesis of continuing current trends in population, economy, technology and human behaviour, without the implementation of a SECAP or any other national or local policy measures.

The soundness of the BAU scenario should be monitored by the signatories themselves as well as by the JRC at least once before the year 2030. This is to allow for evaluation of the reliability of the principles on which basis the BAU projections were made. In the event that this assessment highlights a strong deviation between BAU predictions and the actual situation, the actions and measures foreseen by the SECAP should be revised and an adjustment of the political target might become advisable.

([13]) For more information, see *Long range Energy Alternatives Planning System: An Introduction to LEAP*, 2008 (http://www.energycommunity.org/documents/LEAPIntro.pdf).

2.2.3 Elaboration of the plan - Strategies and set of actions until 2030

The climate action plan must contain a clear outline of the strategic actions that the local authority intends to take in order to reach its commitments in 2030. It has to contain:

- The long-term strategy and goals until 2030, including firm commitments in areas like land-use planning, transport and mobility, public procurement, standards for new/renovated buildings etc.
- Detailed measures for the next 3-5 years which translate the long-term strategy and goals into actions. For each measure/action, it is important to provide a description, the responsible body, the timing (start-end, major milestones), the cost estimation and financing/source, the indicators for monitoring. In addition, for mitigation actions the following should also be indicated: estimated energy saving/increased renewable energy production and associated estimated CO_2 reduction. For the key adaptation actions, the stakeholders involved, the risk and/or vulnerability tackled and the outcome reached should also be specified.
- The commitment taken by the signatories concerns the reduction of the CO_2 emissions in their respective territories. Therefore, the SECAP has to contain a coherent set of mitigation measures covering possibly all the Covenant key sectors of activity: not only the buildings and facilities that are managed by the local authority, but also the sectors of activity in the territory of the local authority: residential sector, tertiary sector, public and private transport. Before starting the elaboration of actions and measures, the establishment of a long-term vision with clear objectives is highly recommended.
- The adaptation strategy should be part of the SECAP and/or developed or mainstreamed in separate documents. Based on recognised local risks and vulnerabilities, the local authority should identify actions aimed at enhancing local adaptive capacity to respond to climate change impact. The key actions should address the hazards producing a high level of risk. Mitigation actions should be looked at through a climate change lens, to understand if they are vulnerable to the impacts of climate change and/or they can influence the vulnerability of natural and human systems to climate change. The SECAP guidebook contains many suggestions of policies and measures that can be applied at the local level.

Additional resources

- Benchmarks of Excellence (BoEs) submitted by Covenant signatories can represent useful examples of implemented actions by Covenant Signatories, Coordinators and Supporters:http://www.eumayors.eu/actions/benchmarks-of-excellence_en.htmlhttp://www.eumayors.eu/Coordinators-and-Supporters-Benchmark-of-Excellence.html

2.2.4 Comprehensive measures that cover the key sectors of activity

The core part of the SECAP relates to the policies and measures that will allow reaching the objectives that have been previously set (see Part 3.a. and Part 3.b.).

SECAP elaboration is only one step in the overall process and it should not be considered as an objective in itself, but rather as a tool that allows to:

- Outline how the city will look like in the future, in terms of energy, mobility, resilience
- Communicate and share the plan with the stakeholders
- Translate this vision into practical actions assigning deadlines and a budget for each of them
- Serve as a reference during the implementation and monitoring process.

Also remind that the work does not finish after drafting the SECAP and its formal approval. On the contrary, this moment should be the start of the concrete work of putting the planned actions into reality. A clear and well-structured SECAP is essential for this (i.e. all actions should carefully be designed and described properly, with timing, budget, sources of financing and responsibilities, etc.).

Part III of this guidebook will provide you with useful information in order to select and devise adequate policies and technical measures for your SECAP. Adequate policies and measures are dependent on the specific context of each local authority. Therefore, defining measures that are suited to each context is also highly dependent on the quality of the assessment of the current framework.

Here is a list of recommended steps for drafting a successful SECAP:

— Make a prospective of best practices: In addition to the resources on policies and measures provided in this guidebook, it may be useful to identify what best practices (successful examples) have delivered effective results in similar contexts in reaching similar targets and objectives than those set by the municipality, in order to define the most appropriate actions and measures. On the Covenant of Mayors' website you can consult the Benchmarks of Excellence (BoEs) submitted by Covenant signatories, i.e. actions which have successfully been implemented and that have led to significant benefits.

— Set priorities and select key actions and measures: Different kinds of actions and measures may contribute to the achievement of the objectives. Undertaking the entire list of possible actions will often surpass the current capabilities of the local authority, in terms of costs, project management capacities, etc. In addition, some of them may be mutually exclusive. This is why an adequate selection of actions in a given time horizon is necessary. At this stage a preliminary analysis of the possible actions is necessary: what are the costs and benefits of each of them (even in qualitative terms).

To facilitate the selection of measures, the local authority may rank the possible measures by importance in a table summarising the main characteristics of each action: duration, level of required resources, expected results, associated risks, etc. The actions may be broken down in short-term actions (3-5 years) and long-term actions (towards 2030).

Specific methods for the selection of priorities are available ([14]). In simple terms, you should:

- define which criteria you want to consider for the selection of measures (investment required, energy savings, employment benefits, improved air

([14]) See for example http://www.energymodel.eu/IMG/pdf/IL_6_-_Priorities.pdf quality, relevance to the overall objectives of the local authority, political and social acceptability …)

- decide which weight you give to each criterion
- evaluate each criterion, measure by measure, in order to obtain a "score" for each measure
- If necessary, repeat the exercise in the context of various scenarios in order to identify the measures whose success is not scenario-dependent.

Such an evaluation is a technical exercise, but it has definitely a political dimension, especially when selecting the criteria and their respective weighting. Therefore, it should be carried out in a careful manner, and be based on relevant expert and stakeholders' opinion. It may be useful to refer to various scenarios.

— Carry out a risk analysis [11]

The selection of actions and measures should also be based on the careful estimation of risks associated with their implementation (especially when significant investments are planned): how likely is it that an action fails or does not bring the expected results? What will be the impact on the objectives? And what are the possible remedies?

Risks can be of different nature:

- Project-related risks: cost and time overruns, poor contract management, contractual disputes, delays in tendering and selection procedures, poor communication between project parties…
- Government-related risks: inadequate approved project budgets, delays in obtaining permissions, changes in Government regulations and laws, lack of project controls, administrative interference…
- Technical risks: inadequate design or technical specifications, technical failures, poorer than expected performance, higher than expected operation costs…
- Contractor-related risks: inadequate estimates, financial difficulties, delays, lack of experience, poor management, difficult in controlling nominated subcontractors, poor communication with other project parties, etc.
- Market-related risks: increase in wages, shortages of technical personnel, materials inflation, shortage of materials or equipment, and variations in the price of the various energy carriers…

Risks may be assessed using conventional quality management techniques. Finally, remaining risks have to be evaluated and either accepted or rejected.

— Specify timing, clear responsibilities, budget and financing sources of each action

Once the actions have been selected, it is necessary to plan them carefully so that they can become a reality. For each action, specify:

- the timing (start date – end date)
- the body responsible for implementation
- the stakeholders involved (only for adaptation actions)
- the risk and /or vulnerability tackled (only for adaptation actions)
- the estimated cost
- the modality of financing: as municipality resources are scarce, there will always be competition for available human and financial resources. Therefore, efforts should be continuously made to find alternative sources of human and financial resources (see Part IIIC).

- the estimated impacts in terms of energy savings, energy production, CO_2 emission reduction
- the modality of monitoring: identify data and indicators to monitor progress and results of each action. Specify how and by whom the data will be collected, and who will compile it.

To facilitate implementation, complex actions could be broken down into simple steps, each of them having its own timing, budget, person responsible, etc.

— Draft the Action Plan

At this stage, all the information should be available to complete the SECAP. Approve the Action Plan and its associated budget

Formal approval of the SECAP by the municipal council is a mandatory requirement of the Covenant. In addition, the local authority should allocate the necessary resources in the annual budget and whenever possible make commitments for the forward (3-5 year) planning budget.

— Perform regular SECAP reviews

Continuous monitoring is needed to follow SECAP implementation and progresses towards the defined targets in terms of energy / CO_2 savings, and eventually to make corrections. Regular monitoring followed by adequate adaptations of the plan allows initiating a continuous improvement cycle. This is the "loop" principle of the project management cycle: Plan, Do, Check, Act. It is extremely important that progress is reported to the political leadership. SECAP revision could for example occur every second year, after the implementation report has been submitted (mandatory as per the Covenant of Mayors' commitments).

2.3 Implementation phase

2.3.1 Implementation of the SECAP

The implementation of the SECAP is the step that takes the longest time, efforts and financial means. This is the reason why mobilisation of stakeholders and citizens is critical. Whether the SECAP will be successfully implemented or will remain a pile of paperwork depends to a high extent on the human factor. The SECAP needs to be managed by an organisation that supports people in their work, where there is an attitude of ongoing learning, and where mistakes and failures are opportunities for the organisation and individuals to learn. If people are given responsibility, encouragement, resources and are motivated, things will happen:

— Provide long-term political support to the SECAP process.

— Make sure that the energy and climate policy is integrated in the everyday life of the local administration.

— Show interest in the plan implementation.

— Encourage stakeholders to act, show by example.

— Networking with other CoM signatories, exchanging experience and best practices, establishing synergies and encouraging their involvement in the Covenant of Mayors.

— Human and financial resources.

In the line of provision of long-term political support to the SECAP process it is recommended to add a reference or link to the EaP countries' national reporting commitments under the UNFCCC and the Paris Agreement, to stress importance of municipal action plans in the context of national commitments under international initiatives and treaties. Particular attention can be paid to Measuring Reporting and

Verification process as tracking tool for implementation of the Paris Agreement by countries. During the implementation phase, it will be essential to ensure both good internal communication (between different departments of the local authority, the associated public authorities and all the persons involved) as well as external communication (with citizens and stakeholders). This will contribute to awareness-raising, increase the knowledge about the issues, induce changes in behaviour, and ensure wide support for the whole process of SECAP implementation.

Box 7 Some tips to put a SECAP into practice

- Adopt a Project Management approach: deadline control, financial control, planning, deviations analysis and risk management. Use a quality management procedure.
- Divide the project into different parts and select persons responsible.
- Prepare specific procedures and processes aimed at implementing each part of the project. A quality system is a useful tool to make sure that procedures are in accordance with the objectives.
- Establish a score-card system for tracking and monitoring your plan. Indicators such as percentage of compliance with deadlines, percentage of budget deviations, percentage of emissions reduction with the measures already implemented and other indicators deemed convenient by the local authority may be proposed.
- Plan the follow-up with the stakeholders establishing a calendar of meetings in order to inform them. Interesting ideas could arise during these meetings or possible future social barriers could be detected.
- Anticipate future events and take into account negotiation and administrative steps to be followed by the Public Administration to start a project. Public projects usually require a long time to obtain authorisation and approvals. In this case, a precise planning including security factors is convenient mainly at the beginning of the SECAP implementation.
- Propose, approve and put into operation a training programme at least for those persons directly involved in the implementation.
- Motivate and offer training and support to your team. Internal people are important stakeholders.
- Inform frequently the city council (or equivalent body) and politicians in order to make them an important part of successes and failures and get their commitment.
- Some measures proposed in the SECAP may need to be tested before a massive implementation. Tools such as pilot or demonstration projects can be used to test the suitability of these measures.

SECAP elaboration and implementation require human and financial resources. Local authorities may adopt different approaches:

— Using internal (in-house) resources, for example by integrating the tasks in (an) existing department(s) of the local authority involved in energy- and climate-related topics (e.g. local Agenda 21 office, environmental and/or energy department).

— Setting up a new unit within the local administration (approx. 1 person/100,000 inhabitants).

— Outsourcing (e.g., private consultants, city-networks, universities …).

— Getting support from local regional and national energy agencies (LAREAs) or Covenant Territorial Coordinators ([15]) (CTCs).

In addition, local authorities may consider developing a joint SECAP in coordination and collaboration with their neighbouring municipalities.

Note that the human resources allocated to the SECAP may be highly productive from a financial point of view, via savings on the energy bills, access to funding for the development of projects in the field of EE and RES. In addition, extracting as much as possible resources from inside offers the advantages of a higher ownership, saves costs and supports the very materialisation of a SECAP. Adequate training should also be offered to officers dealing with SECAP elaboration and implementation. The plan should identify the key financing resources that will be used to finance the actions.

2.4 Monitoring and reporting phase

2.4.1 Monitoring progress

Monitoring is a very important part of the SECAP process. Regular monitoring followed by adequate adjustments of the plan allows initiating a continuous improvement of the process.

Monitoring of progress and energy/CO_2 savings should be an integral part of SECAP implementation (see next chapter). Networking with other signatories developing or implementing a SECAP, will provide additional value towards meeting the 2030 targets by exchanging experience and best practices, and establishing synergies. Networking with potential CoM signatories, and encouraging their involvement in the Covenant of Mayors is also recommended. Liaising with Regions and Provinces who could become Territorial Coordinators and/or with LAREAs could also help municipality receive more support in the development and implementation of a SECAP.

Regular monitoring using relevant indicators allows to evaluate whether the local authority is achieving its targets, and to adopt corrective measures if necessary. Signatories are therefore committed to submit an 'Action Report' **every second year** following the submission of the SECAP.

At least every fourth year after SECAP submission this report has to be complemented by a Monitoring Emission Inventory (MEI). If a signatory chooses to set its objective on the basis of a Business As Usual (BAU) scenario, the soundness of the hypotheses lying behind its definition should be checked at least once before 2030. Moreover, the SECAP itself should contain a brief outline on how the local authority intends to ensure the follow-up of the actions and monitor the results.

2.4.2 Reporting requirements

Covenant signatories commit to submitting their SECAPs within two years following adhesion. The SECAP document must be uploaded in national language (or in English) via the Covenant of Mayors' website. Signatories are required, at the same time, to fill in an online SECAP template in English.

This will allow 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. Dedicated monitoring templates are available to report on the SECAP implementation. The template has to be filled carefully with sufficient level of detail, and should reflect the content of the SECAP, which is a politically approved document. Specific reporting guidelines are available on the Covenant website. The steps of the reporting requirements are summarised in box below.

([15]) Covenant Coordinators (roles, list): https://www.covenantofmayors.eu/about/covenant-community/coordinators.html

Box 8 Steps of the reporting requirements

- Committing to address climate change mitigation and adaptation
- Completing a Baseline Emission Inventory (BEI) and Risk and Vulnerability Assessment (RVA)
- Setting a mitigation target for 2030 and adaptation goals
- Redaction of a Sustainable Energy and Climate Action Plan (SECAP)
- Implementation, monitoring of the SECAP and reporting the progress

Moreover, the template is a valuable tool that provides visibility to the SECAP and facilitates its assessment, as well as the exchange of experience among the Covenant signatories. Highlights of the information collected will be shown on-line on the Covenant of Mayors website (http://www.covenantofmayors.eu/).

The Russian version of the CoM website can be accessed through www.com-east.eu online. The SECAP template is available on-line as an internet-based tool that the Covenant signatories are required to fill in themselves. A public copy of the SECAP template and supporting instructions document are available in the library sections of the Covenant of Mayors websites: in Russian and English

As mentioned before, CoM signatories commit to submitting a "Monitoring Report" every second year following the submission of the SECAP "for evaluation, monitoring and verification purposes". Such report should include an updated monitoring emission inventory (MEI), developed according to the same methods and data sources of the BEI to ensure comparability. Local authorities are encouraged to compile CO_2 emission inventories on an annual basis (see part II). However, if the local authority considers that such regular inventories put too much pressure on human or financial resources, it may decide to carry out the inventories at larger intervals. But local authorities are required to compile a MEI and report on it at least every fourth year, which means carrying out alternatively every 2 years an "**Action Reporting**" – without MEI" - (years 2, 6, 10, 14…) and a "**Full Reporting**" – with MEI (years 4, 8, 12, 16…). For each type of reporting, specific templates are available on the Library of the Covenant of Mayors' website at http://www.eumayors.eu/Covenant-technical-materials.html.

The **Action Reporting** contains mostly qualitative information about the implementation of the SECAP, including barriers encountered during the implementation, status of implementation of each action, etc. The **Full Reporting**, through the MEI, allows analysing the evolution in terms of energy consumption, energy production and CO_2 emissions compared to the BEI: this way it provides a deeper understanding of the results delivered by the SECAP and allows defining corrective and preventive measures when this is required.

The monitoring exercise should be regarded by the Municipal council and by the local administration as an opportunity to reconsider the strategy and the actions of the SECAP in light of the progress achieved, of new available knowledge and expertise, of the latest technological or financial opportunities for sustainable energy projects and/or for adaptation action. The SECAP should indeed be considered as a living document and not as a static one, as it should be periodically adjusted to improve its effectiveness.

Although it is not mandatory, the local authority is encouraged to draft also a monitoring report (in national language) and have it approved by the Municipal Council to ensure transparency and accountability. This monitoring report could be used to reinforce communication towards citizens and stakeholders, keeping them informed on progress achieved, barriers encountered, opportunities, possible need for corrective measures, etc.

As previously mentioned, some indicators are needed in order to assess the progress and performance of the SECAP. Even if a monitoring and reporting document will be published further on, some indicators are suggested in this Guidebook to give an orientation on the type of monitoring parameters that may be used (Annex 1).

Additional resources

— The CoM Quick Reference Guides to monitoring touches on why monitoring is important, how to carry out the monitoring process, tips for success, what to report to the Covenant and the minimum Covenant reporting requirements.

— The Covenant of Mayors for Climate and Energy reporting guidelines contain examples of indicators for mitigation and adaptation

— http://www.covenantofmayors.eu/IMG/pdf/Reporting_Guidelines_Final_EN.pdf

Part II. Baseline Emission Inventory (BEI) and Risk and vulnerability assessment (RVA)

Part 2.a. Guidance on Baseline Emission Inventory (BEI)

The Baseline Emissions Inventory (BEI) quantifies the amount of carbon dioxide (CO_2) emitted due to energy consumption occurring mainly in stationary and mobile sources (i.e. buildings and transport CoM macro-sectors) as well as GHG emissions related to non-energy sectors such as waste and wastewater management.

In the territory of the local authority (i.e. Covenant signatory) ([16]) in the baseline year. It allows for identification of the principal anthropogenic sources of CO_2 emissions and to prioritise the reduction measures accordingly. The local authority may include also methane (CH_4) and nitrous oxide (N_2O) emissions in the BEI. Inclusion of CH_4 and N_2O depends on whether measures to reduce these greenhouse gases (GHGs) also are planned in the Sustainable Energy and Climate Action Plan (SECAP), and also on the emission factor approach chosen (standard or life cycle assessment (LCA)). For simplicity, we mainly refer to CO_2 in these guidelines, but it can be understood to also mean other GHGs like CH_4 and N_2O in the case that the local authority includes them in the BEI and SECAP in general.

Elaborating a BEI is of critical importance. This is because the inventory will be the instrument allowing the local authority to measure the impact of its actions related to climate change. The BEI allows for provision of a reference base year from which changes in emissions and in particular reductions will be monitored in view of achieving the local authority's objective of CO_2 reduction. Emission inventories are very important elements to maintain the motivation of all parties willing to contribute to the local authority's CO_2 reductions objective, allowing them to see the results of their efforts.

The overall CO_2 reductions target of the Covenant of Mayors (CoM) signatories is at least 30 % reduction by 2030 achieved through the implementation of the SECAP for those areas of activity relevant to the local authority's mandate. The reduction target is defined in comparison to the baseline year that is set by the local authority. The local authority can decide to set the overall CO_2 emissions reductions target either in relation to a baseline year / BEI (as 'absolute reduction' or 'per capita reduction') or on the basis of a reference scenario called business-as-usual (BAU).

According to the principles laid out in the CoM, each signatory is responsible for the emissions occurring due to energy consumption in its territory. Therefore, emission credits bought or sold on the carbon market do not intervene in the BEI/ Monitoring Emissions Inventory (MEI). However, this does not prevent signatories from using carbon markets and related instruments to finance their SECAP measures.

The BEI quantifies the emissions that occurred in the baseline year. In addition to the inventory of the baseline year, emission inventories will be compiled in later years to monitor progress towards the target. Such an emission inventory is called a MEI. The MEI will follow the same methods and principles as the BEI. The acronym BEI/MEI is used when describing issues that are common for both inventories. Specific instructions for monitoring SECAP implementation will be published further on.

In these guidelines, advice and recommendations for compiling a BEI/MEI under the CoM are presented. Some of the definitions and recommendations are unique to the inventories under the CoM in order to enable the inventories to demonstrate the progress being made towards the target of the Covenant.

However, as far as possible, the concepts, methodologies and definitions in internationally agreed standards are followed in these guidelines. For example, the local authority is encouraged to use emission factors that are in line with those of the Intergovernmental Panel on Climate Change (IPCC) or European Reference Life Cycle Database (ELCD). However, the local authority is given the flexibility to use any approach or tool that it considers appropriate for the purpose.

([16]) 'territory of the local authority' refers to the geographical area within the administrative boundaries of the entity governed by the local authority.

The results of the BEI are reported by using the online SECAP template available at www.com-east.eu online. The site and the template are available in Russian and in English. Many other related documents such as the instructions on how to fill in the template and also a Microsoft® Excel version of the template are available online in several languages.

This Guidebook is tailored to the specific needs of the Eastern Partnership countries, which are still recovering from economic reform. As such, various specific indicators were calculated for the 6 Newly Independent States (NIS) and a BAU scenario was developed projecting the growth of their economy, and the increase in CO_2 emissions for 2030 as a result of a 'do nothing' stance in terms of policies and the environmental regulations scenario. Some adaptations were agreed in order not to hinder the development of the local emerging economies but to ensure their sustainable development. This is the main reason why, specifically for these countries, the option to set the emission target based on a BAU scenario for 2030 was added.

Yet, some references to European regulations and in particular definitions used in the European Union (EU) were maintained as an alignment or common orientation for the authorities of the different countries with very heterogeneous characteristics of the energy market and of the energy and environment regulations. In particular, in the case of an absence of terminology or definitions in some countries, these orientation lines serve to fill the eventual gaps of the national framework.

3. The Covenant of Mayors approach

3.1 Key concepts

In the compilation of the emission inventories and their on-line reporting ([17]) 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).
- 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 ([18])
- 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.
- Activity data: Activity data quantifies the human activity occurring in the local territory. The main activity data in the CoM key sectors 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
- Emission inventories: Emission inventories quantify the amount of CO2 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 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 baseline year. It allows to identify the principal anthropogenic sources of CO_2 (and other GHGs) emissions and to prioritise the reduction measures accordingly.

([17]) http://www.eumayors.eu
([18]) 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

— 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. 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.

3.2 Boundaries, scope and sectors

The geographical boundaries of the BEI/MEI are the administrative boundaries of the local authority. The BEI will essentially be based on final energy consumption, including both municipal and non-municipal energy consumption in the local authority's territory. However, those other than energy-related sources may also be included in the BEI.

The BEI quantifies the following emissions that occur in the territory of the local authority.

a) Direct emissions due to fuel combustion within the territory in the buildings, equipment/facilities and transportation sectors.
b) Indirect emissions related to the production of electricity, heat or cold that are consumed within the territory according to the specificity of the heat and power grid mix.
c) Other direct emissions, not related to energy consumption that occur within the territory, depending on the choice of BEI sectors.

Points a) and c) above quantify the emissions that physically occur within the territory. Inclusion of these emissions follows the principles of the IPCC used in the reporting of the countries to the UNFCCC and its Kyoto Protocol ([19]).

As explained in point b) above, the emissions due to production of electricity, heat and cold consumed within the territory are included in the inventory regardless of the location of the production (inside or outside of the territory) ([20]).

The same principles apply regardless of the approach chosen (IPCC or LCA), only that within the LCA approach the indirect emissions related to the supply chain of the energy carrier are also taken into consideration. Yet, this is done exclusively through the emission factor chosen for each energy carrier. The definition of the scope of the BEI/MEI ensures that all the relevant emissions due to energy consumption within the territory are included, but no double counting takes place. Emissions other than those that are related to fuel combustion can be included in the BEI/MEI. However, their inclusion is voluntary because the main focus of the Covenant is the energy sector, and the importance of emissions other than energy-related emissions may be small in the territories of many local authorities.

3.3 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

([19]) They are comparable with 'scope 1 emissions'; for example, in the methodology of the International Local Government Greenhouse Gas Emissions Analysis Protocol (IEAP) (ICLEI, 2009) and The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard (WRI/WBCSD, 2004). However, a major difference is that not all emissions occurring within the territory are included; for example, emissions of large power and industrial plants are excluded.

([20]) Such emissions are often referred to as 'scope 2' emissions; for example, in the methodology of ICLEI (2009) and WRI/WBCSD (2004).

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.

3.3.1 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, the baseline year is recommended not be later than 2005.

The year 2005, which is the reference which has been the most commonly used by CoM 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 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.

3.3.2 Emission inventory approach

Greenhouse gas direct and indirect emissions are calculated for each energy carrier by multiplying final energy consumption by the corresponding emission factor. 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 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. 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.

The LCA approach is applied by CoM signatories in some 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 ([21]).

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 [12].

([21]) In these guidelines, biofuel refers to all liquid/gaseous biofuels and biomass to solid biomass.

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.

3.3.3 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.

3.3.4 Emission factors (EF)

After selecting the emission inventory approach, the local authority can either use local emission factors or default (national/global) emissions factors, such as the IPCC (2006) and the CoM default emission factors provided in this Guidebook. 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. 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 ([22]).
- 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

([22]) http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol2.html

CoM default/national/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.

3.3.5 Target setting

The local authority can decide to set the overall CO_2 emissions reductions target either in relation to the base year (as 'absolute reduction' or 'per capita reduction') or in relation to a BAU scenario. The local authority is encouraged to report on the choice in the inventory report.

Table 6. Types of target setting

2030 target basis	GHG reductions target
Base year levels	Absolute Per capita
2030 BAU projection levels	Absolute

- **Setting the target on the basis of the BEI results.**

The GHG reductions target can be set as an 'absolute' percentage or a 'per capita' target of at least 30 % from the results reported in the BEI.

The 'per capita' option is recommended when the scenarios until 2030 show either a sharp decrease or a sharp increase of population within the territory of the local authority. In the case of a strong decrease of population over the years, it is highly recommended that the local authority choose a 'per capita' objective.

Despite the choice, the emissions in the BEI are first calculated as absolute emissions. In case the 'per capita' reduction is chosen, the emissions of the baseline year are divided by the number of inhabitants in the same year, and these 'emissions *per capita* in the baseline year' are used as a basis for calculation of the target.

Even if the authority might find it useful to present the results of the BEI/MEI as 'per capita' in the official SECAP document, in the **online template used for reporting**, it is strongly recommended to use the **absolute values** both for the inventory part and for the SECAP part.

- **Setting the target on the basis of a BAU scenario.**

The business-as-usual (BAU) scenario indicates that no or just actual measurements are taken into account for the future emission trends and that world energy consumption will be more than doubled in the 2000-2050 period.

The national coefficients provided in **Table 44**, which also account for the urbanization level of the country, have to be applied by local authorities to the BEI inventories in order to estimate their 2030 CO2 and GHG emissions.

The local authority has the option to calculate its final target starting from the results of the BEI and foreseeing CO_2 emissions for the territory of the local authority in 2030 (referring to t CO_2 or t CO_2-eq.) ([23]) using a BAU scenario. When preparing a BAU scenario, the local authority has two options.

- Develop its own approach (whenever this option is chosen a reference to the tool/methodology used should be provided in the SECAP document and in the

([23])The possibility of setting the reduction target using a BAU scenario is characteristic for the CoM Eastern Partnership and Central Asian countries. It has the aim of allowing those municipalities that are on a rapid economic growth path to develop their economies in a sustainable manner.

SECAP online template and a short description of the methodology should be included in the SECAP document) ([24]).

- Use the national coefficients for each country.
- The above mentioned national coefficients were calculated by the JRC based on a BAU scenario developed for each of the countries participating in the Eastern Partnership countries. Starting from present data, the BAU scenario projects the evolution of energy and emissions levels until 2030, under the hypothesis of continuing current trends in population, economy, technology and human behaviour, without the implementation of a SECAP or any other national or local policy measures [13].
- The local authority can select its national coefficient according to the chosen baseline year. The coefficient indicates the relative projected increase in GHG emissions between the baseline year and 2030. This implies that to obtain the GHG emissions foreseen for the year 2030, the emission in the baseline year has to be multiplied by the national coefficient K according to the following formula:

$$\boldsymbol{Emission_{CO_2}^{2030} = Emission_{CO_2}^{Baseline\_year} * K}$$

Where:

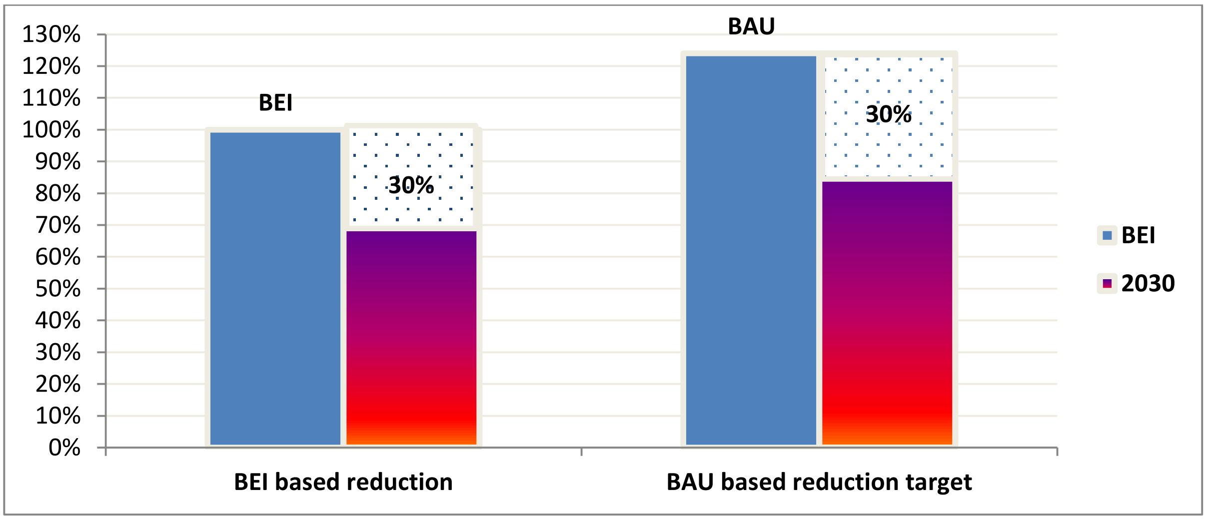
— K is the national coefficient selected according to the chosen baseline year, $Emission_{CO_2}^{Baseline\_year}$ are the emissions in the baseline year.

— $Emission_{CO_2}^{2030}$ are the estimated emissions for 2030.

Therefore, the final reductions target of at least 30 % refers to $Emission_{CO_2}^{2030}$ — the emissions foreseen for the year 2030 according to the BAU scenario.

It is recommended to monitor the representativeness of the BAU scenario at least once before 2030. In case the assessment highlights a strong deviation between the BAU predictions and the actual situation, the actions and measures foreseen by the SECAP should be revised and an adjustment of the reductions target might be advisable. The same national coefficient can be applied both for CO_2 inventories and for inventories that take into account other GHGs and report in CO_2-eq.

Figure 3. Absolute 30 % reduction target based on the BEI results vs. absolute target based on BAU projections



([24]) From open source information, several emissions projection tools and instruments for energy policy analysis and climate mitigation assessments are available.

Setting a 'per capita' target on the basis of a BAU scenario it is not recommended because the elaboration of the BAU scenario, general or custom-made for a city, implies already a certain assumption on the population trend until 2020. n elaborating the national coefficients provided in this Guidebook (to be used for calculating the projection for the total emissions in 2030), based on the results from the **Table 44** BEI trends related to the population evolution at national level were used. Therefore, setting a 'per capita' target based on these coefficients and on the local population trends is not coherent with the general procedure.

3.3.6 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.

- **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.

3.3.7 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 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 **Table 7** for details):

- Aviation and Shipping (except local ferries)
- Nuclear energy*
- AFOLU
- 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 7. 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 ([25])
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 ([26])
	Process emissions from industrial plants (ETS and non ETS industry)
	Other emissions reported under the IPPU sector

([25]) 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. Energy consumption from off road traffic of vehicles/mobile machinery used in airports and harbours is optionally reported under the Transport macro-sector

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

3.3.8 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 [14]([27]). 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.

- Time series consistency

One of CoM guiding principles 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.

- 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:

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

— industry delocalisation

— new information on local emission factors, e.g. to be used instead of default EFs

— correction of heat consumption for outside temperature (i.e. normalising the heat consumption with the heating degree days)

— adding or removing optional activity sectors

— changes in the local territory's boundaries

— methodological changes (not recommended, only if needed)

Examples of recalculations are provided in the Annex. Please note that in case real changes in the local emission factors 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, 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 is the recalculation of the local emission factor for electricity for signatories going from the 2020 to the 2030 target.

- 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.

Additional resources

- BioenergieDat; http://www.bioenergiedat.de/

- Ecoinvent, http://www.ecoinvent.org/database/ecoinvent-33/ecoinvent-33.html

- IEA (2015), World Energy Statistics and Balances documentation. Reports of the International Energy Agency. http://www.iea.org/

- IPCC (2006), 2006 Guidelines for National Greenhouse Gas Inventories, prepared by the National Greenhouse Gas Inventories Programme, Eggleston et al. (eds). Published: IGES, Japan (http://www.ipcc-nggip.iges.or.jp/public/2006gl/).

- NEED Database, http://www.needs-project.org/needswebdb/index.php

4. 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 9).

Activity data ([28]) 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 ([29]), 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 9. 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.

4.1 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 8**.

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.

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

Table 8. Activity sectors and data to be included in the CoM inventories - "Building" macro-sector

<table>
<tr><th colspan="2">Activity sector</th><th>Description</th></tr>
<tr><td colspan="2">Municipal buildings, equipment/facilities</td><td>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.</td></tr>
<tr><td colspan="2">Tertiary buildings, equipment/facilities</td><td>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.</td></tr>
<tr><td colspan="2">Residential buildings</td><td>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.</td></tr>
<tr><td colspan="2">Public lighting</td><td>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.</td></tr>
<tr><td rowspan="2">Industries</td><td>Non-ETS industries or similar (below or equal to 20 MW as thermal energy input)</td><td rowspan="2">All final energy consumption and related GHG emissions occurring in manufacturing and construction industries not covered in the Emissions Trading Scheme 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.</td></tr>
<tr><td>Industries ETS or similar (above 20 MW as thermal energy input)</td></tr>
<tr><td colspan="2">Other: Agriculture, Forestry, Fisheries</td><td>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.</td></tr>
</table>

CoM key sector

The "key" symbol refers to the CoM mandatory key sectors. 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.

4.2 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 9**.

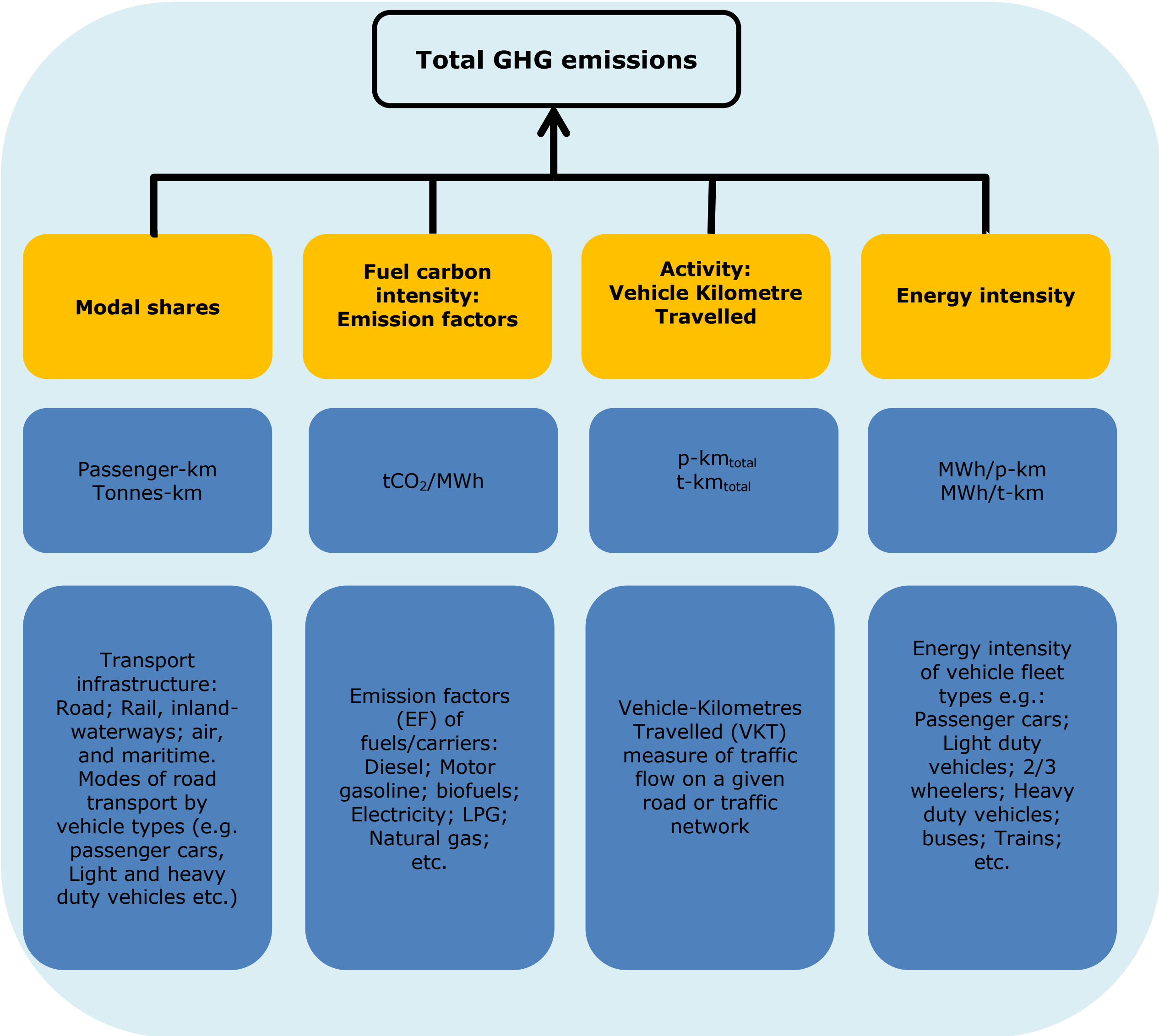
Table 9. Activity sectors and data to be included in the CoM inventories - "Transport" macro-sector

<table>
<tr><th>Activity Sector</th><th colspan="2">Description</th></tr>
<tr><td>Municipal fleet</td><td rowspan="2">Road transportation (see 5.3.1)</td><td>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</td></tr>
<tr><td rowspan="3">Public transport</td><td>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</td></tr>
<tr><td>Off-road transport</td><td>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</td></tr>
<tr><td rowspan="2">Rail transportation (see 5.3.2)</td><td>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</td></tr>
<tr><td rowspan="2">Private and commercial transport</td><td>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</td></tr>
<tr><td>Waterborne navigation</td><td>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</td></tr>
</table>

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 4**):

Figure 4. Transport GHG emission accounting approach



Source: JRC own elaboration, adapted from IPCC 2014 [15](30)

— 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-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);

(30) 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.

— 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 [Wh/l];

In order to ensure the overall consistency of the CoM methodology, it is suggested using the below equation (Box 10), to assess the total GHG emission in the transport sector.

Box 10. How to calculate the GHG emissions in the Transport sector

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

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.

4.3 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 (**Table 10**);, 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.

4.3.1 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 6.2.4) 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) generating electricity for self-consumption within the LAs boundaries are recommended to be included.

  The amount of energy from renewable sources corresponding to guarantees of origin (GO) (similarly defined as in Article 15 of Directive 2009/28/EC) or renewable energy certificates (REC_S), transferred to a third party outside the local administrative boundaries, shall be deducted from the local energy production from renewable sources (see section 6.2)*.

- Local electricity production from non-renewable sources:

  (a) all combined heat and power (CHP) plant/installations shall be included. The amount of energy produced from cogeneration, supplied to a third party outside the local administrative boundaries, shall be deducted from the local energy production (see section 6.2)*.

  (b) electricity-only producing units shall be included if they are not part of the Emissions Trading Scheme (or similar) 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 big 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, the certified electricity (e.g. through guarantees of origins or RECs) 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 6.2.4) and consequently on the emissions associated with the local consumption of electricity. Therefore, when building the subsequent MEI(s), consistency in the selection of 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.

4.3.2 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, 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 10. 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 for self-consumption within LAs boundary from renewable sources and combustible renewables, regardless of the technology and capacity **are recommended** to be reported under this sector. Electricity sold to third parties outside the local administrative boundaries, identified through disclosed attributes such as Guarantees of Origin (GO) and other tracking instruments (e.g. renewable energy certificates (RECs)) shall be excluded.
	Combined Heat and Power	All electricity production from cogeneration units, regardless of the capacity*, **are recommended** to be reported under this subsector (see section 5.4.1). The emission allocated to electricity production should be assessed as explained in Annex. "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 5.4.2). The emission allocated to heat/cold production should be assessed as explained in Annex "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 5.4.2).

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.

4.4 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 11**), the local authority is recommended to use methodologies developed by other international bodies (see section 6.4).

Table 11. 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.

5. 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.

5.1 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 8** and **Table 9**) 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.

<u>Activity sectors</u>
The activity sectors are defined in chapter 2, and further documented in **Table 8**, **Table 9**, **Table 11**, as follows:

— Mandatory requirements refers 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 10**).

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 (3.3.7) and listed in **Table 7**.

<u>Energy carrier categories</u>
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 ([31])) 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 cities. 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 ([32]) (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 Annex.

5.2 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 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.

— Getting data for municipal/institutional buildings and facilities

— Getting data from regional/ national sources

— Getting data from the market operators

— Getting data from a consumer survey

— Making and reporting estimates

([31]) See Annex for the emission factor to be applied to the non-biomass fraction of the municipal wastes.
([32]) 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).

5.2.1 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 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".

5.2.2 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. 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).

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 ([33]) - 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 ([34]). 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.

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. These regional data centres, also referred to as "Regional Energy and GHG Emissions Observatories" ([35]), 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.

5.2.3 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

([33]) 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.

([34]) 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

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

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.

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).

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.

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.

5.2.4 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[36]), 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).

([36]) Using sample size calculator, e.g. https://www.checkmarket.com/sample-size-calculator/

— 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 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).

<u>What to ask?</u>

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 (m^2) 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 (m^2), etc.

<u>What to do with the data?</u>

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.

Box 11. 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.

5.2.5 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.

5.3 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 9**):

- 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.

5.3.1 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).

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 ([37]). 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: 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 ([38]). Using a territorial approach is

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

([38]) 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 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 12. 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 %.

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 12** in **Annex.**

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

large share of local travel and a small share of transit travel, and/or having already an on-going plan based on such approaches.

- 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).

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 ([39]).

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.

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

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.

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 ([40]). 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 12. 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 cities	National databases
Passenger travel mode share surveys	Various national or city-level surveys
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);

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

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 13. 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 for further guidance on data sources and tools).

Box 13. 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**

5.3.2 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.

5.4 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 ([41]). 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.

5.4.1 Local production of electricity (LPE)

In many cases, the information on local production 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 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).

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). In case of CHP power plants, the energy input has to be split between electricity and heat/cold production, as explained in the Annex.

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.

([41]) The energy used by the plant for its own use (not for the production) and the related emissions should be excluded.

5.4.2 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 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 the Annex. 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.

6. 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:

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).

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.

The *CoM emission factors* and/or other *standard* (see Annex) 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.

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).

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).

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 into consideration.

The local authority has the choice to account for CO_2 emissions only or also include CH_4 and N_2O GHG emissions 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 13**).

Table 13. IPCC (1995) and IPCC (2007) GWP values

		IPCC (1995)	**IPCC (2007)**
Greenhouse gas	Mass of GHG in (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

6.1 Emissions from the direct use of energy carriers

The local authority can choose between standard emission factors in line with IPCC principles and LCA emission factors.

The standard emission factors following IPCC principles are based on the carbon contents of the fuels. For simplicity, the emission factors presented here assume that all carbon in the fuel forms CO_2. However, in reality, a small share of carbon (usually < 1 %) in the fuel also forms other compounds such as carbon monoxide (CO) and most of that carbon oxidises to CO_2 later on in the atmosphere.

The LCA emission factors include the actual emissions from all life cycle steps including final combustion, as mentioned earlier. This is of special relevance for biofuels: while the carbon stored in the biofuels themselves may be CO_2 neutral, the cropping and harvesting (fertilisers, tractors, pesticide production) and processing of 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 of GHG emissions, and therefore the LCA approach supports the choice of the most climate-friendly biofuel and other biomass energy carriers.

In the case of a biofuel blend, the CO_2 emission factor should reflect the non-renewable carbon content of the fuel. An example of the calculation of an emission factor for a biofuel blend is presented in Box 14.

Box 14. How to calculate an emission factor for a biofuel blend

A biodiesel blend is used in the city, including 5 % of sustainable biodiesel and the rest conventional diesel oil. Using the standard emission factors, the emission factor for this blend is calculated as:

95 %*0.267 t CO2/MWh + 5 %*0 t CO2/MWh = 0.254 t CO2/MWh

The emission factors for the fuels that are most commonly used within the territories of the local authorities are presented in Table 48 and Table 49 are based on 2006 IPCC Guidelines and the ELCD [16].

If local authorities prefer to use or develop emission factors that better reflect the properties of the fuels used within the territory, they are welcome to do so. The choice of emission factor used in the BEI has to be consistent with the choice of the emission factor used in the MEI.

Box 15 gives additional information on how to deal with biomass or biofuels ([42]) that are used within the territory of the local authority.

([42]) 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.

Box 15. Sustainability of biofuels/biomass

Sustainability of biofuels and biomass is an important consideration in the preparation of the SECAP. In general, biomass/biofuels are a form of renewable energy, the use of which does not have an impact on the CO_2 concentration in the atmosphere. However, this is the case only if biomass/biofuels are produced in a sustainable manner. Two sustainability issues should be taken into consideration when deciding on SECAP measures related to biomass/biofuels, and when accounting for them in the BEI/MEI.

1. Sustainability in relation to CO_2 concentration in the atmosphere

Combustion of carbon that is of biogenic origin, for example, in wood, biowaste or transportation biofuels, forms CO_2. However, these emissions are not accounted for in the CO_2 emission inventories if it can be assumed that the carbon released during combustion equals the carbon uptake of the biomass during re-growth within a year. In this case, the standard CO_2 emission factor for biomass/biofuel is equal to zero. This assumption is often valid in the case of crops that are used for biodiesel and bioethanol, and is valid in the case of wood if the forests are managed in a sustainable manner, meaning that on average, forest growth is equal to or higher than harvesting. If wood is not harvested in a sustainable manner, then a CO_2 emission factor that is higher than zero has to be applied.

2. Life cycle emissions, biodiversity and other sustainability issues

Even though biofuel/biomass would represent a neutral CO_2 balance, its usage may not be considered as sustainable if its production causes high emissions of other GHGs — such as N_2O from fertiliser use or CO_2 due to land-use change — or has an adverse impact on biodiversity, for example. Therefore, it is recommended that the local authority check that the biomass/biofuels used meet certain sustainability criteria established in the national regulations.

In the absence of national regulations regarding the sustainability of biomass/biofuels, the local authority might use the criteria set in the Directive 2009/28/EC on the promotion of the use of energy from renewable sources. Only biomass/biofuels that meet these criteria should be considered as renewable in the context of the CoM.

In the event that the local authority uses standard emission factors and uses biofuel that does not meet sustainability criteria, it is recommended to use an emission factor that is equal to that of the corresponding fossil fuel. For example, if the local authority uses biodiesel that is not produced in a sustainable manner, the emission factor of fossil diesel is to be used. Even though this rule does not follow the conventional emission estimation standards, it is applied to prevent the use of unsustainable biofuels in Covenant cities.

If the local authority uses LCA emission factors and uses biofuel that does not meet sustainability criteria, it is recommended to develop an emission factor that takes into account all the emissions over the entire life cycle of the biofuel.

6.2 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:

- National emission factor for electricity consumption (NEFE)
- Indirect emissions from local electricity production (LPE)
- Purchase and sale of Certified Electricity (CE)

6.2.1 National emission factors for electricity consumption

The electricity consumed within each local municipality or region is often not produced within its territory. Keeping in mind that the focus of Covenant is on the demand side, it is recommended to use a National Emission Factor for Electricity (NEFE) consumption as a starting point to assess the emissions from local electricity consumption. In case of local electricity production and/or purchase of certified green electricity by the local authority, a local emission factor for electricity consumption has to be further assessed from the NEFE by also accounting for the local production and purchase of electricity and the related emissions (see Iancu et al. (2014) Guidebook for calculation details [17]).

The NEFEs for electricity consumption provided in this document were calculated applying IPCC and LCA emission factors to the energy consumed per energy carrier (fossil fuel and non-renewable waste) in the Power and Combined Heat and Power plants to produce electricity, subsequently dividing by the total final electricity consumption (from all energy sources). IEA (2015) national energy data (energy carriers consumed, electricity produced per energy carrier, final electricity consumption) were used. Both main activity producers and auto-producers have been included in the calculation of electricity production and CO_2 emissions.

The NEFEs using the IPCC approach and accounting for CO_2 emissions (tCO_2/MWh) are provided in Annex **Table 51**, whereas the GHG factors (in tCO_2 eq/MWh), which include CO_2, CH_4 and N_2O emissions, are provided in Annex **Table 52**. The NEFEs using the LCA approach (in Annex **Table 53**) were obtained applying the LCA emission factors to the IEA input energy carriers (see for details Koffi et. al. 2017 [18])

The national emission factors fluctuate from year to year due to energy mix used in electricity generation. These fluctuations are caused by the heating/cooling demand, availability of renewable energies, energy market situation, import/export of energy and so on. These fluctuations occur independently of the actions taken by the local authority. Therefore, it is recommended to use the same emission factor in the BEI and in the MEI in order to assess the progress in terms of impacts resulting from the local actions implemented; otherwise, the result of the emission inventory could be very sensitive to factors over which the local authority has no influence.

The national emission factor for electricity has the acronym NEFE. The emission factor chosen is reported in the SECAP template as 'CO_2 emission factor for electricity not produced locally'.

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

> ! 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.

6.2.2 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 ([43])*. 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

([43]) * New criterion as compared to 2010 guidelines 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}) are zero.

All plants that are to be included in LPE (see 5.4.1) should be listed in Section B. Energy supply of the SECAP template, 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 Table 48 and Table 49 [16] 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).

6.2.3 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 (e.g. renewable energy certificates RECs), that meets the criteria for guarantee of origin of energy produced from renewable sources (similarly as 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)

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

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

6.2.4 Calculation of local emission factor for electricity (EFE)

Based on the considerations and assumptions presented in sections 6.2.1 to 6.2.2, the local emission factor for electricity (EFE) to be reported in Emission factors Table of the on-line SECAP template should be calculated has follows:

In the case where the local authority would not be a net exporter of electricity (TCE ≥ LPE + GE) ([44])

([44]) 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 NEFE. However, at the scale of the local authority, these approximations will have a minor effect on the

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

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

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

Where:
EFE = local emission factor for electricity consumption $[\frac{t\,CO_2}{MWh}]$ (Part C of the SECAP template)
TCE = Total electricity consumption [MWh] in the local territory (as per Table A of the SECAP template)
$\sum LPE$ = local electricity production from RES and non RES facilities [MWh] (Part B of the SECAP template)

$\sum CE$ = Certified electricity accounted in the inventory (Part B of the SECAP template)

$NEFE$ = national emission factor for electricity consumption $[t\,CO2/MWh]$ (Part C of the SECAP template)

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

$\sum CO2_{CE}$ = 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, the emission factor for certified electricity is zero. If the LCA approach is used, the local authority has to estimate the LCA CO_2CE either by requesting required information from the power provider or by using the CoM default factors provided for local renewable electricity generation 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.

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.

6.3 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.

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

local CO_2 balance and the formula may be considered as robust enough to be used in the context of the Covenant of Mayors.

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

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 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.

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.

6.4 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 ([45]) 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 ([46])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).

([45]) 2006 IPCC Guidelines for National Greenhouse Gas Inventories,
([46]) http://ghgprotocol.org/sites/default/files/ghgp/standards/GHGP_GPC_0.pdf

7. 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 and to report the key elements of the Emission Inventory approach/options in a concise way in the SECAP document This will facilitate the BEI reporting in the on-line template 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.

7.1 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

— 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.

7.2 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 the following main information should be reported:

- Definition of the local territory 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

It is also recommended eporting the key elements of the BEI/MEI in a summary Table, such as the one below (**Table 14**). This will allow for a better transparency and facilitate the on-line reporting.

Table 14. 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
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.

7.3 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 [14]), available under the Covenant of Mayor Website,, as well as in the different chapters of the present Guidebook.

7.3.1 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 cities. 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.

7.3.2 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 5.4). 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.

7.3.3 Section C - The CO_2 emissions tables

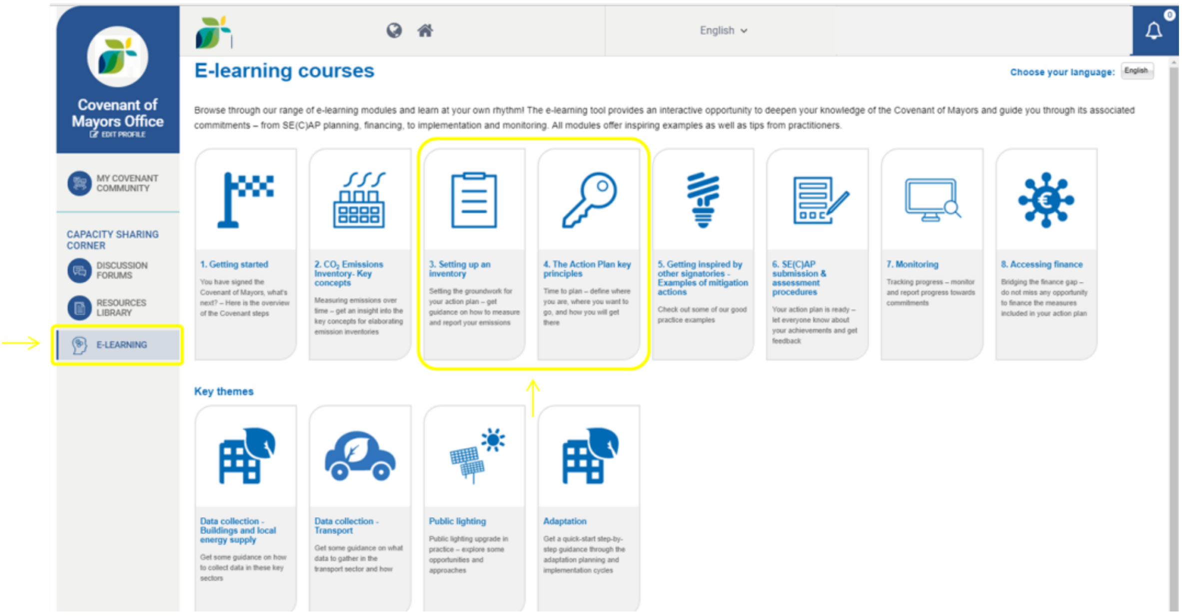
In the case of energy related emissions, the Emission Inventory Section is automatically calculated from the "Final energy consumption" (Section A) and the Emission factors (EF) provided in this section C. The factors proposed by default in the menu of the EF Table are the IPCC or LCA CoM default emission factors. 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

7.4 Reference Covenant Materials:

7.4.1 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 5. E-learning modules



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

7.4.2 Covenant of Mayors Reporting Template and Guidelines

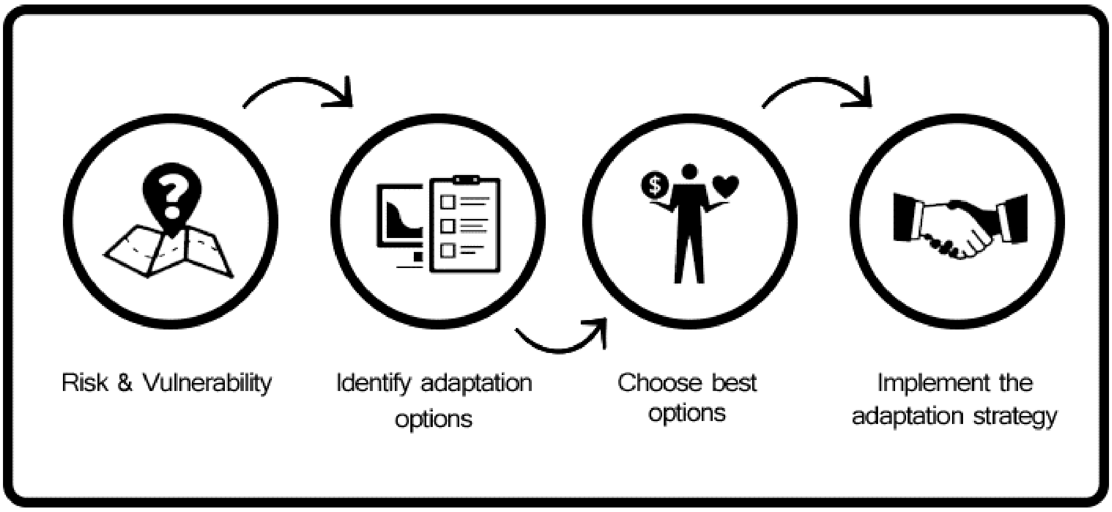
An Excel copy of the Reporting Template (to be filled in every two years by signatories of the Covenant of Mayors in the online reporting platform, the so-called "My Covenant") is downloadable. Moreover guidelines to support signatories of the Covenant of Mayors throughout the online reporting process are available [14].

PART 2.b. Risk and vulnerability assessment (RVA)

Introduction

Climate Change Risk and Vulnerability Assessment (RVA) has been gaining significance since 2010, given its central role in the Cancun Adaptation Framework and the National Adaptation Plans (European Commission, 2013 [19]). 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 [20]). Preparing the ground for an effective adaptation strategy starts from assessing vulnerability and risk (**Figure 6**), which provides the necessary information (*What*? *Where*? *Why*?) to support tailored proactive measures for each site-specific context (*How*?).

Figure 6. From RVA to adaptation strategy.



Source: JRC own elaboration.

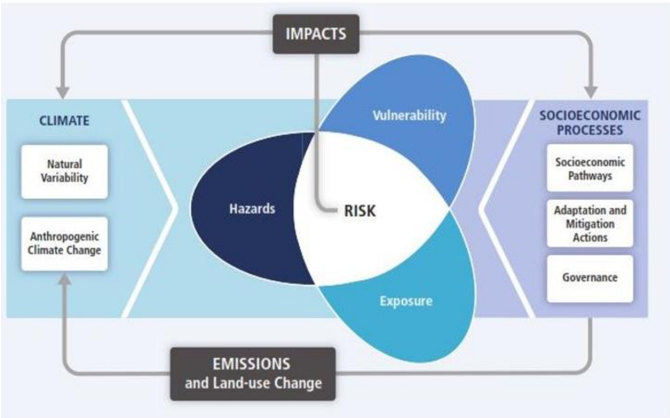
Not all issues that emerge from vulnerability assessments can be addressed, mainly due to budgetary limitations (World Bank, 2010 [21]). Therefore, the compromise solution for adaptation sometime faces a trade-off between environmental, social and economic dimensions. Even though this assessment is a crucial step in developing adaptation plans, the lack of robust estimations of positive and negative impacts, as well as uncertainties still represents the main constraint in assessing vulnerability and risk for most countries and municipalities (EEA, 2014 [22]). Spatially explicit modelling of climate change risks can give an important contribution to (partial) cost-benefit estimation of different investment plans for adaptation (Loyd´s, 2014 [23]), 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 [24]). 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 cities.

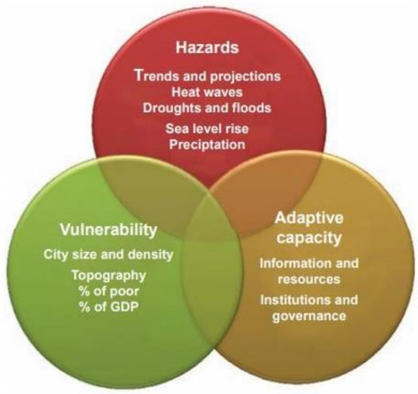
— The necessity of standardization

In the literature, there are very different definitions and ways to assess climate change vulnerability and risk. Scholars from different knowledge domains apply different approaches, often generating misunderstanding in interdisciplinary research on climate change (Fussel, 2007 [25]). The IPCC (2007) [26] 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 [27]) 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 [28]). This risk framework differs, for example, from the one developed by the UCCRN (2011) [29], as displayed in **Figure 7**, 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 7. 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.

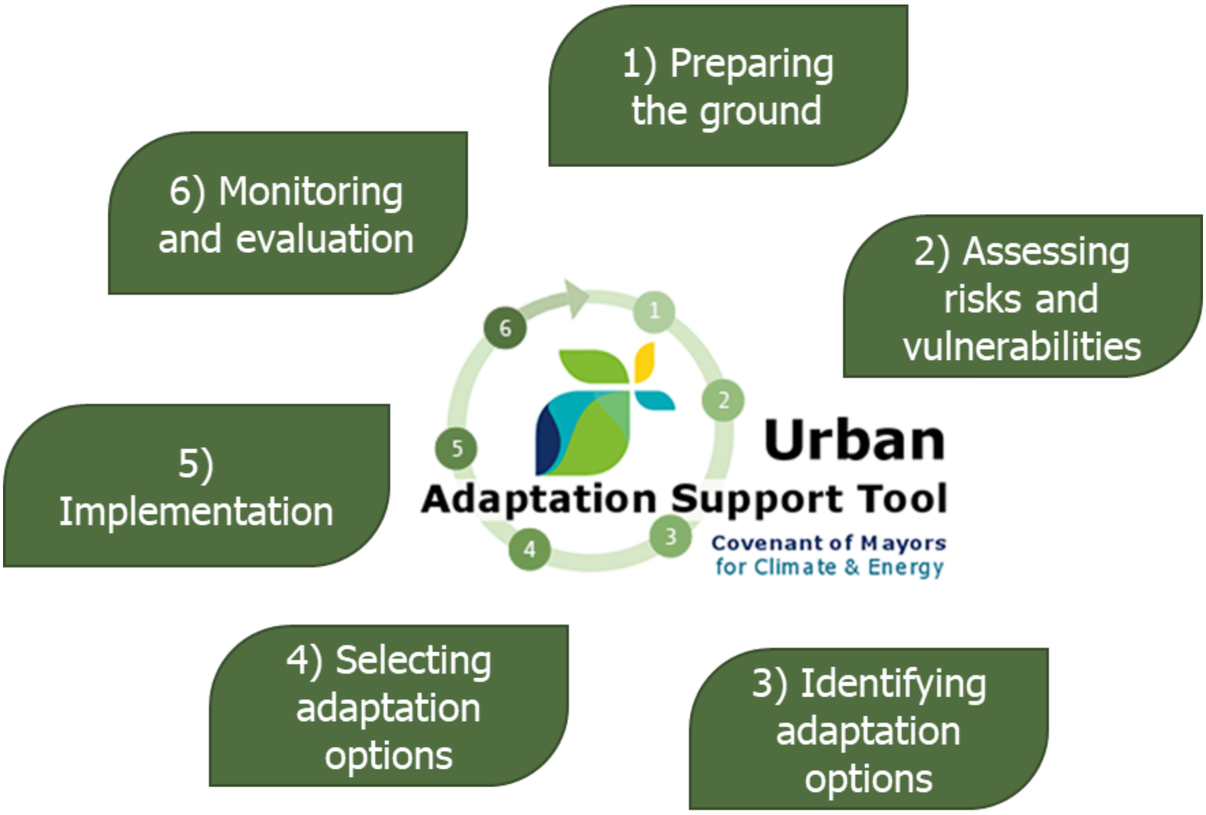
This uncertainty and intricacy hinders and delays local authorities in starting to understand their climate change impacts, vulnerabilities and risks. This is particularly true in small and mid-size cities, which usually rely on limited technical skills and resources.

Therefore, there is a blatant demand for a standardization 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. To date, it is not possible to define a common pattern of RVA application across Europe. Some cities carry out a qualitative assessment based on collected information in literature reviews; others rely on quantitative climate-impact models and expert judgment (EEA, 2014 [22]). Mixed-method approaches, however, are used by most of countries.

— 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 [30]). 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 step in the adaptation cycle (**Figure 8**), which provides the necessary information (What? Where? Why?) supporting tailored proactive measures for each site-specific context (How?).

Figure 8. 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 [21]). 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 [22]).

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 [23]), 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 [24]). 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.

8. Risk and Vulnerability Assessment (RVA) – Main Concepts

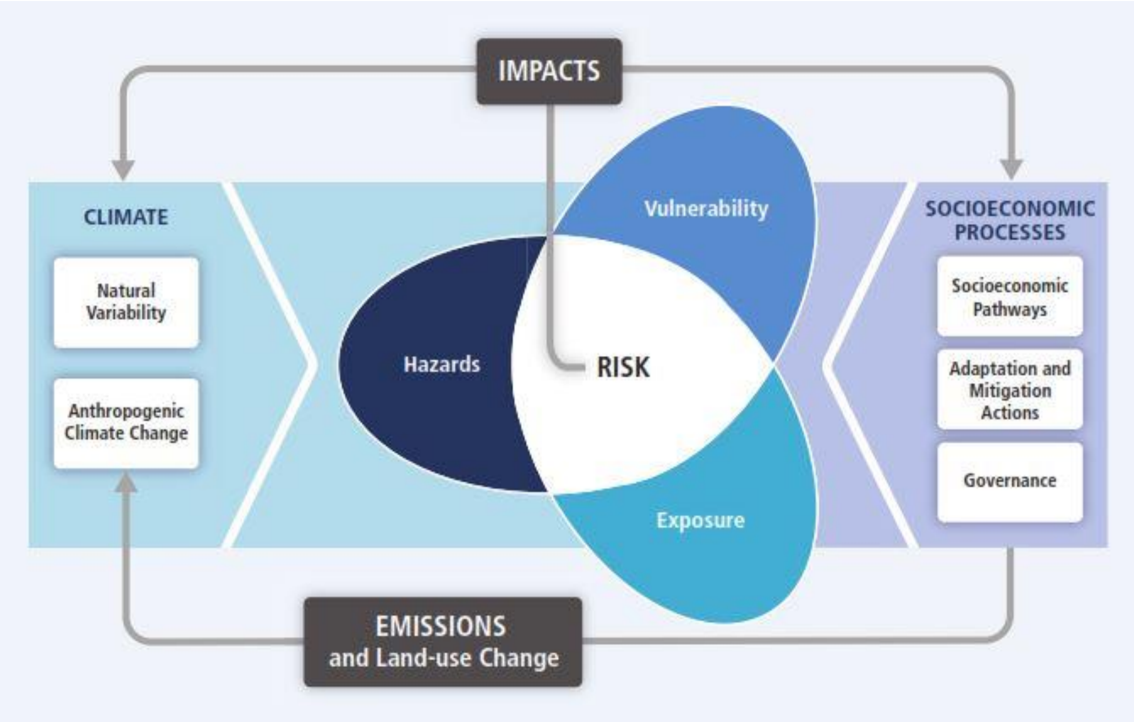
8.1 Fifth Assessment Report – Risk Assessment (2014)

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 [28] (see above).

- Hazards refers to climate-related physical events or impacts.
- Exposure to the population, environment, and assets that might be potentially impacted.
- Vulnerability includes sensitivity or susceptibility to harm, and the adaptive-capacity of the system.
- The term "risk" is used to define the risks of climate change impacts.

Henceforth, we will adopt this definition and framework to propose a RVA for cities.

Figure 9. Climate Risk Assessment framework.



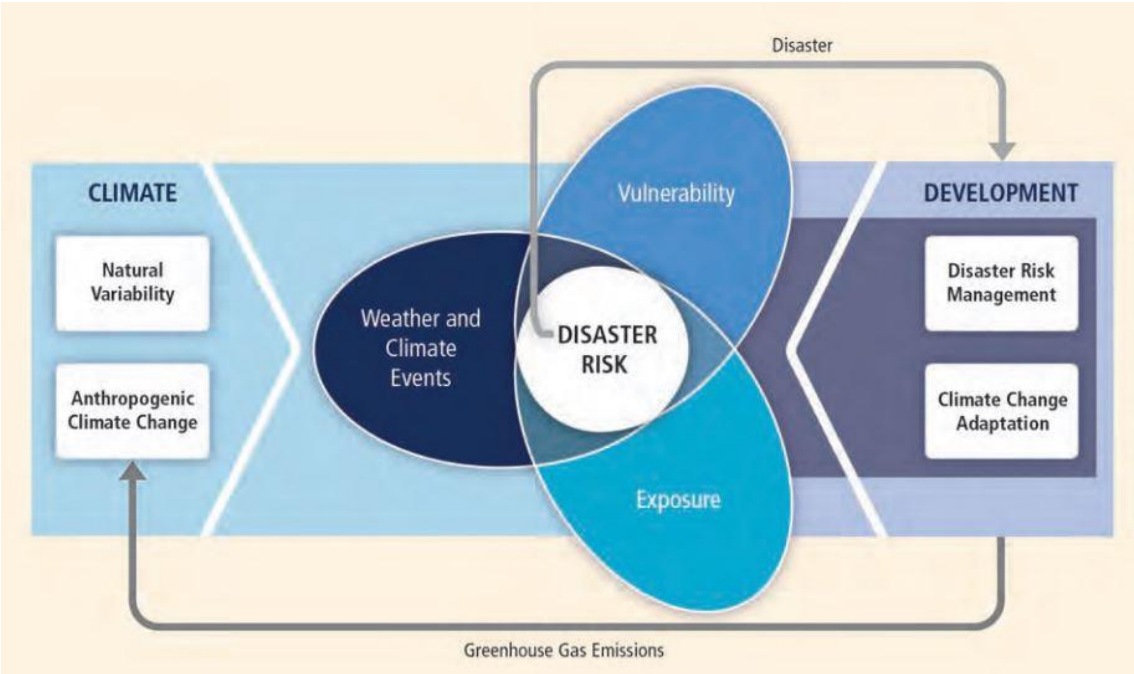
Source: IPCC, 2014.

8.2 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 10**). 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 [28]). 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 [28]).

Figure 10. Core concepts of SREX.



Source: IPCC, 2012 [28].

8.3 Glossary of main terms for understanding RVA

This chapter aims at pointing out the confusion about the terms used to assess climate vulnerability and risk. **Table 15** offers an example of the indicators proposed by Climate-ADAPT platform to calculate city vulnerability to heat waves ([47]).

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) [27].

This lack of agreement about the components of RVA demands a standardization of the main concepts and terms in order to avoid misunderstandings, simplify indicator handling, and help non-expert users to correctly calculate the vulnerability of their city.

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

Table 15. Example of indicators to assess vulnerability to heat waves.

Factors that tend to increase vulnerability to heat waves ...		
Exposure	**Sensitivity**	**Response capacity**
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
	High share of lonely pensioner	

Source: Climate-ADAPT platform, 2017

The following definitions have been excerpted from the Fifth Assessment Report of the IPCC (IPCC, 2014, pp.5 [27]) and will be used henceforth as references:

— Climate change:

Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or 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 forcing 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 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.

— 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.

— 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.

— 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.

— Impacts:

Effects on natural and human systems. In this report, the term impacts 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.

— 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.

— 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.

— 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.

— Maladaptation:

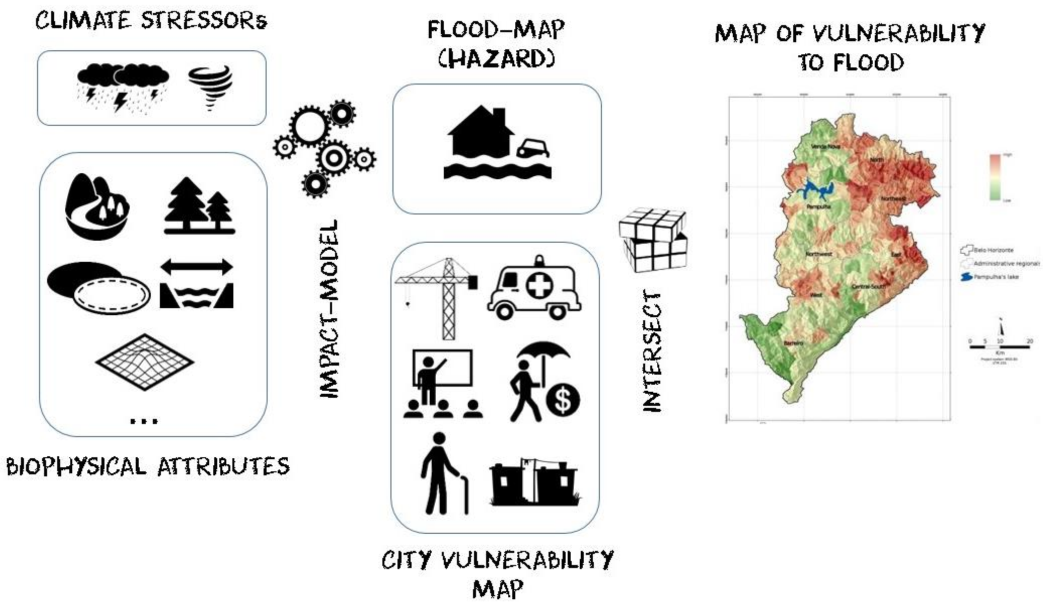
Interventions and investments in a specific location or sector that could increase the vulnerability of another location or sector, or increase the vulnerability of the target group to future climate change. Maladaptation arises not only from inadvertent badly planned actions, but also from deliberate 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.

9. Methodological approaches for RVA

According to the IPCC (2014) [27], risk can be understood either qualitatively or quantitatively. Useful approaches for managing risk do not necessarily require an accurate assessment. We propose two different approaches to help city authorities better understand climate change impacts, vulnerabilities and risks within urban areas. They differ for 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 impact maps (e.g., flood-map) according to specific climate stressor and city biophysical attributes (model´s Input) (**Figure 11**). The spatially explicit approach is most suited for big cities that usually have the necessary resources and capacities to use the models and act on the main outcomes.

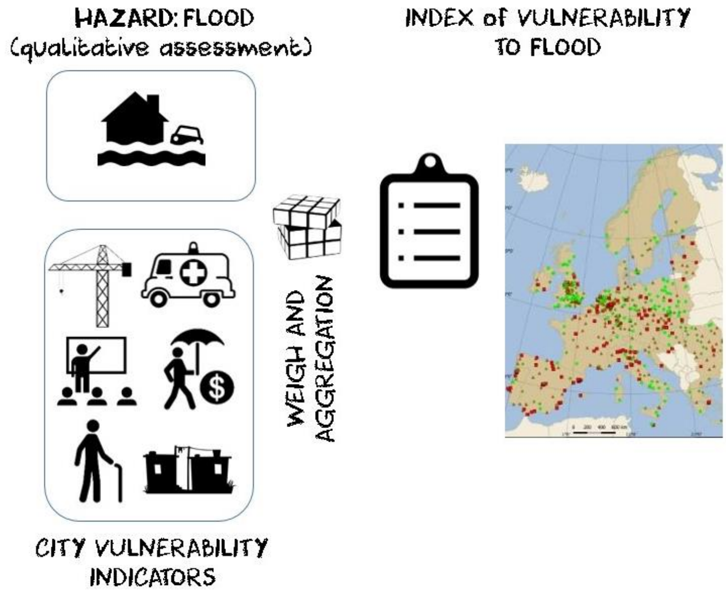
Figure 11. Vulnerability assessment based on spatially explicit climate impact-models.



Source: JRC own elaboration: The final map displays the vulnerability to flood of the city of Belo Horizonte (Brazil) in 2030 [31].

An indicator-based assessment helps users to identify the factors that shape city vulnerability to climate threats through comparable indicators (**Figure 12**) Smaller cities might use a simpler qualitative approach based on the construction of indicators to assess their climate risk.

Figure 12. Indicator-based vulnerability assessment.



Source: JRC own elaboration. 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 [32].

9.1 RVA based on spatially explicit impact models (larger cities)

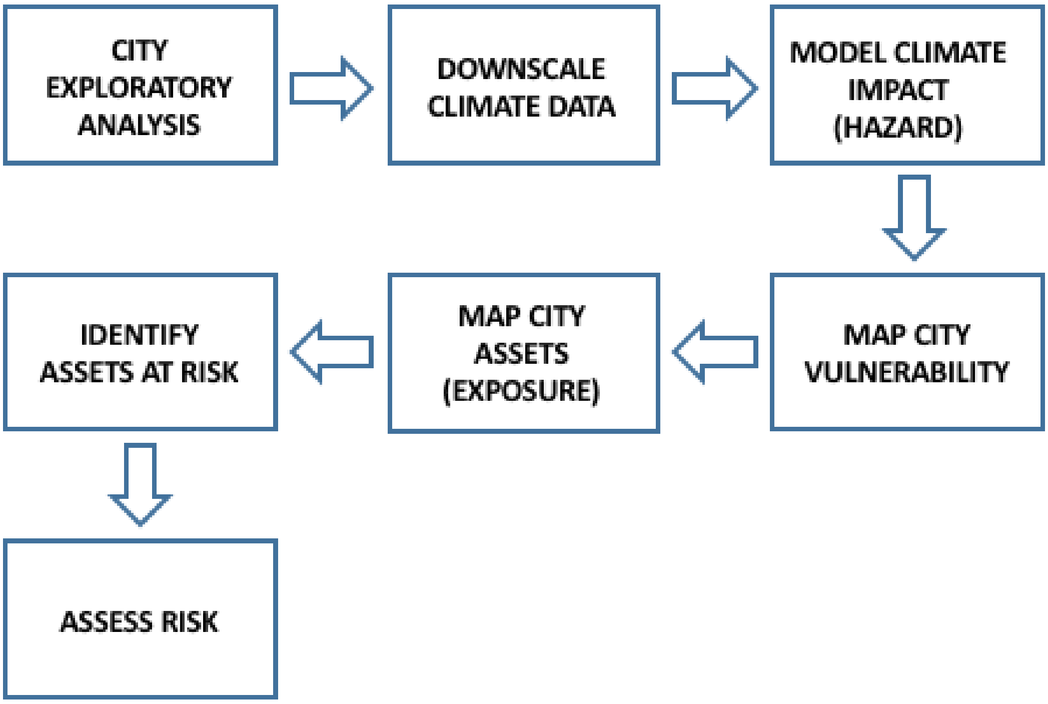
Planning and implementing urban adaptation takes place at a local level. Spatially explicit city-level assessment of risk of climate change impacts is essential to indicate adaptive measures at appropriate scales, taking into consideration the specificities of each context within the urban perimeter. 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 [33]). 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 is often conducted by an external consulting firm or through the assistance of city networks, such as ICLEI and C40. 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. The Emerging and Sustainable Cities initiative of the Inter-American Development Bank (BID) offers some successful examples of collaboration between consulting firms, municipalities and international Agencies in some State capitals of Brazil (e.g., Vitoria and Goiana).

Several modelling steps shape the risk assessment framework, as displayed by **Figure 13**.

Figure 13 Modelling framework for risk assessment.



Source: JRC own elaboration.

9.1.1 STEP 1: Exploratory analysis with city stakeholders

This step includes a kick-off meeting with city stakeholders in order to contextualize the study, understand needs and expectations, identify instances of climate change impacts, select a contact point in the Municipality (usually an officer from Environmental Agency), and clearly explain the RVA approach and the required data.

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 [34].

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 Municipality should be entrusted with facilitating the communication between the parties and fostering data sharing.

Box 16: 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 board;

- Qualitative understanding of city's specificities and climate change impacts.

9.1.2 STEP 2: Downscale global climate data to regional context

Downscaling the results of global climate models (GCMs) to lower levels 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 detailed climate information has to be provided by regional or country research agencies to local authorities. In Brazil, for example, the regionalization of the Met Office Hadley Centre Global Coupled climate model (HadCM3) has been developed by the Meteorological Centre of the National Space Agency ([48]) through the Eta-CPTEC model. The Eta-CPTEC has been configured with a 20 km grid size for the whole of Latin America, and with a finer 5 km resolution only for south-eastern regions of Brazil.

The EURO-CORDEX ([49]) - 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 ([50]) experiments until 2100 with a grid resolution of about 12 km (0,11 degree).

Additionally, local data from city weather stations can be used to refine the calibration of the regional climate models, improving the accuracy of short-term 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. In a study of Belo Horizonte, Brazil [31], a detailed urban climate map has been used to forecast the city vulnerability to heat waves.

Box 17: main activities of downscaling climate data.

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

9.1.3 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 [35]); 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.

Box 18: Main activities of modelling climate impact (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)

The model OUTPUT comes in the form of maps representing – for a specific time window and climate scenario ([51]) – 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

([48]) http://etamodel.cptec.inpe.br/
([49]) http://www.euro-cordex.net/
([50]) Coupled Model Intercomparison Project, Phase 5. https://pcmdi.llnl.gov/mips/cmip5/index.html

([51]) Global Climate Models provide information of temperature and precipitation, among others, according to RCPs scenarios.

networks (e.g., ICLEI or C40) or by regional/national research centres, due to its technical complexity.

9.1.4 STEP 4: Map city vulnerabilities

Each impact 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 ([52]). 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).

For example, in a study of Belo Horizonte in Brazil [31], 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.

The assessment of 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 can be found in [36].

Box 19: Main activities of mapping city vulnerability.

- Understand city specificities that could contribute to aggravating the consequences of 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

It is important to include socio-economic drivers - such as health status, mobility, age, access to resources, among others - to correctly understand associated health outcomes in a vulnerability assessment.

9.1.5 STEP 5: Define exposure by mapping important environmental areas, population and assets within the city

Information about the location of environmental areas, population and properties of relevant city assets, such as buildings, roads, and historical monuments have 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.

([52]) 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.

Box 20: Main activities of mapping city assets (Exposure).

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

Useful information layers about trends in urbanization, population distribution and built-up areas can be downloaded from the Global Human Settlement (GHSL) dataset. The GHSL European Settlement Map is a spatial raster dataset mapping human settlements in Europe as derived from remote sensing image processing (SPOT5 and SPOT6).

9.1.6 STEP 6: Overlap hazard, exposure and vulnerability maps to assess the risks

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

Box 21: Main activities of identifying assets at risk.

- intersect hazard, vulnerability and assets maps (exposure)
- identify assets within hotspots of risk
- repeat this step for each hazard

All the explanatory variables of risk were 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 [37]. 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:

$$\boldsymbol{Risk = Hazard\ x\ Exposure\ x\ Vulnerability}$$

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

The IPCC (2014) [27] 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 and/or inexistent markets. 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, in [36] is 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 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.

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 can be found in [38]. The authors 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.

Box 22: Main activities of assessing the risks

- Approximate unit damage costs and damage functions for each asset
- Multicriteria assessment for invaluable ($) assets
- Quantify expected losses and damages

Impacts on non-market assets – such as social or environmental welfare – that cannot be translated into a monetary dimension, can be evaluated and compared through a Multicriteria Assessment (MCA) to support adaptation planning (EEA, 2016 [39]). Partial cost-benefit analysis can be used within MCA as one more criterion.

9.2 Indicator-based vulnerability assessment (small-mid size cities)

Indicator-Based Vulnerability Assessment (IBVA) has been widely used to assess climate change vulnerability in urban contexts [32]. 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.

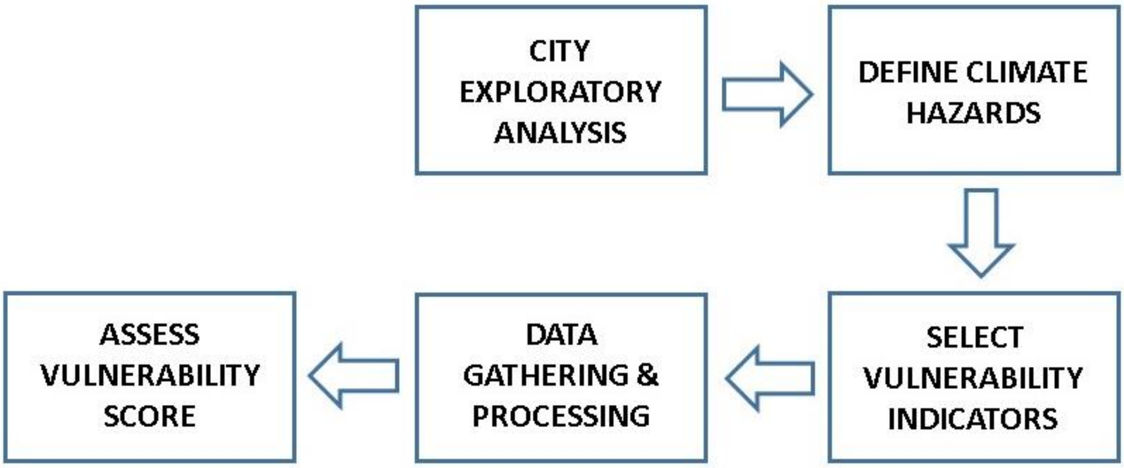
According to the IPCC (2014) [27], vulnerability is described by non-climatic factors covering a system´s biophysical and socioeconomic attributes. Different climate hazards affect different vulnerabilities in the city.

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 demand particular technical capacities or tools. **Figure 14** displays the main steps that shape the IBVA framework:

Figure 14. Sequence of steps for indicator-based vulnerability assessment.



Source: JRC own elaboration.

9.2.1 STEP1: City exploratory analysis

This step 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 Municipality (usually an officer from Environmental Agency), 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 Municipality should be entrusted with facilitating the communication between the parties and fostering data sharing.

Box 23: Main activities of the exploratory analysis of the city.

- Stakeholder engagement

- select a contact point to foster communication and data sharing and crate and Advisory board

- Quantitative understanding od city's specificities and climate change impacts

9.2.2 STEP 2: Identify climate hazards for the city

A qualitative description of time-scales (short, mid and long term) of the expected impacts should be provided in order to correctly prioritize investments.

Box 24: Main activities of defining climate hazards

- gather data about current climate related impacts

- identify climate threats for the city 8short, mid and long term)

There are many easily accessible sources of information about climate change projections and data, such as:

- Technical reports by European and multilateral agencies: EEA, (2016) [39]; Kovats et al., 2014 [40]; Revi et al., 2014 [24]; among others PESETA II and PESETA III projects ([53]).
- Data Sharing Platforms: i) Climate-ADAPT ([54]); ii) IPCC data Distribution Centre ([55]); iii) JPI Climate ([56]); iv) Climate Change Knowledge Portal ([57]), among others;
- National and international meteorological centres, such as the Met Office ([58]) and the European Centre for Medium Range Weather Forecasts ([59]), among others.

9.2.3 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) ([60]).

For example, modified the Social Vulnerability Index [41] 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 [32]. Indicators should be selected on the basis of their analytical soundness, measurability, relevance and coverage [35]. The final list should be validated by the Advisory Group.

Box 25: Main activities of selecting vulnerability indicators

- Focus on socioeconomic, institutional, biophysical, etc. characteristics associated with sensitivity and capacity of adaptation to specific hazard

- Repeat the selection for each hazard

9.2.4 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 ([61]).

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.

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

([53]) https://ec.europa.eu/jrc/en/peseta
([54]) http://climate-adapt.eea.europa.eu/knowledge/tools/urban-adaptation/introduction
([55]) http://www.ipcc-data.org/
([56]) http://www.jpi-climate.eu/publications
([57]) http://sdwebx.worldbank.org/climateportal/
([58]) http://www.metoffice.gov.uk/services/data-provision
([59]) https://www.ecmwf.int/en/forecasts
([60]) Advisory groups and working groups include relevant experts from academia, NGOs, city government and private sector.
([61]) EU28 wide plus Norvay and Switzerland

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 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.

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 26: 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

9.2.5 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 [42]. 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[34] [43].

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 is calculated in [32]. 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. The authors 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 27: 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

Final considerations

Adaptation is novel 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 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 (and among 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. Multi-Criteria Analysis can be used to evaluate and compare climate change risk on tangible and intangible factors, and monetary and non-monetary criteria. This information is necessary to reach a compromise solution to the 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 citizens and 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 citizens and stakeholders ensures a pragmatic assessment of vulnerability and risk focused on real city needs. The city Advisory Group 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

Additional information

[31] Bittencourt, F., Follador, M., Pereira, V., Rocha, A., Vaz, C., Vieira, T., Amoni, M., Bicalho, F., 2017. 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. In Press.

[20] 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.

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

[45] 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.

[46] 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.

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

[48] C40, 2017. Infrastructure interdependencies and climate risk report, pp.56.

[49] DG CLIMA, 2017. Mainstreaming of adaptation into the ESIF 2014-2020. European Commission report, pp.130.

[19] 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.

[50] European Commission, 2014. Multiannual Financial Framework 2014-2020 and EU budget 2014. DG for Budget.

[51] 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.

[39] 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.

[22] EEA, 2014. National Adaptation policy processes in European countries. European Environmental Agency report, No 4/2014, pp.136

[52] 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.

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

[53] Fussel, H.M., 2007. Vulnerability: a generally applicable conceptual framework for climate change research. Global environmental change, 17, pp. 155-167.

[25] Fussel, 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.

[54] 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.

[55] GIZ, 2014. The vulnerability sourcebook. Concept and guidelines for standardized vulnerability assessments. GIZ press, pp.180

[56] Gonzalez, Y., Gomes, G. and Barbosa, P., 2017. A database for identifying EU climate change adaptation policies. European Commission JRC technical report, pp.32.

[57] 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.

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

[26] 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, 976 pp.

[28] 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.

[27] 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.

[36] Karspen, P.S. and Halsenes, K., 2017. Integrated climate change risk assessment: a practical application for urban flooding during extreme precipitation. Climate services 6, pp.55-64.

[58] 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

[40] Kovats, R.S., R. Valentini, L.M. Bouwer, E. Georgopoulou, D. Jacob, E. Martin, M. Rounsevell, and J.-F. Soussana, 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.

[23] Loyd' s, 2014. Catastrophe modelling and climate change. Loyd's press, pp.41.

[37] 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. Hydrol. Earth Syst. Science, 18, pp. 1591-1604.

[38] Naumann, G., Spinoni, J., Vogt J.V., Barbosa, P., 2015. Assessment of drought damages and their uncertainties in Europe. IOP Publishing, Environ. Res. Letters 10.

[59] 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.

[35] OECD and JRC, 2008. Handbook on constructing composite indicators. OECD press, pp.158.

[33] Oppenheimer, M., M. Campos, R. Warren, J. Birkmann, G. Luber, B. O'Neill, and K. Takahashi, 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.

[24] Revi, A., D.E. Satterthwaite, F. Aragón-Durand, J. Corfee-Morlot, R.B.R. Kiunsi, M. Pelling, D.C. Roberts, and W. Solecki, 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.

[60] Ricardo AEA, 2013a. Adaptation strategies for European Cities. Final Report for DG Clima, pp.148.

[61] Ricardo AEA, 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

[62] Reckien, D., Flacke, J., Heidrich, O., Olazabal, M., Foley, A., Hamann, J., Orru, H., Salvia, M., de Gragorio Hurtado, S., Geneletti, D., Prietrapertosa, F., 2014. Climate change response in Europe: what´s the reality? Analysis of adaptation and mitigation from 200 urban areas in 11 countries. Climate Change, 122, I 1-2, pp.331-340.

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

[34] 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.

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

[21] Word Bank, 2010. The economics of adaptation to climate change. A synthesis report. The WB Group, pp.84.

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

[64] UCCRN, 2015. Second Assessment report ARC3.2 – Summary for policy makers. Urban Climate Change Research Network.pp.28

PART III.
Policies, key actions and good practices for Urban Mitigation and Adaptation to Climate Change and Financing SECAPs

PART 3.a.
Policies, key actions and good practices for Urban Mitigation

The Part IIIa of the guidebook has presented a collection of measures to improve energy efficiency and reduce the dependency on fossil fuels by using renewable energies, while helping the cities cope with the effects of climate change. All measures collected in this chapter have been tested and successfully implemented by several cities.

As the reader will probably notice, each measure has not been described in depth, but rather a collection of references and links to more specific documents from reliable sources are given in each chapter.

The measures proposed in this document can be applied to the building, public services, local mobility solutions and the industry sectors. The technologies available for the heat and cooling are also described along with technologies that optimize energy use in municipal water and wastewater systems through cost-effective efficiency actions. Measures in the local transport sector which is part of mobility solutions in cities are described in the section related to Transport of these guidelines.

Some cities with a wide expertise in energy management will probably find these measures obvious. Even in this case, we think some measures, or the references provided in this guidebook, will help them to go beyond the objectives of the Covenant of Mayors.

1. Local Government's policies to support SECAP

The transition towards a more sustainable urban environment at the local level begins with a common understanding that there is significant potential to curb the city's CO_2 emissions. This understanding provides a basis upon which political leadership instigates a process of exploring possibilities and discussing different options with a wide range of stakeholders towards selecting, detailing, implementing and monitoring local action. In this process, municipalities have the capacity to support and mobilize action for local energy generation investments through several modes of urban climate governance.

In the following four modes of urban energy and climate governance are investigated and a policy matrix that summarizes the scope of each mode along with the main tools, the barrier that requires to be addressed, and exemplary actions to support local energy sustainability is provided. The modes of urban energy and climate governance [65] can be mainly summarised as:

- Municipal self-governing
- Municipal enabling (governing through enabling)
- Governing through provision
- Regulation and planning (governing by authority)

Overall, the barriers that can be addressed with each main tool under these modes of governance are different. For this reason, it is often necessary to combine multiple modes of governance to reinforce and align incentives for particular objectives. This must be supported by an analysis of the legal, physical, social and economic barriers hindering local energy generation prior to considering corrective actions and measures.

1.1 Municipal self-governing

Municipalities have the capacity to govern their own activities and undertake strategic investments in municipality-owned assets, which include investments in energy efficiency and local energy generation based on renewable energy sources. The main tools that are used by municipalities in this capacity are energy audits, demonstration projects in public facilities and public procurement, which can be used to better manage the local government estate. Through these tools, municipalities can provide technical validation and stimulate energy efficiency and demand for renewable energy and/or its purchase from district networks (**Table 16**)

Table 16. Municipal self-governing mode of urban climate governance

Mode of urban climate governance	Tools	Barrier addressed	Action examples
Municipal self-governing: Strategic investments in municipality-owned assets to increase local energy generation	Energy management of local authority estate	Lack of transparent and consistent monitoring and control of energy use; Disincentive for energy efficiency efforts in budget supported public entities; Difficulty for public entities to contract energy service providers	Establish standards for monitoring and management of energy to improve efficiency in a systematic and sustainable way; Adopt high energy efficiency performance standard for public buildings;
	Demonstration projects in public facilities	Need for technical validation and demonstration of performances	Town halls with solar energy façades and PV powered schools
	Green public procurement	Need to stimulate demand for energy efficiency renewable energy and/or the purchase of district heating/cooling	Green public procurement for purchasing energy efficient appliances and clean vehicles; Low-carbon, distributed energy supply in public buildings and schools, etc…

Box 28: Pilot project of Heat Pumps in Kindergarten Tbilisi (GE)

30 March 2010: Tbilisi City Hall, the first of the capitals of the EU Eastern Partnership, joined the CoM initiative and officially committed itself to developing a SEAP and BEI in one year. On 30 March 2011, Tbilisi City Hall officially submitted the documents in order to fulfil the obligations of the CoM. On 25 November 2011, the European Commission formally adopted an Action Plan on Sustainable Energy Tbilisi and a baseline inventory of GHG emissions.

16–22 June 2012: Europe celebrated EU Sustainable Energy Week (EUSEW 2012), a campaign that was organised by the European Commission's DG ENER, the European Agency for Competitiveness and Innovation, the European institutions, major energy actors and private companies.

The aim of the campaign was to promote the development of renewable energy and EE technologies and in this way remind the public at large of the renewable energy and EE potential for the mitigation of global and local environmental, social and economic problems. In the framework of the campaign 'Technological Exhibition of Renewable and Energy Efficient Technologies' (16–17 June 2012), the exhibition 'Sustainable Development in Paintings' (18–22 June 2012) was held.

Pilot project of Heat Pumps as one of the alternative energy sources at Tbilisi Kindergarten: in November 2012, the pilot project 'Popularization of Heat Pumps as one of the Sources of Alternative Energy and Completion of the Relevant Projects' was implemented in Tbilisi Kindergarten. The project was implemented by the NGO Renewable Energy Centre under the 'New Applied Technology Efficiency and Lighting Initiative/NATELI II' Project, supported by USAID to Georgia and managed by Winrock International Georgia.

The Kindergarten was selected based on the energy data collected every month by the Department of Economic Policy of the Tbilisi municipality. The pilot project envisaged the installation of two heat pumps, a water boiler and a heating network provided heating, cooling and hot water to the kindergarten using atmospheric air as the source of energy. The outdoor facade of the building was painted in two layers with special innovative ceramic paint additive. Thermal insulation of the building's attic was realised by special thermal pad, and two metal-plastic windows were installed in the attic.

1.2 Municipal enabling (governing through enabling)

As a facilitator, the municipality has an active role in enabling cooperation between community actors, including those that lead to the launch of public-private partnerships to promote local energy generation ([62]). The municipality also has a crucial role in engaging in awareness and capacity building campaigns that promote energy efficiency in buildings, sustainable transport and behaviour, utilization of renewable energy sources and the deployment of local energy generation technologies.

These tools can be actively used within the capacity of municipalities to overcome any lack of business models to leverage financial resources as well as inadequate knowledge and skills (**Table 17**).

([62]) OECD, Cities.

Table 17. Municipal enabling mode of urban climate governance

Mode of urban climate governance	Tools	Barrier addressed	Action examples
Governing through enabling: Facilitating co-operation among stakeholders and awareness building	Labels and certificates in the building sector	Lack of reliable and credible advice on the building performance and awareness of energy savings potential	Implement all national and/or regional provisions; Promote the adoption of additional voluntary schemes.
	Transport	Fragmentation of modes	Integrated ticketing and charging
	Public-private partnerships	Lack of business models to leverage financial resources	Involvement of a range of different partners increases the democracy of the processes; Public-private partnership for anaerobic digestion of biowaste for CHP-based district heating; Co-financing between local and regional authorities and private investors for public energy upgrading.
	Awareness raising/training	Inadequate knowledge and skills that may hinder undertaking renewable energy projects	Promotional campaigns, such as solar energy campaigns, and supporting tools based solar land registries Ensures that municipal staff receive appropriate training; Promote competitions, awards and contests for climate protection and GHG reduction efforts Provide guidelines for energy efficiency improvement in buildings
	Community cooperatives for local energy projects	Need to overcome perceptions of risk as a barrier to citizen involvement	Supporting tools and information sessions for citizen empowerment

1.3 Governing through provision

The municipality is a provider of urban services and as such, has control or influence over infrastructure development. Within this capacity, the municipality can effectively guide development in a way that increases energy efficiency in all urban sectors, support transition to sustainable transport as well as promote local energy production (**Table 18**).

Box 29: Awareness raising event 'Let's save Energy' in Rustavi (GE)

On 2 May 2011, the self-governing city of Rustavi joined the European common vision and signed the CoM agreement, making a commitment to reduce the city's GHG emissions by 2020 by at least 20 %, and to increase and improve the ecological environment of the city.

The city of Rustavi is one of the country's powerful industrial centres, where significant parts of the metallurgical, energy and chemical industries are concentrated. The course of rapid economic development undoubtedly requires consideration of the principles of sustainable development, formed by balance of economic, social and ecological development. Considering these principles, the Development Strategy of the city of Rustavi was developed in 2009, under which one of the priorities is improvement of ecological condition of the city.

The city's SEAP document was prepared in full compliance with the said strategy and reflects reduction of GHG emissions — one of the most important aspects of the improvement of ecological conditions within the obligations under the CoM. Reduction of GHG emissions, namely of CO_2 by 20 % by 2020 compared with the level of 2011 will significantly recover the climate of the city and improve the environment. Furthermore, implementation of the said Covenant will facilitate raising public awareness of environment protection, including entrepreneurs' provision, on the one hand, of further stability of sustainable development.

In the city of Rustavi, with the help of Swiss Agency, the first energy-efficient social hostel was built for 12 socially unprotected families, to replace non-energy–efficient housing for the same number of people. This innovative measure is considered as a short-term one and its implementation will significantly raise public awareness of EE and energy saving matters as well as increase motivation.

On 28 and 29 February 2012, the EECG in partnership with self-governing Rustavi city organised the awareness raising event 'Let's save Energy', through the organisation of Intelligent Energy Days in Rustavi city within the project 'Energy Saving Initiative in the Building sector in Eastern Europe and the central Asian Countries', financed by the European Commission. The abovementioned event had a non-formal educational character that included seminars at five public schools and the replacement of light bulbs in kindergartens.

Table 18. Governing through provision mode of urban climate governance

Mode of urban climate governance	Tools	Barrier addressed	Action examples
Governing through provision: Providing services and financial resources	Public sector financial management and procurement policies	Split incentives; Fragmentation of the building trade	Revise budgetary rules to allow retention of energy cost savings for other justified public spending; Revise public procurement rules to allow for contracting of energy service providers and adopt EE purchase requirements. Make adjustments based on the local peculiarities.
	Direct infrastructure investments for transport	Need for better transport infrastructure to reduce congestion and lower energy consumptions and therefore related emissions	A reliable and affordable public transport infrastructure (light rail system and bus rapid transit)
	Financial incentives in transport	Need to boost market for electric vehicles and promote sustainable mobility	Municipal incentives for purchasing clean vehicles and electric bikes
	Direct energy infrastructure investments	Insufficient energy infrastructure to provide access to renewable energy	Investments in the modernization and expansion of district heating networks Minimum quotas for renewable energy supply or co-generation provided by municipally owned utilities Renewable energy sources in public housing
	Incentives and grants to local energy generation	Insufficient financial incentive; Constrains of local budget; Competition with other investment priorities. Presence of market failures for related technological options	Use public funds (also national) to leverage private and commercial investments; Third party financing; Energy services companies (ESCO) City Council subsidies for renewable energy

Box 30 Why did Gori (GE) join the CoM

Mr Zviad Khmaladze — The Mayor of Gori District: 'Self-governing city of Gori is striving for the implementation of European values and standards. Thus, on July 13, 2012 the Municipality of Gori joined the Covenant of Mayors initiative in order to implement actions in energy efficiency and renewable energy leading to at least 20 % CO_2 emissions reductions by 2020. The savings that municipality will receive after reduction of the consumption of energy resources will be used for the implementation of the other projects in the city. The municipality of Gori hopes for the tight cooperation and assistance with COMO East Office in Tbilisi in order to implement above mentioned commitments.'

Since September 2012, the municipality of Gori has started data and information gathering for SECAP development. The municipality, with the support of the European Union, the World Bank (WB) and the Ministry of Regional Development and Infrastructure of Georgia, implemented the project 'Improvements in Housing and Infrastructure for Conflict Affected People'. In the framework of this project, the walls and floors of the IDP houses were insulated (for people affected by the conflict of August 2008, IDP settlements) in the Gori district.

Polotsk, Belarus

The pilot SECAP action is the installation of high-efficiency LED street lights in the main avenue of the city, Frantsysk Skaryna Avenue. Not only is LED lighting an environmentally friendly solution, it is also a very profitable investment. LED lights use only 10 % of the energy consumed by incandescent lights, their lifetime is over 50 times longer and their maintenance is significantly cheaper. New street lights are accompanied by an information board with some facts about the installation's energy savings and an indication that this pilot action has been financed within an EU-funded project.

1.4 Regulation and planning (governing by authority)

In addition to capacities as implementer, enabler, and provider, municipalities govern by authority through setting regulations and putting forth urban planning principles ([63]). Among other tools, municipalities can revise building codes to promote the improvement of energy efficiency in buildings, impose road charging to reduce congestion as well as incentive the use of renewable energy in the building stock for distributed generation. In the context of local energy generation, this mode of governing involves setting requirements on the mandatory use of renewable energy and ruling on strategic energy planning decisions.

Based on such tools as ordinances and strategic energy planning, the authority of local governments' can assist in addressing certain shortcomings for supporting niche markets and emerging technologies as well as insufficient guidance to inform decision-making for local energy generation (**Table 19**).

Table 19. Policy matrix for local energy generation organized by mode of urban climate governance

Mode of urban climate governance (Error! ookmark not defined.)	Tools	Barrier addressed	Action examples
Regulation and planning: Requirements and guidance in support of energy efficiency and local energy generation	Mandatory standards and building codes Regulation, controls and sanctions	Fragmentation and gaps in the regulatory action of public planning;	Prepare a comprehensive plan to improve energy efficiency in buildings; Develop building codes that addresses energy efficient buildings with minimum energy requirements (stricter than national ones); Introduce subsidies and bonus (e.g. reduction in development fees, expedited permit process or allowances for extra building floor/volume) for high efficiency buildings; Establish a supporting program to assist in the retrofitting of old buildings

([63]) OECD, Cities.

	Zoning, urban regeneration and mixed used developments	Sprawl and brownfields	Urban and transport planning is one of the basic function of municipalities. It has a significant effect on the intensity of urban energy use.
	Regulation and pricing in the transport sector	Disincentive the use of private vehicles and reduce congestion	Road pricing and congestion charges; Parking management
	Ordinances on the mandatory use of renewable energy	Lack of support for niche markets or emerging technologies	Mandatory installation of solar water heating/solar PV systems in new buildings; Construction of nearly or net-zero-energy buildings
	Revision of administrative procedures for energy projects	Uncertainty of administrative procedures	Advantageous conditions to projects in the "Public Interest"
	Strategic energy planning to support local energy generation	Insufficient guidance and access to data to better inform decision-making	Local maps with heat demand density and industrial waste heat;

Box 31 Icherisheher ('Old City') Azerbaijan

In July 2012, Icherisheher ('Old City'), the administrative body of Baku, the capital of Azerbaijan, agreed on the adhesion of the Covenant. Icherisheher administrative staff have good experience in implementing energy efficient measures in the transport sector, and in street and building facade lighting systems. In the Old City there are 452 buildings (1 023 apartments) situated for approximately 4 000 inhabitants.

Activities carried out and flowing action by Icherisheher ('Old City'): an electronic entering system for vehicles has been recently introduced. The outcome has been a 4–5–fold reduction in the number of vehicles entering Old City from 3 500–4 000 to 800–1 000 per 24 hours. There are also limitations for the entry of trucks. Heavy trucks of 5 tonnes and over may enter only with special permission, while all others lighter than 5 tonnes have special hours when they are allowed to enter. At the same time, there is high potential for electricity savings on household and business use as well as on street and facade lightening systems. Icherisheher has started a project on the renovation of street lighting.

Under the EU-funded programme 'Supporting the participation of Eastern Partnership and central Asian cities in the Covenant of Mayors', Icherisheher will develop SECAP through the organisation of capacity development/training, conducting assessments required, public consultation, organisation of awareness-raising events (energy and transport days,) development and implementation of demonstration project, and participating in regional and global networks.

Ukraine

Measures have been implemented in buildings for transforming the Market for Efficient Lighting in Ukraine. The goal of the project is to help transform the market towards more energy-efficient lighting technologies by removing barriers. The project aims at promoting a gradual phase-out of inefficient lighting products in residential and public buildings ( ).

EU programme of financial and technical cooperation with Ukraine. The list of projects includes key information on ongoing EU-funded projects on energy and water ( ).

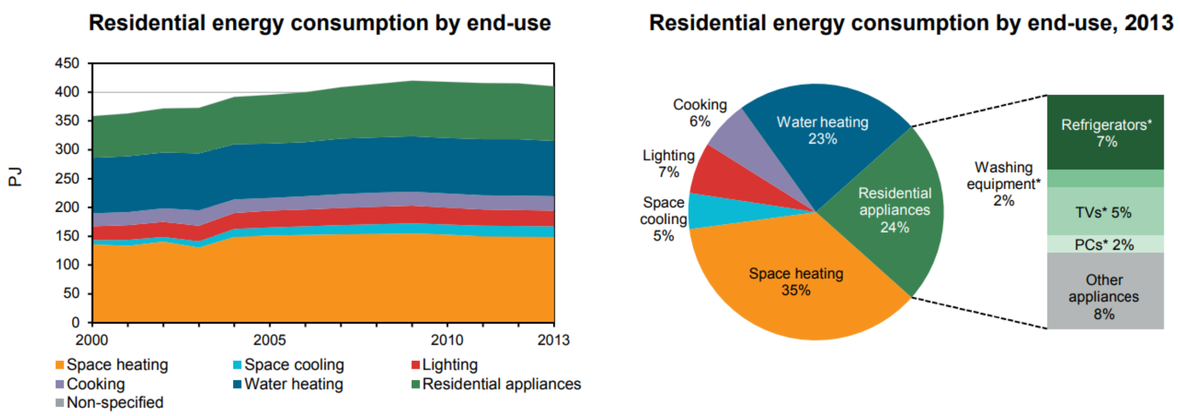
Municipal Heating reform in Ukraine. The USAID project cooperates with the government of Ukraine and local authorities to create a financially viable and stable district heating sector that delivers reliable and quality services to the population, public institutions and local industries.

2. Buildings

Energy consumption in buildings is a large share of the world's total end use of energy. Globally, residential and commercial buildings require approximately 40% ([64]) total end use of energy. Given the many possibilities to reduce buildings' energy requirements, the potential savings of energy efficiency in the building sector would greatly contribute to a reduction of energy consumption. As this reduces greenhouse gas emission, the municipalities should pay a particular attention to the building sector.

Energy is used in buildings for various purposes: heating and cooling, ventilation, lighting and the preparation of hot sanitary water among them. A large part of the energy consumption in residential buildings are used for direct building related use such as space heating, which accounts for more than 50 % in selected IEA Countries (**Figure 15**).

Figure 15: Energy use in residential buildings



Source: IEA

Building-related end-uses - heating, cooling, ventilation and the preparation of hot sanitary water - require approximately 65% of a residential building's energy demand. For service buildings, the share of energy use for other purposes will often be larger and for some types of service buildings it can be more than 50%.

The demand for energy in buildings is linked to a significant number of parameters related to construction design and the usage of the facilities. It is influenced by the following factors:

- Geometry of the building;
- Performance of building envelope;
- Efficiency of equipment, such as type of heating, air conditioning and lighting systems;
- Usage patterns, management of the building and occupancy behaviour;
- Orientation of the building

Additional recourses:

— Report of International Energy Agency "Cities, Towns and Renewable Energy: Yes in my front yard" (2009): The report shows how renewable energy systems can benefit citizens and businesses, and it highlights the role of local municipalities that have the power to influence the energy choices of their citizens. Report includes several case studies chosen to illustrate how enhanced deployment of renewable energy projects can bring benefits, regardless of a community's size or location.

([64]) Source: IEA

- The report “Analysis of Concerto Energy concepts and guidelines for a whole building approach” published within the EU-project ECO-City – Joint Eco City developments in Scandinavia and Spain. The objectives of the report is to demonstrate innovative integrated energy concepts in the supply and demand side in three successful Communities in Denmark/Sweden, Spain and Norway:
- The example of legislations developed for EU countries can be found European Union Law Database EUR-Lex.
- The chapter on energy use in buildings of Working Group III of the Fourth Assessment Report (AR4) of the Intergovernmental Panel of Climate Change. The chapter summarises the different strategies, technologies and systems that can be used in order to reduce the energy consumption in buildings.
- The Sustainable Buildings Centre is an IEA network with focus on policies and measures that lower the energy demand of the buildings sector

2.1 Considerations related to policies in the building sector

Following are some suggestions of policies that can be implemented at the local level in order to boost energy efficiency and renewable in buildings ([65]).

- Regulations for new/renovated buildings:
  - Adopt stricter global energy performance standards than those applicable at national/regional level, especially if such standards are not particularly demanding. Depending on the national/regional regulatory context, local authorities may be able to adopt such standards in their urban planning rules and regulations. Global energy performance standards leave many options open to building designers to choose how they will reach the objectives set. In principle, architects and building designers should be familiar with those norms, as they apply to the entire national/regional territory. Generally, fewer options exist to reduce energy consumption with refurbishments than for new buildings; therefore, the requirements are generally less stringent. Eventually they may be adjusted according to the building's characteristics.
  - Adopt specific standards for building components (thermal transmittance of the envelope, of windows, efficiency of the heating system, etc.). This option has the advantage of being simple to understand and guarantees the minimal performance of the components, even if the overall performance cannot be achieved.
  - Impose the inclusion of some components that will help to improve the energy efficiency (shading devices, presence of meters that record the energy consumption, heat recovery devices for mechanical ventilation, etc.). This can be done as a general rule that would apply to all new buildings, or could be imposed on a case-by-case basis, according to a building's characteristics (e.g. impose the installation of shading devices for buildings with a significant glazing surface oriented towards the south).
  - Impose a certain quantity of renewable energy production/usage, in particular in public buildings.
  - Adopt energy performance standards for renovation works that are not considered as 'major renovation' by national/regional law, and for which no energy performance standards apply.
- Enforcement of regulations:

([65]) USAID — Energy Efficiency in Buildings in Tajikistan. The project aims at demonstrating the potential of RES and EE technologies for improved heating services in the urban residential sector of Tajikistan http://www.carecnet.org/

- Ensure that the energy performance standards are respected in practice and apply penalties if necessary. It is recommended to adopt both 'on paper' and 'on site' verifications. The presence of a representative of the authority at some point during construction/renovation works will clearly show that the authority is taking the regulations seriously, and will help to improve the practices of the construction sector at the local level.

— Financial incentives and loans:

- The local authority could complement the financial support mechanisms existing at national or regional levels with extra financial incentives for EE or RES. Such a scheme could focus on the global energy performance of buildings (e.g. the incentive could be proportional to the difference between a minimal threshold of energy performance, calculated according to the existing national/regional standards, and the level of performance actually achieved), or could be used to support specific techniques that the local authority would consider of particular relevance for new buildings, considering its own context and objectives (thermal insulation, RES, etc.). The latter option is particularly relevant for renovated buildings, for which the precise calculation of overall energy performance is generally less easy than for new buildings. Ideally, the financial incentive would cover (part of) the difference between the cost of 'standard construction work' and a construction/renovation that is considered as energy efficient.
- In addition, the local authority could provide financial support for the purchase of energy efficient equipment that allows the reduction of energy consumption of buildings (efficient light bulbs, efficient appliances, etc.).
- Although financial incentives do reduce the cost of investment related to EE, investors (either citizens, private companies, etc.) still have to face up-front payments. To facilitate the access to capital, the local authority may liaise with local banks and financial institutions so that low-interest loans are available for EE or RES.
- Even if the budgets that the local authority can devote to such subsidies is not immense, they could still make a great difference in terms of citizens' motivation: with proper communication, such subsidies could be seen as a clear sign that the local authority is willing to achieve success in the field of energy and climate policy, and that it is willing to support its citizens in this direction.

— Information and training:

- Make the relevant stakeholders (architects, building developers, construction companies, citizens, etc.) aware of the new energy performance requirements for buildings, and provide them with some motivating arguments (the savings on the energy bills can be highlighted, as well as the benefits in terms of comfort, environmental protection, etc.).
- Inform the general public and key stakeholders about the importance and benefits of behaviour favouring the reduction of energy consumption and CO_2 emissions.
- Involve local companies: they may have an economic interest in the EE and renewable energy business.
- Inform stakeholders about the resources available. For example, where can the information be found, what are priority measures, who can provide proper advice, how much does it cost, how can households do proper work by themselves, what are the tools available, who are the local competent architects and entrepreneurs, where can the necessary materials be purchased locally, what are the available subsidies? This could be done via info days,

brochures, an information portal, an information centre, a helpdesk and other means.

- Organise specific info and training sessions for the architects, workers and construction companies: they must become familiar with the new design and construction practices and regulations. Specific training could be organised to cover basic issues (basic building thermal physics, how to properly install thick insulation layers) or more specific issues that are often neglected (thermal bridges, building air tightness, natural cooling techniques, etc.).
- Make sure the tenants, owners and managers of new and renovated buildings are informed about the building's features: what makes this building energy efficient, and how to manage and operate the equipment and facilities offered in order to obtain good comfort and minimise the energy consumption. All the technical information needs to be passed on to technicians and maintenance companies.

— Promote successes:

- Encourage people to build efficient buildings by offering them recognition. For example, buildings significantly above the legal standards of energy performance could be made visible by, among other means, a label, open day visits, an exhibition at the town hall, an official ceremony and signposting on the local authority's website. The energy performance certificate, which is a requirement of the Energy Performance of Buildings Directive (see above), could be used for this purpose (e.g. the local authority could organise a contest for the first 'Label A' buildings built in the municipality). Other standards can be used as well, such as 'passive house' standard.

— Demonstration buildings:

- Demonstrate that it is feasible to build energy-efficient buildings or to make renovation with high-energy performance standards. Show how it can be done. Some high-performance buildings could be open to the public and stakeholders for this purpose. It does not necessarily need to be a high technology building — the most efficient ones are sometimes the simplest ones: the problem with EE is that it is not always quite visible (think about thick insulation, for example). However, listening to the owner and the occupants talking about their experience, their reduced energy bills, their improved comfort and other advantages should already be worthwhile. Visits during construction stage could be interesting for training and educational purposes for construction companies and architects.

— Promote energy audits:

- Energy audits are an important component of EE policy as they enable identifying, for each audited building, the best measures allowing for the reduction of energy consumption. Therefore, the local authority could promote such audits via the dissemination of proper information, ensuring the availability of competent auditors (training, etc.), providing financial support for audits and other means (see Part III of this Guidebook for more information on energy audits).

— Urban planning:

- Urban planning is a key instrument to boost and plan refurbishments. In addition to setting energy performance standards, as mentioned above under 'regulation', urban regulations should be devised in such a way as not to deter EE and RES projects. For instance, long and complex authorisation procedures to install solar panels on the roofs of existing buildings will be a clear obstacle to RES promotion and should be avoided.

— Increase the rate of refurbishment:

- By accelerating the rate of buildings undergoing energy efficient refurbishments, the impact of the above measures on the energy and CO_2 balance will increase. Some of the above measures, and in particular urban planning, financial incentives, loans or information campaigns about the benefits of energy efficient renovations, are likely to have such an effect.

— Energy taxes:

- Higher energy prices generally increase awareness and motivation towards energy savings. If the local authority has the legal power to do so, it may decide to levy taxes on energy. However, the social consequences of such a measure should be evaluated and debated thoroughly before such a decision is made. In addition, an adequate communication plan should be devised to ensure citizens understand and adhere to such a policy. The question related to the usage of tax revenues should also be dealt with in a very transparent manner (e.g. financing an EE support fund, financial compensation for vulnerable citizen groups, etc.).

— Coordinate policies with other levels of authority:

- A number of policies, instruments, tools in the field of EE of buildings and RES exist at regional and national levels. We recommend that the local authority has a good view of these, in order to avoid duplication, and to take maximum advantage of what already exists.

Some recommendations for public buildings:

- Management of public buildings: a local authority often has control over a large number of buildings. Therefore, a systematic approach is recommended in order to ensure a coherent and efficient energy policy covering the entire building stock over which the local authority exercises control. Such an approach could:
- identify all buildings and facilities owned/managed/controlled by the local authority;
- collect energy data related to those buildings and set up a data management system;
- classify the buildings according to their energy consumption, both in absolute values and per square metre or other relevant parameters like: number of pupils for a school, number of workers, number of users for libraries and swimming pools, etc.;
- identify buildings that consume the most energy and select them for priority action;
- prepare an action plan (part of the SECAP) in order to progressively reduce the energy consumption of the building stock;
- nominate someone in charge of implementation of the plan!;
- verify that the commitments and obligations of the contractors, in terms of EE, are met in practice and apply penalties if this is not the case. Onsite verifications during construction are advisable (e.g. thick insulation that is not adequately placed will not be very efficient);
- recycle the savings: if the local authority's financial rules allow doing so, savings obtained through simple and low-cost measures could be used to finance larger EE investments (e.g. revolving funds).

2.2 Key measure related to building types

2.2.1 New Buildings

As the lifespan of most new buildings is relatively long, their energy efficiency will influence energy consumption for many years. The decision made at the design stage will thus have crucial impact on the energy performance of the building over decades of building use. It is therefore essential that the energy dimension is included as early as possible in the planning and design phases of new buildings. If energy efficiency is incorporated in the early design phase, it is often considerable less expensive, as the form of the building, its orientation, the orientation of its windows, and its structural materials do not bear additional costs.

New buildings can benefit from an integrated design approach, whereby the building performance can be optimised by taking into consideration the interaction of all building components and systems through an iterative process involving all players. An energy performance target can thus be set based on a holistic approach at an early stage of the project, and energy-efficient strategies and technologies can be chosen in view of the climatic conditions and occupant needs. As the energy performance of new buildings decreases, the impact of embodied energy ([66]) will become increasingly important in relation to the operational energy of the building throughout its lifetime.

Optimising the orientation can maximise daylight, minimise heat gains summer and heat losses in winter, which can have a significant impact on heating, cooling and lighting needs. Great opportunity lies in simple design solutions of buildings that respond to location and climate. For instance, for most North American sites ([67]), simply facing the long side of a building within 15 degrees of true south (and using proper shading to block summer, but not winter sun) can save up to 40% of the energy consumption of the same building turned 90 degrees.

Making the building envelope (exterior walls, roof, and windows) as efficient as possible for the climate can also significantly reduce heating/cooling loads, especially in small buildings (the so-called skin dominated building). For such buildings, optimal insulation, high performance windows, ceiling, radiant barriers and reflective insulation systems, combined with heat-recovery ventilation, can reduce heat losses to the environment. Passive solar and internal heat gains can be harnessed in order to offset the remaining heat losses. For warmer climates, reducing the cooling load is possible through various measures such as self-shading through clustering of buildings, highly reflective building materials, improved insulation, night-purge ventilation, installation of fixed or adjustable shading systems etc.

2.2.2 Existing Buildings

Major renovations or refurbishment, occurring at 30-50 year intervals during a building's lifespan, aim to replace or repair parts of a building, such as windows, doors and outdated equipment in the context of new technology and requirements for functionality.

When an existing building is subject to a major refurbishment, it is the ideal opportunity to improve its energy performance. In general between 1.5 % and 3% of the building stock is renovated each year, so that if energy performance standards are applied to such refurbishments, in a few years the energy performance of the entire building stock shall improve accordingly.

([66]) Embodied energy refers to the energy consumed by all processes related to the construction of the buildings (e.g. mining and processing of natural resources to manufacturing, transport and product delivery).

([67]) Energy Efficiency Requirements in Building Codes - Policies for New Buildings. IEA, 2008. Available for download at http://www.iea.org/publications/freepublications/publication/Building_Codes.pdf

The energy consumption of existing buildings can be reduced by upgrading the windows (e.g. using double or triple glazed technology), adding internal or external insulation (if feasible) to walls during renovations, upgrading the heating and cooling systems, insulating the roofs and reducing the air leakage of the building envelope and ductwork. The cost of different technologies is usually a key factor when choosing the preferred measures. This can be determined through a lifecycle analysis, taking into account investment costs, maintenance and operating costs, earnings from energy produced and disposal costs (if applicable). Energy efficient measures will typically have higher investment costs compared to conventional ones but will result in reduced energy costs, hence are more profitable in the long term.

When considering large investments or refurbishments, it is recommended to make an energy audit in order to identify the best options, allowing the reduction of the energy consumption and preparation of an investment plan. Investments may be limited to a building component (replacement of an inefficient heating boiler) or may be related to the complete refurbishment of a building (including building envelope, windows …). It is important that the investments are planned in a proper manner (e.g. first reducing heat demand by dealing with the envelope and then placing an efficient heating system, otherwise the dimensioning of the heating system will be inappropriate, which results in unnecessary investment costs, reduced efficiency and greater energy consumption).

2.2.3 Public Buildings

The local authority should provide an example to a community by implementing and adapting measures of energy efficiency in public buildings, because the sector of public buildings falls under municipality control ([68]). In addition to promoting energy efficiency to the broader public, a leading role for the public sector can help kick start the energy efficiency market for renovation and subsequently bring costs down for private households and businesses. The sector of public buildings considers all buildings that are owned, rented, managed or controlled by the local, regional, national or public administration.

When planning new constructions or renovations, the local authority (if such power is confirmed by national legislation) should set the highest energy standards possible and ensure that the energy dimension is integrated into the project. Energy performance requirements or criteria should be made mandatory in all tenders related to new constructions and renovations.

Different possibilities do exist, which can be combined:

- Refer to the global energy performance norms existing at national/regional level and impose strong minimum global energy performance requirements (i.e. expressed in kWh/m2/year, passive, zero energy). This leaves all the options open to the building designers to choose how they will reach the objectives (provided they know how to do it). In principle, architects and building designers should be familiar with those norms, as they apply to the entire national/regional territory; The example of such norms can be found in the Energy Performance of Buildings Directive (2002/91/EC) ([69]), where EU countries are obliged to set up a method to calculate/measure the energy performance of buildings and to set minimum standards.
- Impose a certain quantity of renewable energy production while preparing new construction site and object;

([68]) IT-Toolkit for energy efficient retrofit measures in government buildings: http://www.annex46.de/tool_e.html
([69]) For countries that are members of Energy Community Treaty. More information on Energy Community Treaty: http://www.energy-community.org.

- Request an energy study that will help to minimise the energy consumption of the building considered by analysing all major options to reduce energy, as well as their costs and benefits (reduced energy bill, better comfort, …);
- Include the building's projected energy consumption as an award criterion in the tender. In this case, energy consumption should be calculated according to clear and well defined standards. A transparent system of points could be included in the tender: (ex: zero kWh/m² = 10 points; 100 kWh/m² and above = 0 points).
- Include the cost of energy consumption over the next 20-30 years in the cost criteria in the tender (do not consider the building construction cost alone). In this case, hypotheses related to future energy prices have to be set and energy consumption should be calculated according to clear and well defined standards.

Box 32. Public Building Energy Conservation and Emission Reduction Moldova

Under the World Bank's Moldova Energy II Project, energy efficiency and fuel switching measures for 20 public buildings (including schools and hospitals) in 13 municipalities resulted in a significant reduction of GHG emissions.

The estimated results included emission reduction of 12 kilotons of carbon dioxide per year over 10 years, resulting in a 20% reduction in fuel consumption in the participating buildings.

The overall project cost was US$39.93 million. Of this amount US$9.1 million was allocated to heating supply and efficiency improvements. The carbon financing provided via UNFCCC CDM mechanism over the project crediting period were US$347,000.

Despite the clear opportunities and benefits of energy efficiency in public buildings, a number of institutional and organizational factors contribute to wasteful or inefficient use of energy in public buildings, including:

Lack of attention and leadership on energy efficiency from top management and elected officials due to higher priorities in other sectors of social importance:

- Divided responsibilities for energy management and capital investment among several agencies or departments of the same government (such as, a "landlord" government services agency, tenant organizations, the budget office, the design and construction authority).
- Little direct incentive for the agency occupying the building to save energy or reduce operating costs (for instance, the agency may not pay utility bills or even rent; and savings go back to the general fund and are not available to the agency for other purposes).
- Limited in-house technical capacity and skills to manage energy use efficiently – which is exacerbated by staff turnover.
- Budget constraints and a limited ability to commit to a multi-year financial obligation such as a third-party energy performance contract or lease of efficient equipment.
- Laws or regulations, common in many countries, that restrict government agencies' ability to borrow funds that are to be repaid from future tax revenue and budget appropriations.

To help overcome these barriers, many programs to improve energy efficiency in public buildings have depended on external technical assistance from donor agencies or worked through networks of municipalities (the CoM-Dep, ICLEI, NALAS, etc.).

The success of all of these types of measures is much more likely if a number of conditions are met. These include:

- Existing legal framework: As other modules in this training series explore in depth, it is important that efficiency efforts be supported by some type of EE law (or EE provisions in relevant laws, such as Laws on Energy, Urban Construction, or Environment).
- Champions: Especially in ministries with small staff sizes and high turnover rates, the successful adoption and implementation of energy efficiency policies and programs often depends on champions inside the government who understand and actively support these efforts.
- Funding: Passage of a law or policy is only the first step. Successful enforcement and implementation of energy efficiency policies and programs is only possible when adequate funding is also made available.
- Creative thinking: Those policymakers who believe that energy efficiency improvements require large investments often underestimate the potential of innovative low-cost measures, such as public outreach and education, which can have tremendous and measurable results.
- Desperate circumstances: Energy shortages and other critical circumstances can help trigger such creative thinking. For example, when Serbia faced a significant electricity deficit, and citizens for the first time faced steep increases in electricity prices, a public outreach campaign (featuring a 20-minute documentary that played 5,300 times across the country) resulted in a 20 percent reduction in consumer electricity use. Similarly, when Ukraine was desperate to reduce gas consumption due to the instability of the Russian gas supply, a public awareness campaign "Save Heat, Save Ukraine!" (mainly financed with corporate social responsibility funds that leveraged USAID funding) resulted in major behavioural changes in space heat conservation.

2.2.4 Historical Buildings

Historic buildings possess cultural, architectural, historical, social and other values. For these buildings, the primary purpose is the preservation and transmission to future generations, under the best possible conditions. As a consequence, specific methods and procedures are required to deal with them.

The energy retrofits for historic buildings must be the result of a balanced process that involves multiple expertise with a mutual feedback: from architectural to technical aspects, from the cultural to the political ones. Moreover, the retrofit, when carefully and holistically developed, may be also considered as a tool to preserve these buildings for future generation, while addressing the current environmental and energy current needs. In order to promote tailored retrofit approaches designed for the specificities of the building, multiple criteria and methods have been developed.

However, there are some methodological points that are in common in the available retrofit strategies: a preliminary deep assessment of the building, the cooperation between different institutions and professionalisms, the development of a decision making process, the choice of strategies and technologies to be used with a case to case approach.

The following list provides a framework that contains some of the common criteria and assessment methods used in retrofit strategies, which can be furtherly detailed with specific insights and elaborations linked to the peculiarities of the building and its surroundings [66].

- Assessment methods:

These methods are used for a preliminary investigation of the building with the aim of increasing the general knowledge of its performance, components and construction procedures. Some measures are developed in the site of the building. They mainly refer to microclimate, thermal comfort and the building envelope. There are also laboratory tests and simulations to foreseen the performance of the building under certain circumstances.

- Energy consumption, energy production and energy supply:

Measures to reduce the energy consumption of the buildings usually affect the building envelope, the HVAC system and the occupant's behaviour. However, it must be considered that historic and traditional buildings were often designed taking into account the local climatic conditions, and hence, they may have a good energy performance. Some typologies of retrofits are usually excluded a priori because they impact the aesthetic and technology compatibility of the building.

The introduction of renewable energy production in this kind of buildings needs preliminary investigations to choose both the suitable technology with a special focus on the up-to-date techniques [67] (such as PV modules integrated into elements of building envelope) and the best application solution that may allow a good visual integration in the architecture. Biomass boilers and CHPs are forms of energy supply with no or low visual impact on the building.

2.3 Measures for energy efficient buildings

All the processes that are involved in the energy efficiency of buildings, from the design and the construction, to the renovation and operation, recognize the provision of healthy and comfortable environments to its occupants as the main purpose of any buildings. The 'sustainable comfort' can be defined as achieving good comfort conditions with no or limited use of resource energy and through the use of environmentally non-harmful materials.

In this framework, a ten-step approach is provided to improve the energy efficiency of buildings, which implies also adopting measures on both thermal and electric energy (e.g. through reducing the wall transmittance in the former and using efficient appliances in the latter). The approach leaves ample freedom to designers while supporting them in adopting solutions that also take into consideration local specificities of climate, culture, locally available materials:

1. Define explicitly the building objectives, with particular focus on the thermal comfort.
2. Assess the microclimatic factors and intervene on the site layout and features which can affect the comfort indoor.
3. Control the heat gains at the external surface of the building envelope.
4. Control and modulate heat transfer through the building envelope.
5. Control the internal gains from appliances and lighting.
6. Allow for local and individual adaptation.
7. Use passive means and strategies to deliver and remove thermal energy to/from the building.
8. Use active heating and cooling systems assisted by natural (and renewable) energy sources.
9. Use high efficiency active conventional heating and cooling plants, if still necessary.
10. Train building managers and occupants on how to use, monitor the performance of and adequately operate and maintain the building.

The first two points refer to the comfort requirements and the multiple interactions between indoor and outdoor environments. Steps 3 and 4 include all technologies and strategies associated to the building envelope from which the net thermal energy needs for heating and cooling depend. Steps 5 and 6 have to do with the way a building is used and occupied. Points 7, 8 and 9 provide a sustainable approach to reach low levels of delivered (or final) energy consumption implementing appropriate system solutions. The last step includes all strategies needed to verify and adapt the building performance during the real-life operation.

Mostly, the suitability of energy-efficient solutions mainly depends on the micro-climate conditions and their cost-effectiveness. The economic issue is related to the maturity of the local market (of materials, technologies and jobs) and to the construction type (i.e. new building or building retrofit). The tables below provide an overview of the prevailing technologies and strategies, which could be considered for cold and intermediate/warm climates (**Table 20**) in accordance to the methodological step (introduced above) and the building type.

Table 20. Building technologies and strategies for cold, warm and intermediate climates, according to methodological step and construction type.

Cold Climate (Heating degree days > 3 350)		**Warm and intermediate Climate** (Heating degree days < 3 350)	
New building	**Renovation**	**New building**	**Renovation**
- Summer Adaptive comfort - Optimised distribution of internal spaces		- Summer Adaptive comfort - Optimised distribution of internal spaces	
- Main building axis oriented east-west and optimised distribution of internal spaces		- Main building axis oriented east-west - Cool materials and finishing for urban surfaces - Inclusion of greening strategies in the design (vegetation and surface water)	- Cool materials and finishing for urban surfaces - Inclusion of greening strategies in the design
- Triple or double-glazed low-e windows	- Double-glazed low-e windows - Exterior storm windows with low-e coating - Internal insulated shades	- Architectural shading - Reflective (cool) roof - Ventilated roof, double-skin façades - Double-glazed low-e or windows with low g-value - Exterior window shading/blinds and dynamic shading - Finishing material - Low heat conductivity building materials	- Reflective (cool) roof - Double-glazed windows with low g-value - Exterior window shading/blinds and dynamic shading - Window film reducing g-value - Finishing material - Low heat conductivity building materials
- Highly insulated roof, external walls and basement - Reduction of thermal bridge - Windows and doors with high airtightness levels	- Medium-highly insulated roof, external walls and basement - Main envelope joints thermal bridge free - Windows and doors with good airtightness levels	- Medium-highly insulated roof and external walls - Optimised thermal mass inertia	- Medium insulated roof and external walls - phase-change materials
- Daylighting solutions - Efficient lighting sources & syst. - Efficient appliances & equip. - Smart shutdown logics	- Efficient lighting sources and systems - Efficient appliances and equipment - Smart shutdown logics	- Daylighting solutions - Very efficient lighting sources and systems - Very efficient appliances and equipment - Smart shutdown logics	- Very efficient lighting sources and systems - Very efficient appliances and equipment - Smart shutdown logics
- Openable windows - Flexible dressing code	- Openable windows - Flexible dressing code	- Openable windows - Ceiling fan - Low thermal insulation furniture - Flexible dressing code	- Openable windows - Ceiling fan - Low thermal insulation furniture - Flexible dressing code
- Architectural features - Dynamic glass/shades - Comfort daytime and night ventilation - Ground heat exchanger	- Dynamic glass/shades - Comfort daytime and night ventilation	- Architectural features - Dynamic glass/shades - Comfort daytime and night ventilation - Ground heat exchanger - Direct or indirect evaporative cooling - Radiative cooling - Open groundwater or surface water systems	- Dynamic glass/shades - Comfort daytime and night ventilation
- Ground source heat pump	- Ground source heat pump	- Ground source heat pump - Solar cooling systems	- Ground source heat pump - Solar cooling systems

- Very efficient HVAC systems - Condensing boiler - Highly insulated distribution plant - Straight distribution ducts layout and efficient fans/pumps	- Very efficient HVAC systems - Condensing boiler - Highly insulated distribution plant - Straight distribution ducts layout and efficient fans/pumps	- Very efficient HVAC systems - Condensing boiler - Insulated distribution plant - Straight distribution ducts layout and efficient fans/pumps	- Very efficient HVAC systems - Condensing boiler - Insulated distribution plant - Straight distribution ducts layout and efficient fans/pumps
- Exhaustive building manuals - Monitoring plan - Maintenance plan	- Clear and exhaustive building manuals - Monitoring plan - Maintenance plan	- Clear and exhaustive building manuals - Monitoring plan - Maintenance plan	- Clear and exhaustive building manuals - Monitoring plan - Maintenance plan

2.3.1 Improvement of the envelope and other aspects

One of the most common strategies for energy retrofit of buildings usually consists in reducing both thermal losses through the envelope and cooling loads, and in controlling the solar heat gains.

The losses of energy through the envelope may be reduced through the implementation of several measures that affects glazing and frames and the walls and roofs characteristics.

- Gains and losses of energy through windows are four to five times higher than the rest of the surfaces. Both daylight provision and gaining or protecting from solar radiation penetration must be taken into account in the choice of appropriate glazing. New technologies with decreased values of transmittance for glazing are available: double-glazed with low emissivity coating, low-Emissivity Argon filled double glazing and triple glazing (respectively up to 1.1 $W/(m^2 \cdot K)$ and 0.7 $W/(m^2 \cdot K)$). Moreover, since the characteristics of frames affect the global window performance, it is necessary to consider also the replacements of these elements in the energy retrofitting of the building. In this regard, thermal break aluminium, plastic and wooden frames show good performances.
- Either internal or external thermal insulation of walls reduces their transmittance values according to specific needs and location of the buildings. Commonly-used types of insulation in building construction include: Fibreglass, Polyurethane foam, Polystyrene foam, Cellulose insulation and Rock wool. These materials also contribute to reduce the effect of thermal bridge and to improve sound insulation and thermal inertia.
- The abatement of cooling loads is achieved by reducing solar radiation penetration through the use of shading devices. These comprise: movable devices which can be controlled either manually or automatically; internal and external blinds which help control lighting level and uniformity, and allow stopping solar radiation before penetrating into the room when arranged externally.
- An increased energy performance of buildings is achievable by operating on the heating system. The overall efficiency of the space heating system includes the efficiency of the generator and the losses of distribution, emission and inaccurate control systems.

Other simple measures may contribute in the reduction of energy consumption in buildings and in configuring sustainable buildings simultaneously. Along with lower environmental impact, sustainable buildings are relatively low cost to run and in the long term, more valuable properties ([70]). Some of the policies described below may need to be supported by specific political strategies adopted by the local authorities.

— Behaviour and building management: adequate behaviour of building occupants may also generate significant savings. Information and motivation campaigns could be organised in order to get support of the occupants. In such cases, it is important that a good example is also given by the hierarchy and by the authorities in charge of the building management. There are numerous social approaches that may help in achieving a behaviour change: Sharing the savings between occupants and the local authority could be a good way of motivating action; cooperating to reach a common environmental goal (families in the same building can work together); competitive approaches provide motivation among occupants especially if publicly recognised. Publicly displaying the energy certificate of the building is an example of sharing that may induce the mentioned approaches among citizens. Moreover, special efforts must be concentrated to lower the rebound effect. Expected energy savings might be reduced by behavioural reactions, which induces an increase in

([70]) LEVEL(s) PROJECT http://ec.europa.eu/environment/eussd/buildings.htm the usage of energy-consuming technologies, made less expensive by efficiency itself.

- Some student-oriented projects ([71]) aimed at teaching them good practices have been developed or are now under development. These projects propose including positive-energy patterns in curricula in order to make students aware of the benefits of energy-efficient behaviour [68]. These initiatives are not only focused on students, but also on parents. In fact, the idea is to bring energy efficiency to the home from school. Significant energy saving reductions through motivation and information in a citizen competition can be seen from the IEE Project Energy Neighbourhood http://www.energyneighbourhoods.eu/gb/
- The management of technical installations in buildings may lead to energy savings: make sure heating is turned off during week-ends and holidays, make sure lighting is off after work, fine tuning of the heating/cooling operation, adequate set points for heating and cooling. For simple buildings, a technician or an energy manager could be appointed for such tasks. For complex buildings, the help of a specialised company may be necessary. Therefore, it may be necessary to renew or set up a new contract with a competent maintenance company with adequate requirements in terms of energy performance. Be aware that the way the contract is drafted could highly influence the motivation of such a company to effectively find out ways of reducing energy consumption.
- Monitoring: implement a daily/weekly/monthly monitoring system of energy consumption in main buildings/facilities, allowing the identification of anomalies and taking immediate corrective action. Specific tools and software exist for this purpose.
- Retro-commissioning: improve the efficiency of equipment and systems in existing buildings. It frequently addresses issues developed throughout the building's life. It consists in the adaptation and regulation of the technical installations to the current uses and owner's requirement (bring equipment to its proper operational state, improve indoor air quality, increase equipment lifespan, and improve maintenance operations and others). The Retro-commissioning ([72]) requires small investments related to the control and regulation of the technical installations which, however, may generate significant savings. Maintenance: good maintenance of the HVAC systems may also reduce the energy consumption with low budgets.
- Location: buildings in winter climates are especially suitable to incorporating passive solar heating strategies that will reduce the heating loads. In contrast, buildings located in summer climates will require active protection against solar radiation in order to minimise cooling loads. Natural ventilation strategies help to increase the comfort in buildings and, hence, wind characteristics and building shapes should be studied in detail.
- Hours of operation: The most energy-intensive building types are those in continuous use, such as hospitals. In these buildings, the balance of heating and heat removal (cooling) may be dramatically different from that of an office building with typical working hours. For example, the around-the-clock generation of heat by lights, people, and equipment will greatly reduce the amount of heating energy used and may even warrant a change in the heating system. Intensive building use also increases the need for well-controlled, high-efficiency lighting systems. Hours of use can also enhance the cost effectiveness of low-energy design strategies. In contrast, buildings scheduled for operations during abbreviated hours, should be designed with limited use clearly in mind.

([71]) Further information on energy efficiency at school available on www.pees-project.eu . Project supported by Intelligent Energy Europe.
([72]) Book: Energy Efficiency Guide for Existing Commercial Buildings: The Business Case for Building Owners and Managers published by ASHRAE.

Most of these measures, along with renewable energy production, are frequently implemented in low energy buildings. The energy-saving potential for this type of building is in the range 60-70%.

Box 33. Improving the indoor environment in Khidistavi School, Gori (GE)

A project on improving the indoor environment was implemented in Khidistavi School (municipality Gori). The building, constructed in 1973, was heated with 22 inefficient wooden stoves and with five electric space heater with 2,2 kWh capacity. School used inefficient bulbs for lighting. School had no central heating, ventilation or air conditioning systems. The unvented wood heaters created unhealthy indoor environment, while providing insufficient heat comfort in winter periods.

Energy audit suggested improving existing condition in the building by implementing the following energy efficiency measures:

- Changing the single-glazed, old wooden frame windows by double-glazed plastic frame windows in the classrooms

- Installation wooden burning boiler and heating systems in the classrooms.

- Installation 125W solar PV and 400W wind generator for electricity supply of heating system circulation pumps.

- The building consumed totally 262 MWh per year prior implementation of energy efficient measures. According to the post-implementation monitoring results, energy consumption in the school reduced by 22% (59 MWh/year). Implementation of small-scale energy-efficiency measures can lead to significant energy and costs savings combined with relatively short payback for some EE measures.

Source: http://www.eecgeo.org/en/projects.htm

2.3.2 Operation and Maintenance

A modern building represents a large investment for the building owner. In addition to the building structure and envelope, building functions rely on installed equipment and systems such as:

- heating, ventilation, and air-conditioning (HVAC) systems
- water heating
- lighting
- fans, pumps, and motors
- elevators
- fire alarms and sprinklers.

All of these systems require proper operation and maintenance to ensure that they function as intended and achieve their optimal efficiency and lifetimes.

Experience has shown that effective O&M is one of the most cost-effective methods for promoting energy efficiency and waste reduction, and provides immediate results. Proper O&M also saves other resources (such as water and labor) and helps to ensure reliability and safety of building systems and equipment.

Inadequate operation and maintenance of energy-using systems -- including losses from steam, water, and air leaks; uninsulated systems; poorly adjusted or inoperable controls; and lack of routine equipment upkeep -- are major causes of waste and expense in buildings.

Due to a variety of reasons – including budget issues, lack of knowledge and capacity, deferred maintenance, and poor training – most public buildings do not have adequate

O&M and are therefore operating at lower efficiencies than designed. Focusing on improving the energy-related O&M of buildings generally provides significant benefits, in terms of energy savings as well as equipment longevity, by maintaining the building at its design efficiency. Since public sector facilities are owned and occupied for an extended period of time by the same entities (for example, government agencies) and for the same functions, the value of effective O&M is particularly compelling in this sector.

There are three main reasons for establishing routines for proper operation and maintenance of building systems:

1. Achieve optimal and/or planned operational performance of the building, and thus help ensure safe, comfortable, and healthy working conditions
2. Keep the operation costs, including energy costs, as low as possible on a permanent basis
3. Prevent large and expensive repairs

A study of U.S. buildings by PECI, a non-profit conservation organization, estimated that O&M programs targeting energy efficiency can could save 5 to 20 percent on energy bills without a significant capital investment. For both small and larger buildings, these savings can represent thousands to hundreds of thousands of dollars each year, and many O&M improvements can be achieved at minimal cost.

In addition to the potential for direct energy and cost savings, a well designed and robust O&M program can have a number of other benefits:

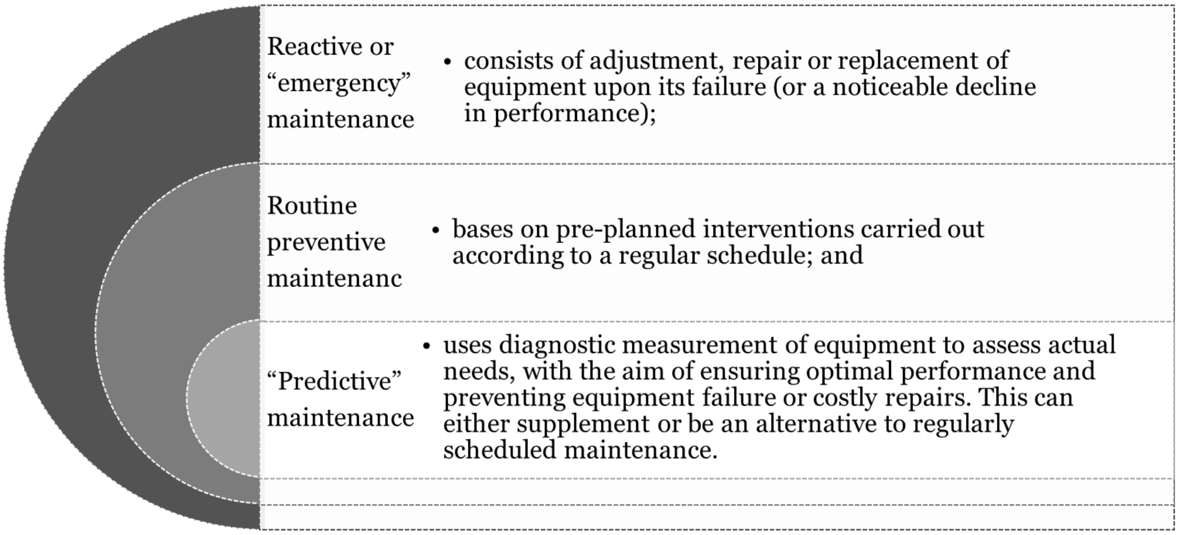
- Safety: A well-functioning O&M program avoids potential hazards from deferred maintenance.
- Health and other employee benefits: Proper O&M reduces the health risks (and associated staff sick days and medical costs) resulting from poor indoor air quality or poor quality lighting. In addition, a healthy, comfortable workplace can contribute to worker satisfaction, higher productivity, and lower turnover for public employees.
- Equipment lifetime: Proper O&M helps ensure that the designed life expectancy of equipment will be reached or exceeded. Conversely, the costs associated with early equipment failure are usually not budgeted and often come at the expense of other planned O&M activities. This can create a "vicious cycle" where O&M becomes increasingly reactive and costly.
- Legal compliance: An effective O&M program increases the likelihood of compliance with local and national regulations for workplace health and safety as well as air and water pollution.
- Leading by example: A well-run public sector O&M program instills pride in building operators and occupants, and when publicized can set an example for nearby public as well as private facilities.

Operation and maintenance consists of decisions and actions related to the control and upkeep of property and equipment.

— *Operation* refers to the scheduling, control, and optimization of building systems.

— The *maintenance* of energy-using: building systems and equipment falls into three main categories (**Figure 16**).

Figure 16: Main categories of maintenance in buildings



While the reactive maintenance approach may appear to be the lowest-cost choice, facilities that rely on this approach are generally exposed to much greater costs -- including risk of equipment breakdowns and costly repairs, lower equipment efficiency that increases energy use and costs, and decreased occupant comfort and productivity. In contrast, preventive and predictive maintenance practices substantially reduce unexpected equipment failures and thus avoid costly repairs, while also increasing energy savings.

Table 21 presents some examples of operational tasks and routines designed to increase the efficiency of various building equipment and systems.

Table 21. Operation functions examples

System Parts	**Operation Function Examples**	**Maintenance Function Examples**
Heating system	Check heating system control settings. For boilers, monitor water quality and return temperature. Check steam trap operation (steam heat distribution only).	Replace broken window panes and caulk cracks. Replace weather-stripping around doors and windows as needed.
Air conditioning system	Ensure proper operation of compressors, condensers, and/or cooling tower. Check all control settings.	Repair distribution line leaks and damaged insulation. Clean radiators and check function of valves. Lubricate bearings.
Ventilation system	Check ventilation unit control settings.	Repair duct leaks and damaged insulation. Periodically change filters. Adjust or replace motor drive belts.
Lighting	Ensure proper operation of all controls.	Clean lighting fixture lamps, lenses and reflectors. Replace failed lamps and ballasts.

System Parts	Operation Function Examples	Maintenance Function Examples
Water and sanitary installations	Check temperature settings in water heating system.	Repair leaks in pipes and insulation of hot water distribution pipes. Replace gaskets in water taps and toilet or urinal valves.
Meters	Monitor meters and monitoring points (such as gauges or computer displays).	Replace broken/faulty meters
Manually controlled systems	Open and close window shades and blinds to let in optimal light and heat. Shut off lights and office equipment and turn off water taps when not in use. Close doors and windows serving conditioned space.	Maintain the windows in clean shape to contribute to maximum light inflow. Install/repair door springs to ensure they do not remain open in heating/air-conditioning seasons, but disconnect the springs during spring and fall contributing to natural ventilation

Source: http://www1.eere.energy.gov/femp/pdfs/omguide_complete.pdf

The reduction of energy consumption in new and old buildings can be optimised with the use of information and communication technologies (ICT). 'Smart buildings' refer to more efficient buildings whose design, construction and operation is integrating ICT techniques like Energy Management Systems (EMS) that run heating, cooling, ventilation or lighting systems according to the occupants' needs, or software that switches off all PCs and monitors after everyone has gone home. EMS can be used to collect data allowing the identification of additional opportunities for efficiency improvements.

Note that even if energy efficiency has been incorporated at the start, a building's actual energy performance can be impaired if builders deviate from the plans or if occupants do not operate the building level EMS according to the plans or specifications ([73]). Assuming the building has been designed and built to specification, poor commissioning (ensuring that the building's systems function as specified), constant change of use and poor maintenance can significantly reduce the effectiveness of any EMS. It is therefore needed to organise daily monitoring energy performance, calculate, set up and control daily energy targets for actual schedule of building use, provide better training to building operators and awareness raising information and behaviour tips to users by simple devices such as visual smart meters or interfaces to influence behavioural change.

The Energy Services Companies' (ESCO) scheme to improve the energy efficiency performance may be applied to all types of buildings of this subchapter. This scheme is explained in Part I (How to Develop a Sustainable Energy Action Plan) financing chapter.

2.3.3 Lighting

2.3.3.1 Domestic and professional buildings lighting

A set of options in the lighting sector allows reaching up to 50% of savings. The most common measure is the replacement of lamps with more efficient ones (lower consumption with the same performance). Moreover, correcting the misuse of the lighting appliances shows to be a significant contribution in the saving options. In this perspective, the systems that can control and modulate the light sources (presence detectors, brightness sensors, dimmers, lighting systems) have a large impact on total lighting energy use. Savings may be also achieved by using high-quality and high-

([73]) In some cases, unrealistic input parameters regarding occupancy behaviour and/or energy management in building energy models may be an additional cause of discrepancies between designed and actual energy performance precision optical appliances that guarantee a high performance of the whole system and by implementing a careful lighting design process. The lighting influence on energy consumption varies according to the types of buildings. In particular, tertiary buildings and offices show the highest energy consumption due to lighting and, hence, may be the target where energy saving strategies may be implemented to yield more efficient results. On the contrary, lighting in residential buildings have a lower impact on the overall energy consumption which implies a limited selection of measures to be implemented, in particular in existing buildings. However, despite being accessible, there is a number of barriers that limits the implementation of efficient lighting. Among these, the unawareness of saving potentials and the higher initial cost of efficient lighting systems ([74]).

Characteristic parameters and definitions

- Luminous flux: is the measure of perceived power of light in the unit time [lm].
- Luminous efficiency: is the parameter that allows an evaluation of the energy efficiency of the lamp. It gives an idea of the amount of absorbed electricity that is transformed into light. It represents the relationship between the luminous flux of the lamp and the electric power supply [lm/W].
- Colour Rendering Index (CRI): ranging from 0 to 100, it indicates how faithfully a light source reveals colours of objects in comparison with an ideal or natural light source. The higher the colour rendering index, the less colour shift or distortion occurs (Table 22).
- Incandescent lamps: typically emit 12 lm/W, representing energy-to light conversion efficiency of 5%. As part of the implementation process of the Directive 2005/32/EC on Ecodesign of Energy Using Products, on 18th March 2008, the Commission adopted the regulation 244/2009 on non-directional household lamps which would replace inefficient incandescent bulbs by more efficient alternatives between 2009 and 2012. From September 2009 and by the end of 2012, lamps at several wattage levels had to be at least class C (improved incandescent bulbs with halogen technology instead of conventional incandescent bulbs).
- Halogen lamps: are incandescent lamps with small sizes that allow their use in compact optical systems for projectors and illumination. They will be banned from September 2018.
- CFL (Compact Fluorescent Lamps) have attracted great interest in households as they can easily be adapted to the existing installation. Due to their Mercury contents, this kind of lamp requires well-planned recycling management. They show a luminous efficiency of about 40-60 lm/Watt.
- LED (Light Emitting Diodes) originally used in electronics are now widespread also as lighting systems. These lamps are energy efficient (class A) and characterized by a high life span. They show a luminous efficiency between about 50-100 lm/Watt.
- Lighting controls are devices that regulate the operation of the lighting system in response to an external signal (manual contact, occupancy, clock, light level). Energy-efficient control systems include:
    - Localised manual switch
    - Occupancy linking control
    - Time scheduling control
    - Day lighting responsive control

([74]) The Greenlight project's webpage contains wider information about lighting http://www.eu-greenlight.org/index.htm Further information on lighting technologies and policies in OECD countries can be found in the document "Lights Labour's Lost: Policies for Energy-Efficient Lighting". Can be downloaded from https://www.iea.org/publications/freepublications/publication/light2006.pdf

Table 22. Light requirements according to the use of building

Colour Rendering Index required	Recommended lamp	Luminous efficiency
Very important 90-100 e.g.: Art Galleries, precision works Luminous flux:1000 lm	26 mm-diameter (T8) linear fluorescent lamp	77-100 lm/W
	Compact fluorescent lamp (CFL)	45-87 lm/W
	Very-low voltage tungsten halogen lamp	12-22 lm/W
	LED	35-80 lm/W
Important 80-89 e.g.: Offices, schools, industrial areas Luminous flux:500 lm	26 mm-diameter (T8) linear fluorescent lamp	77-100 lm/W
	Compact fluorescent lamp (CFL)	45-87 lm/W
	Fitting-based induction lamp	71 lm/W
	Metal halide lamps	65-120 lm/W
	"White sodium" high pressure sodium lamp	57-76 lm/W

2.3.3.2 Strategies for efficient lighting in buildings

Indoor illumination of tertiary-sector buildings uses the largest proportion of lighting electrical energy. On average, lighting accounts for 34 % of tertiary-sector electricity consumption and 14 % of residential consumption in OECD countries ([74]).

Strategies for improving the energy efficiency in lighting vary if either a new building or an existing one is considered. In the first case, more incisive results can be achieved, since architectural issues contribute to the lighting needs of spaces. Building modification to optimise use of natural light is restricted to initial construction and renovation. Natural light during daylight hours limit the use of artificial light, hence reducing electrical consumption and thermal load, and improve comfort. Alongside, 1) the planimetrical distribution of the building, 2) the geometric configuration 3) and the type of windows determine the natural light penetration in rooms.

In addition, these are the factors that influence the energy demand due to lighting in both new and existing buildings:

- the choice of the type of lamp;
- the displacement of lamps;
- and the relation between lamp and luminaires.

In a typical lighting system, only 30% of the lumens emitted by the lamp contribute to the lit environment. There is a huge amount of losses due to the luminaire, the light absorption on surrounding surfaces and the light redirection to avoidable areas. In existing buildings, the most common strategy is the replacement of old inefficient lamps, with new performing ones. Moreover, when estimating a building's lighting needs, various spaces shall be considered separately, both quantitatively and qualitatively (**Table 23**).

Table 23. Light requirements according to the use of building

Colour Rendering Index required	Recommended lamp	Luminous efficiency [lm/W]
Very important 90-100 e.g.: Art Galleries, precision works Luminous flux:1000 lm	26 mm-diameter (T8) linear fluorescent lamp	77-100
	Compact fluorescent lamp (CFL)	45-87
	LED	35-80
Important 80-89 e.g.: Offices, schools, industrial areas Luminous flux:500 lm	26 mm-diameter (T8) linear fluorescent lamp	77-100
	Compact fluorescent lamp (CFL)	45-87
	Metal halide lamps	65-120
	"White sodium" high pressure sodium lamp	57-76

Depending on the type of work developed, the frequency of use and the physical conditions of such spaces, the lighting installations will require different designs. Moreover, sensors and other control devices are frequently used tools for the design and the management of low consumption lighting systems with simple payback of 2-3 years. As a side-effect of the energy saving in lighting, designers should take into account the reduction of cooling needs due to the decrease of heat emitted by bulbs.

Table 24 reports the amount of electricity saved by replacing a 60 W incandescent lamp whose luminous flux is 900 Lumen by a halogen, CFL and LED.

Table 24. Amount of electricity saved by replacing a 60W incandescent lamp whose luminous flux is 800 Lumen by a CFL, LED or halogens

	Incandescent lamps	**Incandescent Halogen lamp**	**CFL**	**LED**
Luminous efficiency	15	22,5	47,5	67,5
Luminous flux (lm)	900	900	900	900
Power (W) = Energy consumption per hour (kWh)	60	43	16	10
Energy saved (%)	-	-28,3%	-73,3	-83,3%

Source: https://ledpro.it/tabella-comparazione-led/.

Recommended illumination levels for correct design of the lighting system in domestic environments are reported in **Table 25**.

Table 25. Recommended illumination levels for correct design of the lighting system in domestic environments

Building area/room	**Luminous flux**
Enterclose	50-150 lux
Reading/studying area	200-500 lux
Writing area	300-750 lux
Dinner area	100-200 lux
Kitchen	200-500 lux
Bathroom: general	50-150 lux
Bathroom: mirror area	200-500 lux
Bedroom: general	50-150 lux
Bedroom: wardrobe area	200-500 lux

Source: ENEA, risparmio energetico con l'illuminazione. Sviluppo Sostenibile, 5 ENEA-Unità RES RELPROM Lungotevere Thaon di Revel, 76 - 000196 Roma

2.3.4 Energy audits & Energy management systems

The purpose of energy audits ([75]) is to perform an analysis of energy flows in every engineering construction (for example, building or district heating network) that allows understanding how efficient the use of energy is. In addition, it should propose corrective measures in those areas with poor energy performance. The characteristics of the construction or equipment to be audited, as well as the energy consumption and performance data, are collected by means of surveys, measurements or energy consumption bills provided by utilities and operators or simulations performed, using validated software. Energy audit typically includes energy use at a given local climate criteria, thermostat settings, roof overhang, and solar orientation. This could show energy use for a given time period and the impact of any suggested improvements per year. Once the energy and performance data are collected and correctly analysed, it is possible to propose corrective measures aimed at improving the energy efficiency of the engineering construction. The outcomes of energy audits should at least be:

- Identification and quantification of energy-saving potentials;
- Energy-efficiency corrective/improvement measure recommendations;
- Quantification of investments to improve energy-efficiency effectiveness;
- A plan/programme to implement measures.

The energy audit is the first step before taking the final decision on which type of measures will be taken in order to increase the energy efficiency. Regardless of measures, an energy audit can reveal bad energy consumption practices.

As measurement and data acquisition are an important issue in evaluation of energy and cost effects of implemented energy-efficiency projects according to the recommendations of energy auditors, the way to do it has to be planned in advance. More information on measurement and verification of implementation of different energy saving measurements can be found on the IPMVP webpage (https://evo-world.org/en/).

From the point of view of energy efficiency, showing energy consumption and progress to people has an awareness effect that can lead to additional saving, due to the change of behaviour.

During the decision process of the financing scheme (i.e. programmatic carbon crediting – financing schemes chapter), the method used to measure savings or energy produced plays an essential role. In fact, this can be a requirement from the bank or fund to access financing. Moreover, when a project is based on an ESCO scheme, the contract should clearly specify how the energy will be measured (heat, electricity or both) and the payment deadlines and penalisation are based on these measurements. In addition, monitoring the energy consumption/savings allow investors and engineering offices to check the accuracy of forecasts and implement corrective measures in case of non-expected deviations.

This chapter related also to the technical measures of energy management systems in buildings, which is technical specification for increasing effectiveness of energy management in organizations that are managing building stock (Integration of an Energy Management System based on ISO 50001:2011).

A significant part of building energy management systems is dedicated to automation of control of physical processes related to creation of indoor climate such as heating, ventilation, and air-conditioning (HVAC). It usually uses software to control energy-consuming units and equipment, and can monitor and report on their performance. BEMS facilitates the integration and interoperation of equipment, appliances, and devices via a network of sensors and controls. Such a BEMS enables two-way data flow between the end user and the end devices in near-real time. It offers remote management of energy-

([75]) Further information and guidelines are available on the GreenBuilding webpage (https://ec.europa.eu/energy/intelligent/projects/en/projects/greenbuilding).

and resource-intensive building subsystems, such as HVAC and lighting, from a central platform, web-based portal, or cloud-based software application. The performance of the BEMS is directly related to the number of comfort parameters, technologies presented, type and source of energy consumed in the buildings. BEMS are generally composed by:

- Sensors and controls: Controllers, sensors (temperature, humidity, luminance, presence…) and actuators (valves, switches…) for different types of parameters Sensor and control technologies for a BEMS provide the intelligent backbone that connects equipment, building subsystems, and analytical tools in near-real time to foster a proactive, reactive, and sometimes autodidact, efficient building technology ecosystem. While sensors and controls are the critical enabling aspect of a BEMS, often they are the most overlooked piece of the system.
- Equipment: HVAC central system with local controllers for separate areas or rooms (when zoning of complex buildings that have multiple functions) and central computer assisted control;
- Software systems: Central control management software for separate areas or rooms (when zoning occurs);
- Services: Monitoring through energy consumption measurement devices. Energy monitoring and targeting is the collection, interpretation and reporting of energy use. Its role within energy management is to measure and maintain performance and to locate opportunities for reducing energy consumption and cost.

The benefits of energy monitoring & targeting include ([76]):

- Achieving energy consumption and cost savings, typically 7%-12%
- Reducing the environmental impact of energy usage
- Providing energy information for assessing energy projects and new plant acquisitions
- Improving preventative maintenance
- Avoiding waste and improving product quality through increased control

'Most energy efficiency in buildings, industry and other sectors is achieved through changes in **how energy is managed** in a facility, rather than through installation of new technologies,' by ([77]). Putting in place an energy management system in accordance with international standards (such as ISO 50001) can be an excellent way to do this. Energy Management Standard ISO 50001 describes a framework and best practice methodology to integrate EE into daily management practices.

In general, energy management systems provide the following:

- A framework for understanding significant energy uses: evaluating energy use for all major facilities and functions in the organisation, and establishing a baseline for measuring future results of efficiency efforts.
- Action plans for continually improving energy performance. A detailed action plan is required for the systematic implementation of energy performance measures, and is regularly updated to reflect recent achievements, changes in performance and shifting priorities.
- Structure and organisational framework to sustain energy performance. The support and cooperation of key people at different levels within the organisation should be gained. Success frequently depends on the awareness, commitment and capability of the people implementing the projects.

([76]) Source: Sustainable Energy Authority of Ireland

([77]) Matteini, M., United Nations Industrial Development Organization http://www.iso.org/sites/iso50001launch/documents.html.

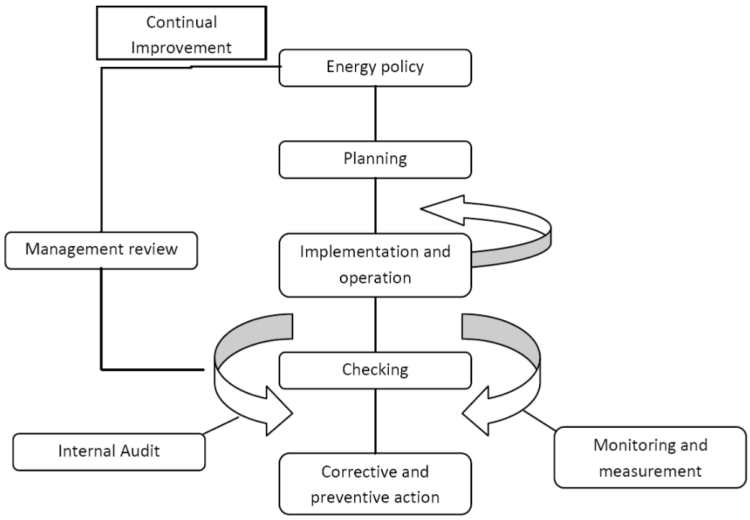
- Improvements over time and change of personnel. Evaluation results and information gathered during review processes are used to create new action plans, identify best practices and set new performance goals.

Energy management systems can help to achieve the following:

- management focus on EE issues;
- systematic activity on improvement of EE;
- obligation to train and raise awareness;
- obligation to provide resources;
- continuity through changes in personnel.

Figure 17 shows the possible model of an energy management system according to ISO 50001 ([78]).

Figure 17. A model of an energy management system according to ISO 50001



The model in **Figure 17** is based on the 'loop' principle of the project management cycle: Plan, Do Check and Act. It can be applied in any organisation, including a public authority. Such a cycle can also be implemented for managing a SECAP; for example, to follow SECAP implementation and the progress of planned actions. More information about this can be found in the list of recommended steps for drafting successful SECAPs

For an energy management system, the project management cycle (Plan, Do, Check and Act) can be detailed as follows:

The **first step, 'Plan'**, is dedicated to setting up a commitment for the continuous improvement of energy planning. Goals for an energy management system are to be established to guide daily decision making, and represent the basis for tracking and measuring progress. It is also important to create an action plan that defines technical steps and targets, and that determines roles and resources.

The following requirements are to be implemented in this step by the organisation that decides to follow ISO 50001 standards:

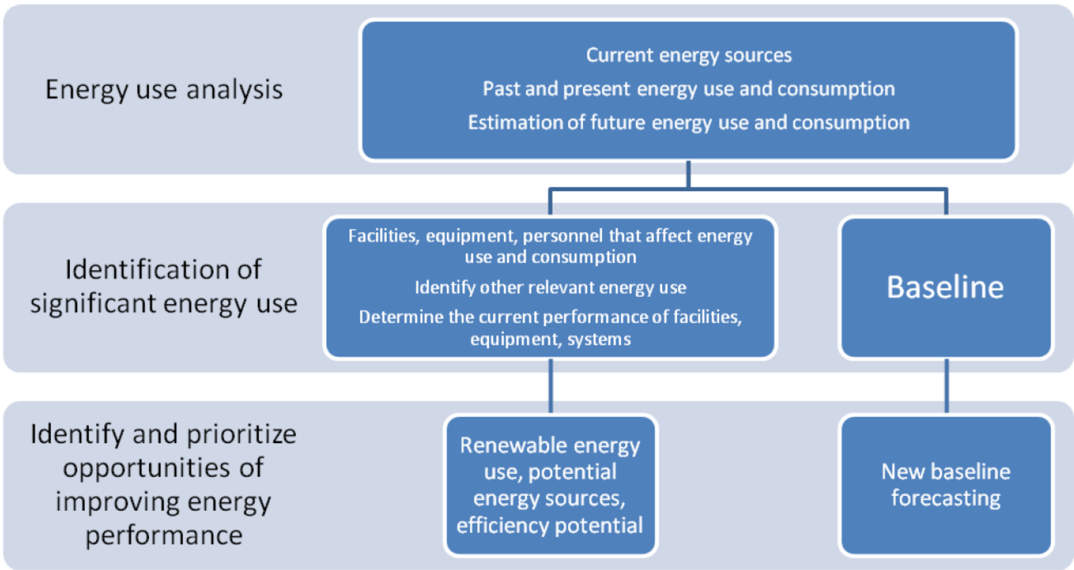
- establish the goals of an energy management system;
- approve the energy policy;
- identify and prioritise energy uses;
- identify and understand applicable legal requirements;
- list and prioritise improvement opportunities;

([78]) Guidelines 'How to develop a Sustainable Energy Action Plan integrated with an Energy Management System based on ISO 50001:2011', directed by SOGESCA s.r.l., supported by Intelligent Energy Europe, 2013.

- identify a set of actions suited for measuring energy performances and energy performances improvements;
- measurable objectives for energy performances improvement.

Implement the abovementioned steps, the current performance of energy systems should be assessed, which involves evaluating energy use for all major facilities and establishing a baseline to measure future results of efficiency efforts. The general concept for energy use analysis and obtaining the energy baseline is indicated in **Figure 18** ([79]). The local authority should collect accurate and comprehensive energy consumption data related to buildings and facilities.

Figure 18. Energy use analysis and baseline



The **second step, 'DO'**. For the implementation of the action plan established in the previous step, an energy team should be built, including the allocation of resources and responsibilities. Furthermore, the importance of communicating and posting goals is strongly emphasised as it can motivate staff to support energy management efforts throughout the organisation. The support should be built in for energy management initiatives/goals at all levels of the organisation.

— According to ISO 50001 standard, the following requirements are to be implemented in this step:

- form an energy team with determined roles, resources and responsibilities;
- assign tasks and grant competence;
- coordinate and manage internal and external communication;
- define and control documentation related to an energy management system;
- establish proper operational control.

The communication methods and strategy suggested for supporting the SECAP may by coupled with methods applied in energy management systems.

The next **steps, 'CHECK' and 'ACT'**, involve evaluating the progress of planned activities, and providing recognition of achievements to those who helped the organisation. This motivates staff and brings positive exposure to the energy management programme. Training activities, access to relevant information and transfer

([79]) Guidelines 'How to develop a Sustainable Energy Action Plan integrated with an Energy Management System based on ISO 50001:2011', guidelines directed by SOGESCA s.r.l., supported by Intelligent Energy Europe, 2013.

of successful practices should also be implemented along with a tracking system for monitoring progress.

According to the ISO 50001 standard, the following requirements are to be implemented:

- monitor and measure energy consumption;
- compare regular and expected consumption;
- asses energy policy objectives;
- manage non conformities, corrective measures and preventive measures;
- control records;
- plan and carry out an internal audit of the energy management system;
- review the energy management system.

This approach helps to monitor the progress of planned activities in the organisation, thus contributing to the performance of regular SECAP reviews, which are described in the list of recommended steps for drafting successful SECAPs.

The following is an example of a structure that the city of Lviv set up for developing and implementing its local energy strategies. The M&T system established responsibility, created transparency, and enabled informed control of energy and water use in public buildings, laying a solid foundation for sustained improvements in energy and water efficiency

The data were gathered in a database that recorded monthly energy consumption for 503 public buildings from 2006, and evaluated by various departments/units: branch energy managers, Unit of Energy Management of Economic Division, and the first deputy mayor. Thus, with application of the energy management system, the information has become available for decision makers. The benefits of implementing the energy management system included establishing benchmarks for monthly energy use for all buildings. This was performed considering the values measured in the previous years and relevant changes in the technical parameters of the buildings. Compliance with the energy consumption targets in individual buildings was analysed and discussed at the monthly meetings of the energy management team in the Lviv municipality.

An energy management system can help in the process of SECAP preparation and further implementation, especially in the public building sector. Some key benefits of why to use an energy management system to support SECAP development and implementation include the following:

— Introduces an 'energy culture' within the local government;

— Ensures cooperation between different offices and departments;

— Helps to plan, implement and monitor the SECAP actions that involve the public authority directly;

— Supports data collection and rationalisation;

— Introduces the concept of continuous improvement, fostering the 'process' approach of the SECAP.

The examples of energy management systems in buildings can be found at the webpage of the Sustainable Energy Authority of Ireland (https://www.seai.ie/energy-in-business/).

Box 34. Energy Management System, Lviv (Ukraine)

Lviv, a city of 760,000 residents in Western Ukraine, where the Alliance to Save Energy provided technical assistance to develop an Energy Management System for the city. The program began in 1997 with the training of local building engineers on energy management techniques, including energy audits and the utilization of the ASE 2.3 energy accounting tool and Building Energy Efficiency Project software. These tools were applied to calculate, monitor and analyze energy utilization and expenditures in the education department of Lviv, and to implement better energy management plans for schools in the city and throughout the region.

In addition, municipal energy management units (EMUs) were set up and monthly utility consumption data were collected for 530 public buildings. The data was analyzed against a historical target, enabling the city to spot and immediately mitigate inefficiencies. Databases generated using the software tool ranked schools by energy intensity, highlighting the most energy intensive school buildings. These tools and databases have proven useful in underpinning school renovation proposals and helping more than 900 schools manage their energy use.

Training and capacity building activities were targeted at designated energy managers in the Lviv administration as well as individual public buildings. This has laid the foundation for further work by the Lviv authorities in municipal energy planning and management for other public buildings. After the technical assistance ended in 2005, Lviv has continued its energy management work under the European Energy Cities initiative. Through the Monitoring and Targeting (M&T) program, a new Energy Management Unit was established within the city administration, and resources were mobilized to train all responsible personnel on building utility use in each administrative division, unit, or building. The M&T program provides the city management with monthly consumption data for district heating, natural gas, electricity and water in all of the city's 530 public buildings. Actual consumption is reviewed monthly against the target, with deviations spotted and acted upon immediately, and the performance of buildings is communicated to the public through a display campaign.

The M&T program has achieved significant savings with minimal investment and program costs: By 2010 the city reported monitored reductions in annual energy consumption in its public buildings of about 10 percent and reductions in tap water consumption of about 12 percent. This generated estimated net savings of 9.5 million UAH (US$1.2 million) as of 2010. Strong city government leadership and commitment have been key success factors in this program.

2.3.5 Office appliances

Energy savings in office appliances are possible through the selection of energy-efficient products. Only an assessment of the systems and the needs can determine which measures are both applicable and profitable. This could be done by a qualified energy expert with IT experience. The assessment conclusions should include hints for procurement of the equipment, via purchase or leasing. The definition of energy-efficiency measures in IT in the early planning stage can result in a significant reduction of loads for air conditioning and UPS, and thus, can optimise the efficiency for both investments and operation costs. Additionally the duplex printing and paper saving in general are important measures for saving energy for paper production, as well as reducing operation costs. The following tables (**Table 26, Table 28**) show the potentially significant energy savings measures which might be applicable to your IT landscape. In each table the measures are presented, beginning with those that have a large potential impact and are the easiest to implement.

Table 26. Step 1: Selection of energy efficient product – Examples

Description of measure	Saving potential
Centralised multi-function devices replacing separate single-function devices save energy, but only if the multi-function is used	Up to 50 %
Centralised printer (and multi-function devices) replacing personal printers save energy, when well dimensioned for the application	Up to 50 %

Table 27. Step 2: Selection of energy-efficient devices in a defined product group – Examples

Description of measure	Saving potential
The specific appliance dimension for the realistic application is the most relevant factor for energy efficiency	Not quantified
Use of Energy-Star criteria as a minimum criterion for call for tender will prevent the purchase of inefficient devices	0 – 30 % compared to state of the art
Make sure that the power management is part of the specification in the call for tender and that it is configured by installation of the new appliances	Up to 30 %

Table 28. Step 3: Check power management and user-specific saving potentials – Examples

Description of measure	Saving potential
The power management should be initiated in all devices	Up to 30 %
Screensavers do not save energy and thus, should be replaced by a quick start of standby/sleep mode	Up to 30 %
Use of a switchable multi-way connector can avoid power consumption in off-mode for a set of office equipment for night and absence	Up to 20 %
To switch off monitors and printers during breaks and meetings reduce energy consumption in stand-by mode	Up to 15 %

The label "ENERGY STAR" ([80]), available for energy-efficient office equipment, covers a wide range of products from simple scanners to complete desktop home computer systems. The requirements and specifications of a product to be labelled can be found at www.eu-energystar.org. A product-comparison tool is available that allows the user to select the most energy-efficient equipment. The EU Ecolabel Product Catalogue ([81]) covers a wide range of product groups, namely Personal, Notebook and Tablet Computers and makes sure that the products constant in the catalogue are of high energy efficiency, are designed to have a longer lifetime, less hazardous substances and are designed to be easier to repair, upgrade and recycle in comparison with regular devices in the market.

([80]) Further information available at www.eu-energystar.org
([81]) http://ec.europa.eu/ecat/

2.4 Infrastructure lighting

Local authorities can establish specifications for outdoor lighting and infrastructure lighting including standards for lighting fixtures and requirements for light levels.

2.4.1 Traffic Lights

The availability of compact LED packages on the market boosts the replacement of incandescent lamps in traffic lights with more energy-efficient and durable LED ([82]) ones. This action yields a significant reduction of energy consumption. A LED array is composed by many LED unities. The main advantages of LED traffic lights are:

- The light emitted is brighter than the incandescent lamps, which make LED traffic lights more visible in adverse conditions.
- A LED's lifespan is 100 000 hours (about 10 times more than incandescent bulbs). This implies a significant reduction of maintenance costs.
- The energy consumption reduction is higher than 50 % with respect to incandescent bulbs.

2.4.2 Public lighting

Public lighting is an essential municipal service. It offers significant potential for energy efficiency ([83]), in particular through the replacement of old lamps with more efficient ones, such as low pressure, high pressure lamps or LED. Over the years the efficiency of lamps has improved significantly. The high-pressure mercury lamp is the most frequent in public lighting. It has been used since 1960s and is extremely energy in-efficient. High-pressure sodium and Metal Halide lamps are very energy efficient ones and commonly used recently. Replacing lamps is the most effective way to reduce energy consumption. However, some improvements, such as the use of more efficient ballast or adequate control techniques, are also suitable measures to avoid the excess of electricity consumption. In addition, the use of autonomous public solar street lighting systems powered by PV panels with energy storage battery is spreading across cities.

Luminous efficiency, CRI, duration, regulation or Life Cycle must be included in the set or design parameters for the choice of the most suitable technology. For instance, if a high CRI is required in a public-lighting project, the use of LED technology is recommended. This technology is a suitable solution to reach a good balance between CRI and Luminous efficiency. If CRI is not essential for a given installation, other technologies may be more appropriate. In the following **Table 29**, recommended lamps for public lighting are reported in case of either replacement or new installation.

Table 29. Recommended ended Lamps Direct substitution and new installation

Type of intervention	Original Lamp	Luminous efficiency	Recommended lamp	Luminous efficiency
Direct substitution	High pressure mercury lamps Arc lamps	32-60 lm/W	Standard high pressure sodium lamp	65-150 lm/W
		30-50 lm/W	Metal Halide Lamp	62-120 lm/W
			LED	65-100 lm/W
New Lighting Installation		Less than 60	Low pressure sodium lamp	100-200 lm/W
			Standard high pressure sodium	65-150 lm/W
		More than 60	LED	65-100 lm/W

([82]) LED – Light Emission Diode
([83]) Further information available at www.eu-greenlight.org and www.e-streetlight.com (European project supported by Intelligent Energy Europe)

Arc discharge lamps, such as fluorescent and HID (High Intensity Discharge) sources, require a device to provide the proper voltage to establish the arc and regulating the electric current once the arc is struck.

Other measures may be implemented to achieve significant energy reduction:

— Take into consideration the use of the public area (parking, pedestrian, dangerous intersection) in order to provide the appropriate kind of lamp and level of lighting.

— Ballasts: compensate voltage variation in the electrical supply. Since the electronic ballast does not use coils and electromagnetic fields, it can work more efficiently than a magnetic one. These devices allow a better power and light intensity control on the lamps. The energy consumption reduction caused by electronic ballasts has been estimated around 7% ([84]). In addition, LED technology not only reduces the energy consumption, but also allows an accurate regulation depending on the needs.

— Electronic photo-switches can contribute to the electricity savings in public lighting by reducing night burning hours (turning on later and turning off earlier).

— A tele management system enables the lighting system to automatically react to external parameters like traffic density, remaining daylight level, road constructions, accidents or weather circumstances. Even if a tele management system does not reduce the energy consumption in lighting by itself, it can reduce traffic congestion or detect abnormalities. Tele management systems can be used to monitor failed lamps and report their location. Maintenance expenses can be reduced by considering the remaining life of nearby lamps that might be replaced during the same service call. Finally, data collected by the tele management system that tracks the hours of illumination for each lamp can be used to claim warranty replacement, establish unbiased products and supplier selection criteria, and validate energy bills.

Box 35 Pilot poject on street lighting in Polotsk (BY)

The pilot SECAP action is the installation of high-efficiency LED street lights in the main avenue of the city, Frantsysk Skaryna Avenue, in Polotsk (BY). Not only is LED lighting an environmentally friendly solution, it is also a very profitable investment.

LED lights use only 10 % of the energy consumed by incandescent lights, their lifetime is over 50 times longer and their maintenance is significantly cheaper.

New street lights are accompanied by an information board with some facts about the installation's energy savings and an indication that this pilot action has been financed within an EU-funded project.

2.5 Public Procurement

2.5.1 Green public procurement

Public procurement refers to the process by which public authorities, such as government departments or local authorities, purchase work, goods or services from companies ([85]). Public procurement and the way procurement processes are shaped and priorities are set in the procurement decisions, offer a significant opportunity for local authorities to improve their overall energy consumption performance.

Green public procurement is the process whereby public authorities seek to procure goods, services and works with a reduced environmental impact throughout their life cycle when compared to goods, services and works with the same primary function that

([84]) E-street project www.e-streetlight.com. Supported by Intelligent Energy Europe
([85]) https://ec.europa.eu/growth/index_en

would otherwise be procured ([86]). This means that public contracting authorities take environmental considerations into account when procuring goods, services or works. Sustainable public procurement goes even further and means that the contracting authorities take into account the three pillars of sustainable development – the effects on environment, society and economy - when procuring goods, services or works.

Energy efficient public procurement allows improving energy efficiency by setting it as relevant criteria in the tendering and decision-making processes related to goods, services or works. It applies to the design, construction and management of buildings, the procurement of energy consuming equipment, such as heating systems, vehicles and electrical equipment, and also to the direct purchase of energy, e.g. electricity. It includes practices such as life-cycle costing ([87]), the setting of minimum energy-efficiency standards, the use of energy efficient criteria in the tendering process, and measures to promote energy efficiency across organisations.

Energy-efficient procurement offers public authorities, and their communities, social, economic and environmental benefits:

— By using less energy, public authorities will reduce unnecessary costs, and save money.

— Some energy-efficient goods, such as light bulbs, have a longer lifetime and are of higher quality than their cheaper alternatives. Purchasing them will reduce valuable time and effort involved in frequently replacing equipment.

— Reducing CO_2 emissions as a result of energy-efficient procurement will help public authorities to decrease their carbon footprint.

— Through leading by example, public authorities help to convince the general public and private businesses of the importance of energy efficiency.

The interest in developing Green Public Procurement regards not only its impact in terms of CO_2 emission reduction, whose average (see study "Collection of statistical information on Green Public Procurement in the EU" ([88]) carried out for the European Commission-DG Environment) is 25%, but also in terms of its financial impact, whose average is 1,2% of savings. Here are some examples of energy-efficient measures proposed in high-priority product groups (**Table 30**).

In the transport sector, the Directive 2009/33/EC on the promotion of clean and energy efficient vehicles requires that lifetime impacts of energy consumption, CO_2 and pollutant emissions are taken into account in all purchases of public transport vehicles. As reported in the following table, a public procurement may require environmental specifications for the municipal fleet. Moreover, since purchases of public vehicles represent a market of high visibility, a general application of this directive can promote a broader market introduction of clean and energy efficient vehicles in the cities and reduce their costs through economies of scale, resulting in a progressive improvement of the whole vehicle fleet.

([86]) http://ec.europa.eu/environment/gpp/what_en.htm

([87]) Life-cycle costing refers to the total cost of ownership over the life of an asset. This includes acquisition (delivery, installation, commissioning), operation (energy, spares), maintenance, conversion and decommissioning costs.

([88]) This study can be downloaded from http://ec.europa.eu/environment/gpp/study_en.htm. The report presents the statistical information and conclusions about the investigation done in the 7 most advanced European Countries in Green Public Procurement. It was found that the CO_2 emissions savings was in the range -47%/-9% and the financial impact was in the range -5,7%/+0,31%.

Table 30. Examples of energy-efficient measures proposed in high-priority product groups

Product group	**Examples of Public procurement requirement**
Public transport	Purchase low-emission buses and public fleet vehicles. The buses have to be equipped with driving-style meters to monitor fuel usage.
Electricity	Increase the share of electricity from renewable sources going beyond national support schemes. This measure can be completed by including the purchase of energy-efficiency services. For example ESCOs.
IT products	Purchase of environmentally friendly IT goods that meet the highest EU energy standards for energy performance. Provide training to users on how to save energy using their IT devices.
Building construction/ renovation	Use of localised renewable energy sources (RES) Impose high efficiency standards that reduce the building's energy consumption

Green, sustainable or energy-efficient public procurement are highly recommended. However, in the context of the Covenant of Mayors, only measures related to energy-efficient public procurement will be reflected in the CO_2 emission inventories, since the initiative focuses on the energy consumption and emissions occurring within the municipality.

The purchase of energy efficient homes and appliances are other source of energy conservation/savings. Directive 1995/13/EC implementing directive 1992/75/EEC, and Directives 1996/60/EC, 1998/11/EC, 2002/40/EC, 2006/32/EC, 2010/30/EU, 2010/31/EC effective for all EU countries and other members of Energy Community Treaty ([89]) (Ukraine and Moldova as contracting parties and Georgia as candidate country) oblige domestic appliance producers to label their products, offering to the customers the possibility to know the energy efficiency of these devices.

The national directives or standards can also be applied for labelling domestic appliances in countries of Eastern Partnership and Central Asian Countries. The appliances included in these regulations are: refrigerators, freezers and their combinations, washing machines, driers and their combinations, dishwashers, ovens, water heaters and hot-water storage appliances, lighting sources, air-conditioning appliances and even buildings. It is highly recommended to choose A+ or A++ labeled appliances or buildings.

2.5.2 Joint public procurement

"Joint procurement" (JP) ([90]) means combining the procurement actions of two or more contracting authorities. The key defining characteristic is that there should be only one tender published on behalf of all participating authorities. Such JP activities are not new – in countries such as the UK and Sweden public authorities have been buying together for a number of years – though, in many European countries, especially in the South, there is often very little or no experience in this area. There are several very clear benefits for contracting authorities engaging in JP arrangements:

([89]) Title II of the Treaty establishing the Energy Community extends the acquis communautaire to the territories of the Contracting Parties. The Energy Community acquis comprises the core EU energy legislation in the area of electricity, gas, environment, competition, renewables, energy efficiency, oil and statistics. More information available at Energy Community webpage.

([90]) Guidelines for the implementation of Green Public Procurement and Joint Public Procurement can be found in the webpage of LEAP project www.iclei-europe.org/index.php?id=3113. This project is funded by the European Commission's DG ENV through a project LIFE. http://ec.europa.eu/environment/life/index.htm

— Lower prices: Combining purchasing activities leads to economies of scale. This is of particular importance in the case of a renewable energy project whose costs may be higher than conventional projects.

— Administrative cost savings: The total administrative work for the group of authorities involved in preparing and carrying out one rather than several tenders can be substantially reduced.

— Skills and expertise: Joining the procurement actions of several authorities also enables the pooling of different skills and expertise between the authorities.

This model for Public Procurement requires agreement and collaboration among different contracting authorities. Therefore, a clear agreement on needs, capacities, responsibilities and the common and individual legal framework of each part is a must.

Box 36 Joint procurement of clean vehicles in Stockholm (SE)

The City of Stockholm and other Public Administrations organised a joint procurement of clean cars. The city worked to introduce a large number of clean vehicles. The initiative resulted in a two-year framework agreement involving six vehicle suppliers. Over 800 Electric Vehicles have been purchased thanks to this agreement. Sweden is a country with good conditions for EVs . Electricity is affordable and is generated mainly from hydro or nuclear plants, which don't produce CO2 emissions. The infrastructure and distribution system for electricity is also well established. Approximately 65 % of Swedes have easy access to charging/electric outlets near home or work. Splitting the procurement into multiple stages was positive and renewed competition tendering, introduced after a change in legislation, was a new method in vehicle agreements.

Source: http://www.eltis.org

2.5.3 Green energy purchasing

The purchase of Green Electricity ([91],[92]) by the Public Administration, Households and Companies, is a great incentive for companies to invest in the diversification of clean energy generation power plants. There is some experience of municipalities buying Green Electricity from power plants owned by a municipal company.

Box 37 Green energy purchase Geetbets (BE)

The electric energy used in municipal buildings and for public lighting of Geetbets is provided by Certified green electricity. This is bought through a purchase organised by Infrax, the company that operates, maintains, and develops electricity, natural gas, cable television, and communication networks in Belgium.

Source http://www.covenantofmayors.eu/actions/benchmarks-of-excellence_en.html

([91]) Demand Side Management Information available on the International Energy Agency Demand Side Management webpage www.ieadsm.org . The Topten websites provide a selection of best appliances from the energy point of view www.topten.info (project supported by Intelligent Energy Europe)

([92]) Further information in the document "Green electricity - making a difference" by PriceWaterhouseCoopers

3. Urban & land-use planning

Land-use planning has a significant impact on the energy consumption in both the transport and building sectors. Strategic decisions concerning urban development, such as avoiding urban sprawl, influence the energy use within urban areas and reduce the energy intensity of transport. Compact urban settings may allow more cost-effective and energy-efficient public transport. Balancing housing, services and work opportunities (mixed use) in urban planning have a clear influence on the mobility patterns of citizens and their energy consumption. Local and regional governments can develop sustainable mobility plans and encourage a modal shift towards more sustainable transport modes.

Building shape and orientation play an important role from the point of view of heating, cooling and lighting. Adequate orientation and arrangement of buildings and built-over areas make it possible to reduce recourse to conventional air conditioning. Planting trees around buildings to shade urban surfaces, and green roofs to reduce their temperature, can lead to substantial reductions in energy consumption for air conditioning. Proportion between width, length and height, as well as its combination with the orientation [69] and proportion of glazed surfaces, should be studied in detail when new urban developments are proposed. In addition, sufficient green areas and planting trees next to the building can lead to a reduction in the energy needs and then reduce GHGs.

There are also examples of local authorities that have started to develop CO_2-free settlements or even set up an overall objective to become 'fossil fuel free'. CO_2-free settlements mean retrofitting districts in such a way that they do not consume fossil fuels. Urban density is one of the key issues influencing energy consumption within urban areas. **Table 31** considers the effects (both positive and negative) of urban density, which may have conflicting effects.

Table 31. Positive and negative effects of urban density on energy consumption [69]

Parameters	**Positive effects**	**Negative effects**
Transport	Promote public transport and reduce the need and length of trips by private cars	Congestion in urban areas reduces fuel efficiency of vehicles
Infrastructure	Shorten the length of infrastructure facilities such as water supply and sewage lines, reducing the energy needed for pumping	
Vertical transportation	-	High-rise buildings involve lifts, thus increasing the need for electricity for vertical transportation
Ventilation	-	A concentration of high-rise and large buildings may impede urban ventilation conditions
Thermal performance	Multi-unit buildings could reduce the overall area of the building's envelope and heat loss from the buildings. Shading among buildings could reduce solar exposure of buildings during the summer period	-
Urban heat island	-	Heat released and trapped in urban areas may increase the need for air conditioning The potential for natural lighting is generally reduced in high-density areas, increasing the need for

Parameters	Positive effects	Negative effects
		electric lighting and the load on air conditioning to remove the heat resulting from the electric lighting
Energy systems	District cooling and heating systems, which are usually more energy efficient, are more feasible as density is higher	-
Use of solar energy	-	Roof and exposed areas for collection of solar energy are limited
Ventilation energy	A desirable air-flow pattern around buildings may be obtained by proper arrangement of high-rise building blocks	-

Urban planning is a key instrument allowing the establishment of EE requirements for new and renovated buildings.

Box 38 Urban planning in Groningen (NL)

Since the 1960s, the municipality of Groningen has been way ahead in its traffic plans and spatial planning policies, implementing urban policies that have led to a car-free city centre and a mixed public space, with all areas easily reachable by bicycle.

The basic concept used in urban planning was based on the 'compact city' vision, which placed an integrated transport system high on the municipal agenda. The main objective was to keep the distances between home and work, or home and school relatively short, so that the use of public transport forms a good alternative to the private car in terms of travelling time. The residents should have opportunities to shop for their everyday needs in their own neighbourhoods, while the city centre should serve as the main shopping centre. Sports facilities and schools should be close to the living areas. A series of sound transportation policies has been developed to favour walking, public transport and predominantly cycling. A traffic circulation plan divided the city centre into four sections and a ring road was built encircling the city and reducing access to the centre by car. During the 1980s and 1990s, a parking policy was strictly implemented. Car parking with time restrictions was introduced in a broad radius around the city centre.

Park and ride areas were created combined with city buses and other high-quality public transport. Investments in cycling infrastructure have been made to expand the network of cycling lanes, improving, among others, the pavements and bridges for cyclists, and offering many more bike parking facilities.

Cooperation and participation by the local population or particular social groups has been sought in relation to various actions. In addition, an extension of the travel management policy, based on a regional mobility plan, has been prepared in cooperation with provincial and national decision makers. This has resulted in a city centre that is entirely closed off to cars; it is only possible to travel between sectors by walking, bicycle or public transport.

Source: EAUE database 'SURBAN - Good practice in urban development' and the 'Fiets Beraad' http://www.fietsberaad.nl/library/repository/bestanden/document000113.pdf

Urban regulations ([93]) should be devised in such a way as not to deter EE and RES. For instance, long and complex authorisation procedures will be a clear obstacle to RES and EE promotion and should be avoided. Such considerations should be integrated into the local authorities' urban planning schemes.

([93]) Document: Community Energy; Urban Planning for a low carbon future http://www.chpa.co.uk/news/reports_pubs/Community%20Energy-%20Urban%20Planning%20For%20A%20Low%20Carbon%20Future.pdf.

Box 39 Quick tips on urban and land-use planning

- Introduce energy criteria in planning (land use, urban, mobility planning)
- Promote mixed use (housing, services, jobs)
- Plan to avoid urban sprawl:
- Control the expansion of built areas
- Develop and revitalise old (deprived) industrial areas
- Position new development areas within the reach of existing public transport lines
- Avoid 'out-of-town' shopping centres
- Plan car-free or low-car–use areas by closing areas to traffic or introducing congestion charge schemes, etc.
- Promote solar oriented urban planning, for example by planning new buildings with an optimum sun-facing position

4. Transport

As the number of vehicles is expected to grow in the coming years, national governments are becoming more and more aware of the need to devise specific measures in order to limit energy consumption in the transport sector. To this end, they have adopted regulations or plans that in some cases also address urban mobility ([94]).

Before the local authority proposes specific policies and measures concerning transport, an in-depth analysis of the local current situation is highly recommended. The actual means of transport and the possible connections or synergies with different means of transport must be well matched with the geographic and demographic features of the city and with the possibilities to combine different types of transport.

Effective, Sustainable Urban Transport Planning (SUTP) ([95]) requires a long-term vision to plan financial requirements for infrastructure and vehicles, to design incentive schemes to promote high-quality public transport, safe cycling and walking, and to coordinate with land-use planning at the appropriate administrative levels. Transport planning should take into account safety and security, access to goods and services, air pollution, noise, GHG emissions and energy consumption, and land use, as well as cover passenger and freight transportation and all modes of transport. Solutions need to be tailor-made, based on wide consultation with the public and other stakeholders, and targets must reflect the local situation. This chapter aims to offer different possibilities to municipalities to build their own SUTP.

— Reducing the need for transport ([96]): Local authorities have the possibility to reduce the needs for transport. Following are some examples of policies to be implemented locally.

  - Providing door-to-door access choices across the urban agglomeration. This objective may be reached through an appropriate combination of less flexible means of transport for long and medium distances and other more flexible means, such as bike hiring for short distances.
  - Making efficient use of space, promoting a 'compact city' and targeting the urban development towards public transport, walking and cycling.
  - Strengthening the use of ICT. Local authorities have the opportunity to use ICT to implement online administrative procedures and avoid the transport of citizens to fulfil their obligations with public administrations.
  - Protecting existing short routes in the network in order to diminish the energy consumption of those less efficient or more necessary means of transport (i.e. massive public transport).

— Increasing the attractiveness of 'alternative' transport modes: Increasing the modal share for walking, cycling and public transport can be achieved through a wide variety of plans, policies and programmes. As a general principle linked to transport policies, managing the overall offer and demand of transport is essential to optimise the use of infrastructure and transport systems. This allows for making

([94]) For further information on the transport sector in Transport Research Knowledge Centre (TRKC), see http://www.transport-research.info online. The project was funded by the European Commission's Directorate-General for Energy and Transport (DG TREN) under the Sixth Framework Programme (FP6) for Research and Technological Development. This chapter is based on the document *Expert Working Group on Sustainable Urban Transport Plans* provided by the International Association of Public Transport (UITP). See http://www.uitp.org online.

([95]) For further information about SUTPs, see http://ec.europa.eu/environment/urban/urban_transport.htm online. In addition, the webpage http://ec.europa.eu/environment/urban/pdf/transport/2007_sutp_annex.pdf provides an important amount of information concerning local transport policies and good practices in several European cities.

([96]) This paragraph has been developed using information from the Moving Sustainably Project that contains an interesting methodology aimed at implementing SUTPs. Further information is available at http://www.movingsustainably.net where it is possible to find a methodology to develop SUTPs.

compatible the different means of transport such as bus, train, tramway and underground to take advantage of each one and avoid unnecessary overlapping.

— Public transport: Increasing the modal share for public transport requires a dense network of routes that meets the mobility needs of people. Before implementing any transport policy, the local authority should determine the reasons/factors in why citizens/businesses are NOT using public transport. Therefore, it is essential to identify barriers to public transport use. Some examples ([97]) of such barriers to bus use are:

- inconvenient stops and inadequate shelters;
- difficulty in boarding buses;
- infrequent, indirect and unreliable services;
- lack of information on services and fares;
- high cost of fares;
- long journey times;
- lack of practicability of connections between different modes of transport;
- fear of crime, particularly at night.

To increase the share of public transport among citizens, the local authority could implement the following measures:

— Develop a set of indicators measuring the access to public transport of citizens. Perform a comprehensive analysis of the current situation and adopt corrective actions to improve these indicators. The network should be attractive and accessible for all communities of interest and ensure that stops are sited within walking distance from key residential, commercial and tourist centres.

— A marketing strategy and service information availability should be integrated across public transport modes within 'travel to work' urban areas. The use of marketing enables a permanent improvement in all customer relations activities like sales, advertising, branding, network design, product (public transport) specifications, complaint management and customer service.

— Promote collective transport programmes for schools and businesses. This requires a forum with companies, unions and consumer associations in order to identify their needs, share the costs of the service and maximise the number of citizens with access to public transport.

— Provide an integrated public transport information service through a call centre, information centres, 24 hour information points and the Internet.

— Services need to be reliable, frequent, cost- and time-competitive, safe to use and perceived by the public as such. Therefore, an important communication effort is necessary to inform users about the advantages of using public transport with respect to other means of transport.

— Information about services needs to be 'real-time', widely available and include predicted arrival times (for arriving passengers, it is also possible to give information about connections). For example, displays may give passengers a countdown in minutes until the arrival of the next bus, as well as showing the stop name and current time.

— 'Public transport only' and priority routes will be essential policies. This will reduce travel time, which is one of the factors most considered by users when choosing

([97]) These reasons exposed as an example stem from the document *Lancashire Local Transport Plan 2008-2010*, which can be downloaded at http://www.lancashire.gov.uk/environment/ online.

among the different means of transport. Spatial planning should deliver the required loading factors to allow public transport to compete with car transport.

- Work in partnership with the district councils and others to ensure a high standard of provision and maintenance of the public transport infrastructure, including bus shelters and improved facilities at bus and rail stations.
- Create a suggestion box to consider the ideas of users and non-users in order to improve your service. Consider the possibility of creating a 'transport charter' according to the specific needs of a group of users.
- Create a Free Tourist Shuttle System with a fixed route and stops at a variety of popular tourist destinations. This would eliminate vehicle trips and parking spaces at popular destinations and provide an easy transportation alternative for tourists who are uncomfortable with a complex transit schedule.

It is important to keep in mind that choices are occasionally based on comparisons between public transport and car use. For instance, some actions aimed at increasing the share of public transport are not only linked to the measures undertaken in this sector, but also in other areas such as reducing the use of cars (e.g. public parking pricing policy). The monitoring results of public transport may be a valuable indicator to know the effectiveness of some policies mentioned in this chapter.

4.1 Cycling

Increasing the modal share for cycling ([98]) also requires a dense network of well-maintained routes that are both safe to use and perceived by the public as such. Spatial and transport planning should treat cycling as an equal mode of transport, along with cars and public transport. This means reserving the space that is necessary for the 'cycling infrastructure', direct connections and ensuring continuity with attractive and secure cycle parking facilities at transport hubs (train and bus stations) and workplaces. Infrastructure design should ensure that there is a hierarchy of routes that are safe, attractive, well lit, and signposted, maintained all year round, and integrated with green space, roads and the buildings of urban areas.

The international transport forum ([99]) (Organisation for Economic Co-operation and Development (OECD)) has identified seven key policy areas in which authorities can act to promote cycling.

— Image of cycling: it is not only a leisure/sport activity but also a means of transport.

— Infrastructure: an integrated network of cycling paths connecting origins and destinations, and separate from motorised traffic, is essential to promote cycling.

— Route guidance and information: information such as number or colour of the cycling ways and distances in order to make them easy for cyclists to follow.

— Safety: approve standards for safe driving and avoid the mixture of bicycles and other heavy means of transport.

— Links with public transport: develop parking facilities at railway stations or tramway/bus stops. Rent bicycles at public transport and railway stations.

— Financial arrangements for cycling infrastructure should be considered.

— Bicycle theft: prevent theft by imposing electronic identification bicycles and/or the realisation of a national police registration for stolen bicycles ([100]).

([98]) More information about cycling policies, increasing bicycle use and safety, by implementing audits in European cities and regions, can be found on the ByPad project webpage http://www.bypad.org. *National Policies to Promote Cycling*, OECD .

([99]) See https://www.itf-oecd.org/ online. and http://www.oecd.org/environment/greening-transport/

It is also recommended to increase Workplace Shower Facilities for cyclists. Facilitate bicycle commuting by requiring new developments to provide shower and changing facilities, and/or offer grant programmes for existing buildings to add shower facilities for cyclists.

Box 40. Cycling infrastructure in the City of Lviv (Ukraine)

The City of Lviv (Ukraine) is working to enhance its cycling infrastructure and to facilitate the use of bicycles. The aim is to increase the share of citizens using the bicycle as a regular transport mode. To this end, a systematic approach has been adopted and covers:

- a working group composed of representatives of the city administration, of planning and design institutes, of NGOs and of other stakeholders meets regularly to initiate projects and activities and to monitor progress;

- the City Council approved a City Plan in 2010, followed by an Implementation Plan adopted by the Executive Committee of the city of Lviv: the Implementation Plan sets the target of 270 km of cycling infrastructure to be built by 2019;

- a cycling advisor has been appointed to coordinate and motivate the various actors towards successful implementation of the project;

- technical recommendations have been drafted and are continuously updated;

- the Council is actively pursuing additional funds;

- thanks to the support of NGOs and other partners, citizens' awareness is raised through specific activities.

4.2 Walking

As previously stated for *Cycling*, increasing the modal share for walking requires a dense network of well maintained routes that are both safe to use and perceived by the public as safe to use. Spatial planning should reserve the space that is necessary for the 'walking infrastructure' and ensure that local services are sited within walking distance from residential areas.

Many urban areas have produced design manuals that provide detailed specifications for the practical tools and techniques that deliver high-quality, walking-friendly urban environments. Examples of such environments are 'pedestrian only zones' and 'low-speed zones' with lower vehicle speed limits that allow pedestrians and cars to safely share the same space. In these areas pedestrians always have priority over cars.

Walking, cycling ([101]) and public transport can become more attractive alternatives if car travel becomes more difficult or expensive.

Disincentives include:

— Pricing ([102]): By making car drivers pay a fee for driving in the city (centre), drivers can be charged some of the social costs of urban driving, thus also making the car a less attractive option. Experience from local authorities that implemented congestion charges shows that they can reduce car traffic considerably and boost the use of other transport modes. Pricing can be an effective instrument to reduce congestion and increase accessibility for public transport.

([100]) Policies implemented by the Dutch Ministry of Transport, Public Works and Water Management. *National Policies to Promote Cycling*, OECD.

([101]) Measures aimed at making travel by car less interesting should be developed at the same time as those aimed at offering better alternatives to users. In order to avoid negative consequences, these types of measures should be debated and planned thoroughly.

([102]) Further information on urban road user charging may found on the CURACAO — Coordination of Urban Road User Charging Organisational Issues. This project has been funded by the European Commission through the FP6.

— Parking management: Parking management is a powerful tool for local authorities to manage car use. They have several tools to manage parking such as pricing, time restrictions and controlling the number of available parking spaces. Parking time restriction for non-residents, for example, to two hours, is a proven tool to reduce commuting by car without affecting accessibility to urban shops. The number of parking spaces is sometimes regulated by the local building act, demanding a certain number of parking spaces for new developments. Some local authorities have building regulations whereby location and accessibility by public transport influence the number of parking spaces allowed. Adequate pricing of urban parking lots is another important tool with similar potential to influence urban driving as congestion charging. These types of actions should be done with the support of technical and social studies aimed at ensuring equal opportunities among the citizens.

— Information and marketing: Local marketing campaigns that provide personally tailored information about public transport, and walking and cycling alternatives have been successful in reducing car use and increasing levels of public transport use. These campaigns should also use arguments of the health and environmental benefits provided by walking and cycling.

— Information about how to start a campaign and where sources of information can be found are available in the report *Existing methodologies and tools for the development and implementation of SECAP* on methodologies collection (WP1). The full version of this document can be downloaded from the Institute for Energy and Transport ([103]) webpage. As an example of a successful awareness campaign, the European Commission's Directorate-General for Energy (DG ENER) organises every year the European Sustainable Energy Week (http://www.eusew.eu).

4.3 Municipal and private vehicle fleet

Municipal and private vehicles' emissions reductions may occur by using hybrid or other highly efficient technologies, the introduction of alternative fuels and promoting efficient driving behaviour. Among the main uses of green propulsion in public fleets are the following:

Use hybrid or totally electric vehicles in public fleets. These types of vehicles use a fuel motor (hybrid vehicles) and an electric engine whose aim is the generation of power for motion. The electricity to be supplied to the vehicles is stored in batteries that can be recharged either by plugging the car into the electrical grid or producing the electricity on board, taking advantage of braking and the inertia of the vehicle when power is not demanded. Make use of fully electric vehicles in public transport and recharge them with renewable electricity.

— Use biofuels in public fleets and make sure that vehicles ([104]) acquired through public tenders accept the use of biofuels. The most common biofuels that can be supplied by the market are biodiesel, bioethanol and biogas. Biodiesel and bioethanol can be used in mixes in diesel and gasoline engines, respectively, whereas biogas can be used in natural gas vehicles (NGVs).

— Like battery electric cars, if produced from renewable sources, hydrogen fuel cell vehicles generate virtually zero CO_2 emissions over the entire fuel pathway from production to use. Again, like charging electric cars, hydrogen will require the installation of new distribution and refuelling infrastructure. Public fleets are ideal applications as fleet vehicles typically return to a central base for garaging, fuelling and maintenance. Hydrogen buses and delivery vans are of special interest to cities, due to their zero emissions (ultra-low if combustion engines), low noise, extended operating range and comparable refuelling times in relation to diesel

([103]) See http://iet.jrc.ec.europa.eu/energyefficiency/ online.

([104]) Further information on car emissions can be found at http://www.vcacarfueldata.org.uk/index.asp.

buses. Demonstrations have proved high levels of reliability and public acceptance. Development efforts continue with a view to further improving performance, durability and reducing lifetime costs.

— Promote low fuel consumption, hybrid and electric vehicles through a low taxation regime. This can be done dividing vehicles into different categories according to the priorities of the local authority.

These more energy-efficient vehicles can also be promoted by local authorities through the application of local incentives, such as:

- free parking;
- test fleet (companies can borrow an alternative fuelled vehicle for a week to try out the new technology, the efficiency, the refuelling, etc.);
- special lanes for alternative vehicles;
- access to city zones with restrictions for high-GHG–emitting cars — for example, cultural city centres and environmental zones;
- no congestion charges for clean vehicles;
- some examples of national incentives are tax reductions on fuel and on vehicles, and regulations that favour the use of alternative vehicles by companies;
- 'Environmental Loading Points' adjacent to pedestrian areas only open for alternative vehicles.

Efficient driving behaviour may reduce cars' GHG emissions up to 15 %. The European project ECODRIVEN ([105]) provides good practices for drivers. In the framework of the 2006/32/EC Directive, some European countries have through their National Energy Action Plans signed agreements with driving schools in order to spread the knowledge of efficient driving practices to citizens. Some of these training courses are not only addressed to car drivers, but also to truck drivers.

In the following a description of the use of natural gas as a vehicle fuel is provided, which has an advantage of reduced greenhouse gas emissions and the emissions that affect air quality. It also describes fuelling system along with economics and safety of natural gas technology.

Natural gas is widely available all over the world as one of the cleanest fossil fuels. When used as a vehicle fuel, it has fewer greenhouse gas emissions than petrol or diesel, and none of the particulates associated with diesel. Natural gas can be used in all classes of vehicles:

- light transport vehicles (including motorcycles, cars, and vans);
- heavy-duty vehicles (trucks, buses, even ships and ferries).

Natural gas vehicles (NGVs) are available from different manufacturers (an example of the catalogue can be found in the NGVA Europe).

When comparing to traditional diesel or petrol vehicles, natural gas vehicles have the following benefits:

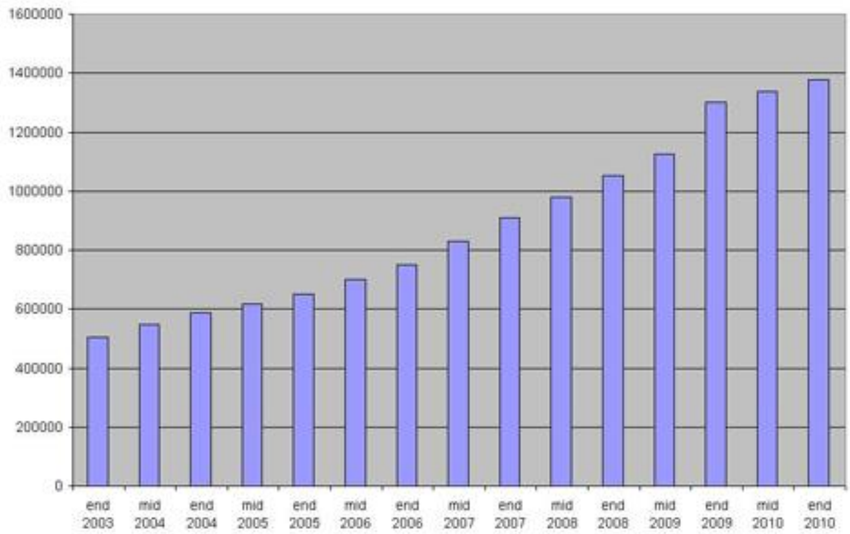
- Reduced greenhouse gas emissions and emissions of nitrogen oxides;
- No particulate emissions associated with diesel;
- Natural gas can be derived from renewable sources, such as biomethane;
- Natural gas vehicles provide noise reductions up to 50%;
- Lower operational costs of NGV;

([105]) https://ec.europa.eu/energy/intelligent/projects/en/projects/ecodriven

- Natural gas can be used in all vehicle classes with established technology;
- Widespread availability of natural gas;
- Safer than most liquid fuels.

These benefits are the driving force for the increasing number of NGVs, which has doubled from year 2005 to 2010. International Association for Natural Gas Vehicles (IANGV) is projecting that this will increase to 50 million vehicles by 2020.

Figure 19. NGV market grow in Europe from 2005-2010



Source: Association for Natural Gas Vehicles (IANGV)

Among the CoM-East countries, Armenia has the largest share of NGVs (more than 55%) followed by Ukraine and Tajikistan, that have 27% and 11%, respectively. Number of total NGV vehicles (except ships, trains and aircraft), and their shares are presented in (**Table 32** ([106])). The data were gathered for year 2011 for all countries, except for Kyrgyzstan, Georgia and Tajikistan, where statistics were available for years 2007, 2008, and 2005, respectively.

Table 32. Statistical information on NGVs status in CoM East countries

Country	Total NGVs	NGVs shares
Armenia	244	55,5%
Belarus	4.6	0,2%
Georgia	3	0,6%
Moldova	2.2	0,4%
Ukraine	388	27,1%

<u>Natural Gas Systems and Technologies</u>. For natural gas vehicles, there are two following fuel options ([107]):

- Mono fuel NGVs that run only on natural gas. Such NGVs can be optimised to run on natural gas by using higher compression ratios, which generally leads to higher engine efficiencies. This is possible because natural gas has a higher octane number than either petrol or diesel, which means the compression

([106]) *Source: NGVA Europe,* statistical information on the European and Worldwide NGV status
([107]) Source: International Association for Natural Gas Vehicles

ratios can be increased without inducing knocking. Natural gas vehicles have a spark-ignition internal combustion engines and are broadly similar to petrol vehicles but with different fuel storage and delivery mechanisms. Since natural gas does not liquefy under compression, it must either be stored on board vehicles as very high pressure compressed natural gas (CNG), usually at 200 bar. CNG fuel tanks have to be strong to withstand in excess of 200bar pressure, and they are usually made out of thick and heavy steel. NGV fuel tanks are therefore either large or heavy, which means natural gas is best suited for larger vehicles such as trucks, buses or vans. Nevertheless, favourable taxation policies can lead to CNG cars being reasonably popular.

- Dual-fuel NGVs that can switch between natural gas and petrol. Many light-duty NGVs (cars and vans) have dual-fuel engines to eliminate the danger of running out of fuel and unable to find a natural gas refuelling station. This is more likely to be a problem with light-duty vehicles since they have more varied and less predictable traveling pattern than trucks or buses. Moreover, light-duty vehicles have difficulties in accommodating large fuel tanks. However, dual-fuel NGVs cannot be optimised to operate on natural gas and therefore do not show full potential for reducing tailpipe emissions.

Refuelling of NGVs is safer than refuelling of vehicles with petrol or diesel, as no evaporative emissions occur during fuelling. Refuelling procedure takes approximately the same amount of time as for traditional vehicles, and is a simple procedure, where the refuelling nozzle clicks onto the receptacle on the vehicle for filling. When the cylinder is full, the dispenser automatically shuts off, indicating that it is ready to be disconnected from the vehicle. Options for refuelling include public station and home refuelling. The location of public stations located in different countries and a gas supplier that offers home refuelling can be found from "Country specific facts and developments" ([108]).

4.3.1 Environmental aspect

Urban Emissions. NGVs are generally very clean in terms of air quality emissions that can affect human health. They involve particulate matter (PM), carbon monoxide (CO), oxides of nitrogen (NOx) and the carcinogenic hydrocarbons (HC). Near-zero PM emissions of NGVs is a particular advantage when natural gas replaces a diesel, which is usually the case for heavy duty vehicles.

In addition, mono-fuel NGVs produce little or no evaporative emissions during both refuelling and combusting fuel in NGVs engines. In petrol vehicles, evaporative and fuelling emissions account for at least 50% of a vehicle's total hydrocarbon emissions.

When comparing to traditional diesel or petrol verticals, the exhaust emissions of natural gas vehicles can be reduced as following ([109]):

- Exhaust emissions of carbon monoxide (CO) can be reduced by 70%;
- Exhaust emissions of non-methane organic gas (NMOG) can be reduced by 87%;
- Nitrogen oxides (NOx) can be reduced by 87%;
- Carbon dioxide (CO2) by almost 20% below those of gasoline vehicles.

Greenhouse Gases. Natural gas contains smaller amount of carbon per unit of energy, than any other fossil fuel, and thus produces lower carbon dioxide (CO2) emissions per kilometre of NGVs. While NGVs do emit methane, another principle greenhouse gas, any increase in methane emissions is more than offset by a substantial reduction in CO2 emissions compared to other fuels. Testing of NGVs has indicated that

([108]) Source: *NGV Statistics*
([109]) Source: International Association for Natural Gas Vehicles

NGVs produce up to 20 % less greenhouse gas emissions than comparable petrol vehicles, and up to 15% less greenhouse gas emissions than comparable diesel vehicles.

4.3.2 Economics and Safety

Economics. The costs of the NGVs are typically higher than traditional vehicles, but users of NGV have the advantage of cheaper fuel. The same tendency persists for other alternative fuel vehicles. For example, a NGV is approximately 3.000 Euro more expensive when compared to a petrol car, the 800 Euro more expensive when compared to a diesel ([110]). However, expenses for the fuel compensate the increased price of a NGV. For example, if 20.000 km is travelled in one year, the NGV amortizes in 4 years. NGV refuelling stations are expensive and only commercially viable if they refuel a relatively largely number of vehicles. Therefore the market penetration of NGVs suffers from the classic problem, when fuel suppliers are reluctant to construct refuelling stations until there are sufficient numbers of NGVs and operators are unwilling to purchase the vehicles until there are sufficient refuelling stations.

Safety. The fuel storage cylinders used in NGVs are much stronger than petrol fuel tanks. The design of NGV cylinders are subjected to a number of federally required "severe abuse" tests, such as heat and pressure extremes, gunfire, collisions and fires. NGV fuel systems are "sealed," which prevents any spills or evaporative losses. Even if a leak were to occur in an NGV fuel system, the natural gas would dissipate up into the air because it is lighter than air. It also has a narrow range of flammability, that is, in concentrations in air below about 5% and above about 15%, natural gas will not burn. The high ignition temperature and limited flammability range make accidental ignition or combustion of natural gas unlikely. In addition, natural gas is not toxic or corrosive and will not contaminate ground water.

Additional resources

- European Commission Transport Webpage — Clean Urban Transport This webpage covers a wide range of information on policies, programmes and tools about Urban Mobility and Clean and Energy Efficient Vehicles. See http://ec.europa.eu/information_society/activities/ict_psp/cf/expert/login/index.cfm online.
- Eltis, Europe's web portal on transport: ELTIS supports the transfer of knowledge and exchange of experience in urban and regional transport. The database currently contains more than 1 500 good practice case studies, including cases from other initiatives and databases like EPOMM, CIVITAS, SUGRE, LINK, ADD HOME and VIANOVA. See http://www.eltis.org online.
- The CIVITAS Initiative: The CIVITAS Initiative, launched in 2002, helps local authorities to achieve a more sustainable, clean and energy-efficient urban transport system by implementing and evaluating an ambitious, integrated set of technology- and policy-based measures. On the website, examples of successful implementation of sustainable transport initiatives can be found (http://www.civitas-initiative.org). (http://www.civitas-initiative.org/docs1/GUIDEMAPSHandbook_web.pdf).
- The GUIDEMAPS handbook is designed to support transport decision makers and designers in European cities and regions. A particular emphasis of the handbook is on using stakeholder engagement tools and techniques to overcome communication barriers in the transport decision-making process. It provides examples and indications of the relative costs of different tools and techniques related to project management and stakeholders' engagement
- Sustainable Urban Transport in Eastern Europe and Central Asia (ECA) Region and http://www.mobilnist.org.ua online.

([110]) *Source: International Association for Natural Gas Vehicles*

- LUTR-PLUME: The LUTR website hosts the PLUME project (Planning and Urban Mobility in Europe), aiming at developing strategic approaches and methodologies in urban planning that all contribute to the promotion of sustainable urban development. The website contains state-of-the-art reports and synthesis reports related to many transport and mobility issues. See http://www.lutr.net/index.asp online.
- HITRANS: HiTrans is a European project with the aim of facilitating the development of high-quality public transport in medium-sized European cities (populations 100 000–500 000). The project has produced best practice guides and guidelines for use by local authorities. See http://www.hitrans.org online.
- European Natural gas vehicle association (web: https://www.ngva.eu)
- NGV communications group (web: http://www.ngvjournal.com/) and news and information for the natural gas vehicle industry (web: http://www.ngvglobal.com/)

4.4 Smart transport

Urban traffic control systems are a specialised form of traffic management that integrate and coordinate traffic signal control. The primary purpose of urban traffic control is to optimise overall traffic performance in accordance with the traffic management policies of the local authority. It uses the signal settings to optimise parameters such as travel time or stops. Urban traffic control systems are either fixed-time, using programmes such as TRANSYT, or real-time, such as SCOOT ([111]). Widespread experiments have demonstrated the benefits of such systems; that is, efficiency gains improve the environment, queues and safety, with typical reductions in accidents of the order of 10 %. However, it is important to bear in mind that the potential for these benefits may be eroded by induced traffic.

In addition, the control systems may be used for the regulation of priorities of different interest groups such as pedestrians, cyclists, disabled persons or buses. For instance, these control systems can distinguish whether a bus is on time or late and to what degree. Depending on this analysis, the priorities of traffic regulation will be readjusted in order to minimise delays and make public transport by bus more effective.

Box 41 Example of smart transport in Tbilisi (GE)

In order to reduce traffic congestion, Tbilisi City Hall has introduced the Green Wave system at Pekini Avanue, allowing for an uninterrupted stream of vehicles through six intersections: before, around 2 100 cars per hour had to stop at 4 out of 6 different intersections. After the introduction of a new system, around 800 cars have to stop at only two intersections, thus increasing the speed of the traffic flow and reducing the amount of fuel used by vehicles ([112]).

In the near future, the Green Wave system will be introduced at other intersections. The municipality will create a Traffic Lights Management Centre that will ensure efficient electronic management of traffic lights throughout the whole city.

Another possibility offered by control systems in big cities is 'Ramp Metering', which consists of a traffic management tool that regulates the flow of vehicles joining the motorway during busy periods. The aim is to prevent or delay the onset of flow breakdown. Benefits include ease of congestion and improvement in traffic flows, higher throughput during peak periods, smoother, more reliable journey times and improved energy consumption.

Box 42 Example of smart transport in Yerevan (AM)

To optimize city transportation, Yerevan Municipality has started rethinking it public transportation system, with rerouting of all public bus routes, developing of unified ticketing system for buses, metro and trolleys, transitioning from small passenger mini-buses to large, cleaner fuelled city buses, while building several interconnections among the city roads to introduce a circular road, which will avoid the city centre and connect the suburbs through a Green Wave.

In addition, the City plans building large parking locations on the city periphery with bus hub connections to ensure that vehicles arriving from outside Yerevan have an incentive to leave their cars and transition to public transport thus reducing the traffic congestion.

([111]) TRL — Transport Research Foundation based in the United Kingdom (http://www.trl.co.uk).
([112]) Source: Sustainable Energy Action Plan — City of Tbilisi — 2011–2020.

5. Local Energy Generation

5.1 Municipal policies for local energy generation

In this section examples of policies and best practices are described according to the four modes of governance, namely municipal self-governing, governing through enabling, governing through provision, and regulation and planning. As evident by subsequent discussions, a successful implementation of measures with widespread impact requires well-rounded to support from multiple modes acting in combination to local energy generation.

5.1.1 Municipal self-governing

— Management of the local government estate to increase local energy generation: The municipality requires renewable energy generation to provide for a high share of the building energy needs in the design of new public buildings and the retrofit of existing public buildings. Town halls with innovative solar energy façades and schools that are powered by photovoltaic panels may be given as initial examples. When possible, the municipality can also require DH/C grids in public buildings areas, including through contract to connect municipal buildings to the district heating and/or cooling network.

— Renewable energy demonstration projects in public facilities: Public buildings provide important opportunities as demonstration sites for renewable energy technologies. Municipalities can publicly test and show the success of renewable energy measures that are implemented in public buildings. Moreover, priority may be also given to less wide-spread testing technologies, such as low-power absorption, chillers and microcogeneration. It is important that the results of the pilot installations (positive and negative) are shared with the stakeholders. The pilot projects can also attract the interest of private stakeholders upon which similar projects can be replicated across the city. Additional opportunities include the use of biogas from wastewater treatment facilities in a cogeneration plant or in public vehicles fleet driven by biogas/natural gas.

— Public procurement: In addition to the mobilization of public resources for renewable energy projects, municipal purchases of certified green electricity can increase the share of electricity consumption from renewable sources, going beyond national schemes. Public procurement can also be used to prescribe a share of renewable supply in the case of service contracts to municipality owned facilities. One of the prerequisites for the use of public procurement as a strategic tool to increase local energy generation in municipality-owned assets is the identification of appropriate public buildings and facilities. Public facilities that typically have high energy intensity profiles include swimming pools, sports facilities, and office buildings as well as hospitals or retirement homes. Inefficient heating plants and boilers at these sites can be replaced by cogeneration, trigeneration, renewable energy installations or a combination of both according to the energy demand profile for heating and cooling. Actions at these sites can also have a high replication potential across the private sectors, such as the food industry and hotels, among others. For this reason, a strong communication policy is essential to share the results with the private sector.

Possible Actions with High Replication Potential

— Substitution of the old heating and cooling plants by trigeneration installations to provide the base demand of heat and cold throughout the year in municipal buildings.

— Substitution of a public swimming pool's old heating plant by an installation of a combined solar thermal and biomass system, financed through an ESCO scheme.

5.1.2 Municipal enabling

Public-private partnerships: Cooperation between the municipality, local investors, and local citizens are deemed to be vital factors of success for realizing the transition to 100% renewable energy systems [70]. The leadership of local governments usually have a crucial role in forging partnerships and pooling resources across the public and private sectors. Examples include public-private partnerships for anaerobic digestion of biowaste for CHP-based district heating and the co-financing of public energy upgrading between local and regional authorities and private investors. Especially in the bioenergy sector, the supply of urban biowaste can depend on citizen awareness and motivation to put aside organic waste for separate collection. For this reason, it is also important to motivate citizens in partaking in waste management strategies to enable the use of organic waste to produce biogas.

Box 43 Berlin Solar Atlas (DE)

Integrated in the Berlin Economic Atlas, the Solar Atlas shows the solar potential of each building in the city in clear, sharp images in both 2D and 3D. Property owners and investors can use the Atlas to determine whether a building's roof is suitable for a solar installation and whether the investment will pay off. The Atlas provides key information at a glance on such matters as the potential power output, reductions in CO2 emissions, and estimated investment costs.

Source: http://www.businesslocationcenter.de/en/berlin-economic-atlas/the-project/project-examples/solar-atlas

Awareness raising and training activities: Examples of training material may be found on European projects' web-pages ([113]). Promotional campaigns, such as solar energy campaigns, can be effectively combined with supporting tools, including the provision of a solar atlas and solar land registry.

Box 44 Vlaams-Brabant Climate Map (BE)

The climate map of the Vlaams-Brabant Province includes over 1,192 local climate and energy initiatives and projects in the areas of mobility, building, agriculture, energy production and consumption. It is an interactive map that enables municipalities and local stakeholders (e.g. companies, citizen groups, schools, etc.) to include their actions in a user-friendly way. Renewable energy producers can use the map to calculate their contribution to the CO2 reduction efforts of the province.

Source: http://www.eumayors.eu/en/

Community cooperatives for local energy projects: Community cooperatives for local energy projects can enable citizens to have collective ownership and management of such projects, including those based on renewable energy generation ([114]). At the same time, community cooperatives require a certain level of citizen engagement and empowerment. For this reason, awareness building activities can be used to mitigate perceptions of risk of renewable energy cooperatives that can hinder the profitability of such initiatives as well as their contribution to energy transition objectives. In this case, awareness building in support of local energy generation can also be used to satisfy needs to empower community participation and buy-in in such initiatives [71].

([113]) Energy Efficiency Training of Trainers (EETT) *https://ec.europa.eu/energy/intelligent/projects/en/projects/eett*
([114]) https://transitionnetwork.org/

Box 45 Solar Systems Integration Manual in Lisbon, Portugal

Historic buildings exempted within the Portuguese national legislation on buildings energy performance for the obligation for installing solar thermal systems in residential buildings. Although one can easily understand the importance of preserving the national patrimony, this exemption is often misunderstood by investors and property developers that heritage buildings should not comply with the actual requirements for energy efficiency and comfort in residential buildings. As a consequence, these districts are abandoned and left derelict, a common situation in several European countries. To overcome this trend it is important to upgrade residential historical buildings to modern standards, including the possibility of integrating solar technologies.

In the Baixa Pombalina's urban regeneration plan, Lisboa E-Nova , in cooperation with the Lisbon Municipality and IGESPAR (the entity responsible for the management of the national archaeological and architectural heritage), promotes the programme 'Solar Systems Integration Potential in the Lisbon Baixa Pombalina Area'. The project outcomes will be incorporated in the area's urban regeneration plan to promote the integration of solar systems during refurbishment while following cultural heritage requirements. To complement this potential assessment, there will be an Integration Manual, to be developed according to existing market solutions on solar systems and to the relevant criteria for integrating such systems in historical buildings. The solutions identified can be adopted also in other protected historical areas across Europe.

Source: Fernandes, J. Solar Thermal Systems in Lisbon Historical Baixa Pombalina, Lisboa e-Nova

5.1.3 Governing through provision

- Direct energy infrastructure investments: The utilization of renewable energy sources in the urban built environment may be limited due to insufficiencies in the energy infrastructure. In this case, direct investments at the local level are needed, including those for modernizing and expanding DH/C networks. In combination with regulatory means of governance, municipalities can further require that connections to the DH/C network are compulsory for buildings located in related zones. In the case of municipally owned utilities, minimum quotas for renewable energy sources or co-generation can be set. Otherwise, municipalities can involve utility companies in new projects for local energy generation to take advantage of their experience, facilitate greater access to the grid and reach a larger share of individual consumers. Public housing further provides a venue to promote the integrated use of renewable energy sources, including solar thermal, solar PV, biomass and micro-cogeneration. This entails adapting the design of public housing to the requirements of these options.

- Incentives and grants to local energy generation: Municipalities can issue municipal green bonds and create funds for renewable energy deployment. The provision of financial opportunities such as these can overcome market failures and address economic barriers for the widespread deployment of related technologies. In addition, municipalities can provide subsidies for connections to the district heating network as well as those that may involve the use of any low temperature heating systems that can reduce the operating temperature of the network to increase its efficiency [72].

- Subsidies for local electricity and thermal energy production based on CHP plants as well as the provision of financing for demonstration projects on smart grids can also accelerate progress towards CO_2 mitigation targets based on local energy generation.

5.1.4 Regulation and planning

- Ordinances on the mandatory use of renewable energy: Solar Thermal Ordinances (STOs) represent one of the most prevalent forms of mandatory regulations for renewable energy. STOs are legal provisions making the installation of solar thermal systems in buildings mandatory. The obligation mainly applies to new buildings and those undergoing major refurbishment. The owner must then install a solar thermal system meeting legal requirements. Most of the existing STOs are connected to national or regional energy laws and implemented through the municipal building codes. A growing number of European municipalities, regions and countries has adopted such obligations ([115]). In addition, municipalities can require mandatory installations of photovoltaic systems among other renewable energy technologies.

- Ordinances on the mandatory use of renewable energy: Regulatory measures can further require households and private companies to purchase green electricity through obligations on local energy suppliers. Alternatively, consider establishing a joint framework agreement to purchase green electricity.

- Review and revise urban planning regulation to consider the necessary infrastructures required for the development of the DH/C.

- Adapt the administrative procedures to shorten the time required to obtain permits, and reduce local taxes when energy efficiency improvements or renewable energy sources are included in the proposals. Declare these projects as "Public Interest" and apply them advantageous administrative conditions when compared to non-energy efficient projects. Administrative procedures should be clear, transparent and quick enough to facilitate the development of DH/C projects to alleviate any barriers and uncertainty.

- Contact networks of other local authorities or European/national/regional local authorities and produce a common proposal of new regulation for the promotion of distributed energy generation addressed to the relevant public authorities.

- Set up rules to clarify the roles and responsibilities of all actors who are involved in selling and buying energy, especially in cases where experience and regulations may be previously lacking, including those for new DH/C networks. Check that duties and responsibilities are clearly identified and that each actor is aware of them. In the energy-selling sector, make sure that measurements of energy are in accordance with recognised standards, e.g. International Performance Measurement and Verification Protocol (IPMVP). Transparency is a key aspect from the point of view of consumers and investors. "Rules of the game" should be in force as soon as possible. Convoke all stakeholders to obtain their views and understand their interests and concerns.

- Strategic energy planning to support local energy generation: in addition to setting regulations, strategic energy planning tools and decisions provide a means for local authorities to evaluate and enforce decisions to promote local energy generation. Box 49 exemplifies instances in which strategic energy planning would be necessary to promote the generation and utilization of local energy resources, including those of residual heat from the industry, data centres, and wastewater treatment plants. Local maps with information on heat demand densities and the locations and magnitudes of residual heat from industry and power generation can largely facilitate this process ([116]).

In addition, land use planning should be considered for large-scale solar plants and wind turbines. These aspects call for integrated urban planning processes to support local energy generation decisions as the basis for additional action, such as:

- Establish an integrated urban planning process to promote renewable energy generation deployment. Identify possible sites to install local energy generation installations, such as those for solar, wind, small hydro and biogas, ensuing the availability and compatibility of space to achieve projects. If needed, provide public space to install local energy generation installations. Some European local authorities offer rooftops of public buildings to private companies for rent to produce energy by means of

([115]) Solar Thermal Ordinances = Making a commitment to local sustainable energy, *http://www.estif.org/fileadmin/estif/content/projects/prosto/downloads/prosto%20brochure.pdf*
([116]) Pan-European Thermal Atlas (PETA 4.2) *http://www.heatroadmap.eu/maps.php*

photovoltaic collectors ([117]). The contract duration is established beforehand and the objective is to exploit large unused spaces to promote renewable energy.

- Establish integrated urban planning processes, including those to promote DH/C networks and cogeneration plants. Develop appropriate mapping tools of thermal energy demand from buildings based on reliable data from utilities.

Box 46: Planning for Local Energy Generation and Utilization

- Evaluate geothermal energy potential considering legal and technical barriers of ground perforation and the environmental effect on the underground water layer.

- With regard to the use of biomass, make a technical and economical evaluation of the potential of the biomass harvested in public spaces, companies and citizens' properties, the potential impacts of biomass combustion on air quality and health should be also evaluated.

- Consider the integration of residual heat into the district and cooling network, including sources of residual heat from the industry, data centres, wastewater treatment plants, and waste incinerators.

5.2 Key measures for transition to sustainable local energy systems

Policy measures give direction to increasing the valorisation of local opportunities in the context of local characteristics and available measures. This section is intended to provide a collection of key measures to promote the uptake of renewable sources and integrated urban energy systems. The options for the transition to sustainable local energy generation systems range from decentralised renewable energy options to centralised solutions, such as cogeneration and district heating and/or cooling networks.

In this context, there is increasing interest in the decentralisation of the energy supply with more local ownership. Local energy supply options can take the form of district energy systems, local power generation utilities, and energy services companies (ESCO). Local authorities can be in whole or partial owners of these utilities and promote community partnership. Decentralised renewable energy technologies offer the possibility to produce energy with a much lower impact on the environment when compared to conventional energy technologies. Distributed electricity generation allows to reduce electricity transport and distribution losses and to use micro-cogeneration technologies while increasing the penetration of low-scale renewable energy technologies. The electricity grid must be able to distribute this energy to the final consumers when the resources are available, and rapidly adapt the demand, or cover the energy that is required using more adaptable technologies when the former are not available, such as hydropower or biomass. Centralised options include cogeneration power plants and DH/C networks. Cogeneration (or CHP – Combined Heat and Power) and DH/C networks offer an efficient way of producing electric power and thermal energy for urban areas. Cost-effective policies that maximise efficiency benefits should focus on measures targeting areas with high heating and cooling densities. In addition, DH/C provides a proven solution for the efficient use of multiple renewable energy sources on a large scale, including biomass, geothermal, and solar thermal energy resources, and recuperates the residual heat from electricity production, fuel and biofuel-refining, waste incineration, and industrial processes. The Heat Roadmap Europe Pan-European Thermal Atlas (PETA) maps the magnitude and localities of such opportunities, including urban biowaste, surplus heat from thermal generation with the main activity of electricity generation, and various industries ([118]). Opportunities for the utilization of bioenergy resources, solar

([117]) Guide for local and regional governments "Save the Energy, save the climate, save money" (2008). CEMR, Climate Alliance, Energie-Cités, *http://www.ccre.org/img/uploads/piecesjointe/filename/sustainable_energy_en.pdf*
([118]) Pan-European Thermal Atlas (PETA 4.2) *http://www.heatroadmap.eu/maps.php*

thermal district heating, and geothermal heat are also emphasized within the common mapping platform. Table 33 summarizes the key measures to promote local energy generation by renewable energy source or technology, based on compilations from the Covenant of Mayors Signatories' Benchmarks of Excellence ([119]).

Table 33. Policy measures to promote local energy generation by renewable energy source

Area of intervention	Policy measure
Local electricity generation: Photovoltaics	Municipal financing and ownership of PV pilot plants on public buildings (rooftop PV and building-integrated PV systems)
	PV installations on the roofs of bus sheds (968 kW in Mantova, IT) or parking lots
	Construction of a PV park on ground of municipal property at a former landfill site (994 kW in Torrile, Italy; Évora,PT)
	Concession of surface rights and renting of rooftop areas in public buildings for PV
	PV installations in public buildings based on collaboration with the ESCo and third-party financing for PV systems in school buildings
	Public-private partnership for Photovoltaic Solar Park (24.2 MW in Coruche, Portugal)
	Energy supplier obligations for PV systems • Mandate for PV system installations equal to a given share of the total installed power in the municipality
	Municipality bonus for photovoltaic and solar thermal installation on citizen's roof
	Interest-free loans for associations or schools for PV panel installations (Bree, BE)
	PV systems that supply electric vehicle charging stations (135kW in Poole, UK)
	Awareness building and supporting tools • Solar land registry for roof-top photovoltaic or solar thermal installations (Paris, FR) • Solar chart for identifying preferable areas for solar energy technologies (Lisbon, PT) • Solar roof cataster (Bremen, DE; Fürstenfeldbruck, DE; Hanover, DE; Barcelona, ES and others)
	Real time electricity generation data on PV systems of the City Council (Málaga, ES) and visual consoles on CO_2 reductions
	Public awareness to reach annual increase targets for PV in the private buildings
	City supported photovoltaic campaign • One million square metres of solar modules by 2020 (Hanover, DE)
	Land use planning for utility-scale photovoltaic plants in the municipality
Local heat generation: Solar thermal	Solar collectors on rooftops of municipal buildings, swimming pool facility, sport buildings and schools (including flat-plate and parabolic solar collector installations) • Replacement of electrical heaters and boilers in public buildings
	Ordinance for installing solar collectors • Solar collectors in all buildings in the health care sector (Zagreb, HR) • Solar thermal systems in 100% of schools that include south-facing facades and terraces (Loures, PT)
	Purchasing groups to allow widespread diffusion of solar thermal technology
	Targets to increase the area of solar thermal in the municipality
Local electricity generation: Wind energy	Wind and solar farm with citizen cooperation (Nijmegen, NL)
	Installation of wind power farms • Promotion of locally owned wind turbines (Ringkøbing-Skjern, DK) • Public procurement of municipality owned wind turbines (4 x 3.3 MW in Eskilstuna, SE that is 40% of the municipal electricity load) • Co-ownership of wind-power plants (municipal company in Lund, SE)
	Attraction of companies that want to generate electricity from wind energy • Prioritized case handling and licencing of wind turbines
	Land use planning for wind turbines
Local electricity generation: Hydroelectric power	Mini-hydro plants on municipal waterworks • Ronchi Valsugana, IT
	Attraction of investment to realize an in-stream tidal hydro power plant (10 MW)
	Run-of-river hydroelectric plants • Produces the amount of electricity needed for public building and public lighting loads (Roman, RO)

([119]) Covenant of Mayors for Climate and Energy Signatories' Benchmark of Excellence.

	Hydroelectric power plant construction (Manerbio, IT; Mazzin, IT; Rosà, IT)
Bioenergy	Biogas cogeneration plant for electricity and thermal energy provision based on anaerobic digestion (Annicco, IT)
	Biogas cogeneration based on zootechnical wastewater and silage cereals
	Biogas driven district heating network
	New anaerobic digestion plant in public waste recovery and treatment company
	Public-private partnership between the municipality and waste management utility for anaerobic digestion of biowaste for CHP-based district heating (Este, IT)
	Recovery of methane gas from landfills to produce electricity based on gas engines • 120 wells degassing biogas capture and network piping (Málaga, ES)
	Biomass based district heating network and/or biomass boilers for replacing diesel boilers (local wood chips < 60 km from sustainable management of forests) • 6MW in Banja Luka, BH
	Consortium for a cogeneration plant based on biomass certified as sustainable (waste produced locally or from local consortium companies (Bagnolo San Vito, IT)
	Installation of wood chip boilers in the CHP plant for carbon neutral district heating • Fuel switching in Liepāja, LT and other signatory municipalities
	Collection and recycling of used cooking oil for biodiesel production (Loures, PT)
Geothermal energy	Construction of a geothermal power plant
	Low enthalpy geothermal heating for municipal residential building
Renewable energy (other)	City Council grants and subsidies for renewable energy (PV, solar thermal, biomass, ground source heat pumps) • Subsidy per square meter of solar thermal collector area (Bonn, DE) • Grants for solar collector and heat pump installations (Alken, BE) • Subsidy to renewable heat sources in residential buildings (Gdynia, PL)
	Clean technology funds for renewables
	Promotion of distributed energy generation based on Urban Building Regulations and simplified building authorization procedures
	Public buildings that are self-sufficient based on on-site renewable energy • Self-sufficient town hall based on bioenergy and PV (Baradili, IT)
	Demonstrations of net or nearly zero energy building with renewable energy • Net zero energy schools (Göteborg) • Viikki Environment House as nearly zero energy office (Helsinki, FI) • Pilot public school built according to the Nearly Zero Energy (NZE) Standard (Winkelomheide, BE) • Co-financing of a near zero energy school building with local and national funds (Scuola Pascoli)
	Public buildings with bioclimatic design principles and renewable energy utilization • Public social building complex • Energy renovation of public buildings including solar thermal collectors (Karlovac, HR) • Daycare centre with solar and geothermal energy (Kozani, GR)
	Brownfield urban development with renewables and sustainable districts • Transformation of former port and industrial area into a new sustainable district (Ravenna, IT) • Sustainable Järva with 10,000 m^2 solar cells (Stockholm, SE)
	Co-financing between local and regional authorities for public energy upgrading • Co-financing of solar thermal systems on public buildings (Castelnuovo Rangone, IT)
	Purchasing of certified renewable power for public buildings and public lighting • Joint framework agreement for purchasing 100% green electricity (Province of Limburg, Netherlands)
	Onshore Power Supply with high-voltage for docking ships in the port (Gothenburg)
	Awareness building actions • Experimental sessions on renewable energy for students • Training campaigns organized by the local energy utility/agency

Source: Compiled from entries in the Covenant of Mayors Benchmarks of Excellence

The above grouping of the best practices by renewable energy source or technology is also indicated by options for local electricity generation or heat generation as relevant. In other cases, processes for local energy generation for power and heat/cold are combined and/or relate to central district energy infrastructure. For these cases, **Table 34** provides a similar compilation for CHP plants, DH/C systems, and smart grids. Similarly, modes of urban climate governance that are involved in the measures are marked to showcase the integrated approach that is needed to support local energy generation solutions.

Table 34. Policy measures to promote CHP, district energy/cooling systems and smart grids

Area of intervention	Policy measure
Combined heat and power	Cogeneration plant for municipal buildings
	Biomass-based combined heat and power plant to support the district heating system (Jönköping, Sweden 340 GWh_t 130 GWh_e)
	Modernization of the cogeneration plant with fuel flexibility for waste and bioenergy (Västerås, SE)
	Investment of the public utility company in a new cogeneration plant with both district heating and cooling infrastructure • Bioenergy based plant with co-location of PV panels on the roof of the plant (Fürstenfeldbruck, DE)
	Subsidies for CHP electricity production
District heating/ cooling plant	Large scale solar thermal solutions in district heating systems (Marstal District Heating in Aeroe, Denmark)
	Flue-gas heat recovery to increase efficiency of heat production (Riga, LV)
District heating/ cooling network	Contract to connect municipal buildings and schools to the district heating network • Commitment to invest 10% of the contract sum to energy retrofitting and maintenance (Milan, IT)
	Integrated heating systems between public buildings (Vittorio Veneto, Italy)
	Initiative to increase the purchased volume of energy from the district heating network • Subsidies and/or obligations for connection to district heating
	Modernization and rehabilitation of district heating and/or cooling networks • Remote monitoring of pipelines and insulation to reduce heat losses (30% to 12% in Bielsko-Biala, PL)
	Installation of thermal energy distributors and thermostatic radiator valves in the district heating network (Rijeka, HR)
	Connection of low energy houses to a low-temperature district heating network (Västerås, SE)
	Connection of buildings and industries to the district cooling network • Energy efficient data center with PV on the server hall roof (Växjö, SE)
	Utilization of residual heat from urban wastewater (Aachen, Germany)
	Utilization of industrial waste heat • Recovery of waste heat from the local steel industry (Finspång, SE) • Substitution of the use of natural gas based on the use of waste heat from a pulp mill (Judenburg, AT)
	Cooperation to establish noise barriers for road and rail traffic equipped with solar energy collectors to support the local district heating system (Lerum, Sweden)
	Cooperation with the local energy utility to establish a district heating network
	Interconnection of district heating networks and extension of distribution piping
	Urban energy planning to increase the connection of buildings to the district heating network (Kristianstad, SE)
	Increase in the share of renewable energy sources in the district heating network • From 40% to 75% in Ringsted, DK
Smart grids	Cooperation with the district network operator for demand side management • Monitoring and response to peak load in public buildings towards a future smart grid (Glasgow, UK)
	Financing of pilot projects on smart grids and allocation of local demonstration sites (local, regional, national, and EU funds)

In addition to the energy sector, opportunities for local energy generation exist within the water and waste sector. A cross-sectoral perspective that is not limited to only one sector is therefore necessary. **Table 35** complements this aspect based on a compilation of policy interventions for measures involving waste management, wastewater treatment plants, and water management. The relevant modes of urban climate governance are marked to emphasize the integrated approach that is needed also in these areas of intervention.

Table 35. Policy measures for waste and water management including wastewater treatment

Area of intervention	Policy measure
Waste management	Separate waste collection to increase the recycling of municipal solid waste and the use of organic waste for biogas production
	Use of green waste for the production of compost and pellets (Lakatamia, CY)
	Utilization of organic waste for composting rather than waste-to-energy incineration
Wastewater treatment plants	Self-sufficient wastewater facility based on methane driven combined heat and power plant (Neumarkt in der Oberpfalz, DE)
Water management	Integration of renewable sources for supplying power to pumping tapwater
	Reduction in electricity usage for pumping based on reductions in water losses in the drinking-water distribution network Seixal, PT; Bilbao, PT
	Information system for energy and water use in the public sector (Voznesensk, UA)

Source: Compiled from entries in the Covenant of Mayors Signatories' Benchmarks of Excellence

5.2.1 Energy in buildings

Renewable energy will play a major role in tackling climate change and can provide an affordable and secure source of energy, including in the building stock. Renewable energy is cheaper now than ever due to technological developments, mass production and market competition. In the case of photovoltaic (PV) electricity generation, the technology has reached or on the verge of matching household electricity prices for grid-parity in certain contexts [73]. Key measures for the deployment of decentralised renewable energy in buildings consist of photovoltaic electricity generation, solar thermal systems, biomass systems, and geothermal heat pumps.

Developments are further driven by legislation on nearly zero-energy targets that require buildings to produce nearly as much energy as used on an annual basis, which is possible based on the integration of distributed energy generation from renewable energy sources in buildings ([120]). In Europe, all new buildings are required to satisfy nearly zero-energy performances by the end of 2020 while all new public buildings shall be nearly zero-energy by the year 2018 ([121]). Both targets affect the building stock at the local level.

As indicated by the case study of the Viikki Environment House in Helsinki, Finland (Box 47), nearly zero-energy targets in buildings will require the effective use of multiple local energy generation options, including solar, geothermal, wind energy, and district heating.

Box 47. Viikki Environment House: Helsinki, Finland

Viikki Environment House was the first nearly zero energy office building built in Finland. It was completed in 2011. The building has been awarded with several prizes. The design of the building envelope and building service systems are based on maximal energy efficiency. The building is equipped with solar panels on the roof and integrated to facade, ground source cooling and micro wind turbines. Building is heated with district heating.

5.2.1.1 Solar thermal installations

Solar thermal technology brings a significant CO_2 emission reduction as it entirely substitutes fossil fuels. Solar collectors can be used for domestic and commercial hot water, heating spaces, industrial heat processes and solar cooling. The amount of energy produced by a solar thermal installation will vary depending on its location. This option may be taken into account in most of the countries due to the increase of fossil fuels and

([120]) Nearly zero-energy buildings, *https://ec.europa.eu/energy/en/topics/energy-efficiency/buildings/nearly-zero-energy-buildings*

([121]) Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the Energy Performance of Buildings, *http://data.europa.eu/eli/dir/2010/31/oj* decrease of solar collector prices. Further information on solar thermal strategies can be found on European Solar Thermal Technology Platform webpage.

The performance of solar thermal collectors represents the percentage of solar radiation converted to useful heat. It can be calculated when the input and output average temperature ($T_{average}$), environment temperature ($T_{environment}$) and solar irradiation (I) are known. Coefficients a_0 and a_1 depend on the design and are determined by authorised laboratories. I is the solar irradiation at a given moment.

$$\eta = a_0 - a_1 \frac{(T_{average} - T_{environment})}{I}$$

At a certain environmental temperature, the lesser the average input/output temperature is, the higher the whole performance will be. This is the case of low temperature installations (swimming pools) or low solar fraction (30-40%) installations. In these cases the energy production per square metre (kWh/m^2) is so high that the simple payback of the solar installation is significantly reduced. Designers must consider that for a given energy consumption, the energy yields per square metre (kWh/m^2) will decrease as the total surface of the collector is increased. As in this case the cost of the whole installation will go up, it will be required to estimate the most cost-efficient size.

Considering the positive effect on the profitability of low solar fraction and the effect of economies of scale in large plants, these installations might be implemented using an ESCO scheme ([122]) in swimming pools. For the examples of technical and economical project for swimming pools, an interested reader is refereed to website supported by Intelligent Energy Europe ([123]). Solar thermal energy is also applied in district heating and cooling, laundries, car washing and industries [74]. Many municipalities have found these a cost-effective alternative for satisfying the large need for hot water supply in municipal kindergartens.

Box 48. Expansion of RES utilization in the Novogrudok region (BY)

Since 2012 city administration has worked with the initiative for the larger utilization of RES with support from EC, Energy Charter and the Italian Kietti province. The project introduced the solar thermal collector for kindergarten in 2014. The project also developed a roadmap for further expansion of RES utilization in the Novogrudok region aimed at establishment of environmentally clean zone during 2014-2025, followed by RES development strategy.

Source: Novogrudok SEAP available the CoM website

The JRC has created a database ([124]) that contains solar radiation data for European and other countries. These data may be used by the designers for the evaluation of the necessary collector's surface by using, for example, an f-chart or direct simulation model. The database is focused on the calculation of photovoltaic installations, but data linked to the solar radiation may also be used for solar thermal installations designs:

Additional resources:

— IEA report on Solar Heating and Cooling (2012) that aims to identify the primary actions and tasks that must be addressed to accelerate solar heating and cooling development

5.2.1.2 Bioenergy for bioheat and/or bioelectricity in buildings

Currently, the use of bioenergy for heating as bioheat in the residential, services, and industry sectors exceeds the use of bioenergy in the power and transport sectors as bioelectricity and biofuels. In the case of biomass, sustainably harvested biomass is

([122]) Further information is available at https://ec.europa.eu/energy/intelligent/projects/en/projects/st-escos.
([123]) http://www.buildup.eu/en/news/solar-energy-use-outdoor-swimming-pools
([124]) http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php

considered a renewable resource. However, while the carbon stored in the biomass itself may be CO_2 or greenhouse gas neutral, the cropping and harvesting (fertilisers, tractors, pesticide production) and processing to the final fuel may consume an important amount of energy and result in considerable CO_2 releases, as well as N_2O emissions from the field. Therefore, it is imperative to take adequate measures to make sure that biomass, used as a source of energy, is harvested in a sustainable manner and used in the most efficient manner possible, including in systems for both bioheat and bioelectricity.

Biomass is considered as a renewable and carbon-neutral energy source when the territorial approach is used for the CO_2 accounting. If the Life Cycle Analysis (LCA) approach is chosen for the CO_2 emissions inventory, the emission factor for biomass will be higher than zero so that differences between both methodologies in the case of biomass may be very important. Following the criteria established in the 2009/28/EC Directive on the "Promotion of the Use of Energy from Renewable Energy Sources," biofuels will be considered as renewable if they fulfil specific sustainability criteria.

Biomass systems are available on the market from 2 kW onwards. During a building refurbishment, fossil fuel boilers (in particular coal) can be replaced by biomass systems. The heat distribution installation and radiators are the ones used with the previous installation. A biomass storage room must be foreseen for the accumulation of pellets or wood chips. The performance of the combustion and the quality of the biomass are critical to avoid the emissions of particles into the atmosphere and the system must be adapted to the type of biomass that is to be used. Related best practices include the use of biomass in boilers for replacing diesel boilers and in CHP based DH/C networks.

The examples of installations of biomass boilers are indicated at webpage of BioHousing project supported by Intelligent Energy Europe. The project's webpage offers a tool aimed at comparing costs of biomass and other fossil fuels ([125]).

Additional resources:

- IEA report on Bioenergy for Heat and Power (2012)

- Examples on heat production from biomass in Ukraine can be found at the webpage of Scientific Engineering Centre "Biomass" and in the "Prospects for Hear Production from Biomass in Ukraine" paper of Bioenergy Association of Ukraine

5.2.1.3 Condensing boilers

A condensing boiler is a high efficiency modern boiler that incorporates an extra heat exchanger so that the hot exhaust gases lose much of their energy to pre-heat the water in the boiler system. Condensing boilers are able to extract more energy from the combustion gases by condensing the water vapour produced during the combustion. A condensing boiler's fuel efficiency can be 12% higher than that of a conventional boiler'. Condensation of the water vapour occurs when the temperature of the flue gas is reduced below the dew-point. For this to occur, the water temperature of the flue gas exchanger must be below 60 ºC. As the condensation process depends on the returning water temperature, the designer should pay attention to this parameter so as to ensure it is low enough when it arrives to the exchanger. In case this requirement is not fulfilled, condensing boilers lose their advantages over other types of boilers. When a conventional boiler is replaced by a condensing one, the rest of the heat distribution installation will not undergo major changes.

([125]) Further information on Biomass Boiler Installation is available at https://ec.europa.eu/energy/intelligent/projects/en/projects/biohousing

Box 49 Example of high-efficiency boilers in Voznesensk (UA)

During 2010-12 the Voznesensk City ouncil implemented a project transitioning some of the municipal buildings to modern high-efficiency boilers working on various biomass energy sources (briquettes, bark, wood waste, sawdust, etc.) during the day, while switching to electric heating and at night from 23:00 to 6:00 am, taking the advantage of the night-time tariff which was four times lower than the daytime at the time. The project included secondary school № 2, №10, kindergartens № 1, №4 and №6. Financing sources: Local Authority's own resources and allocations from the state funds, with overall Implementation cost of € 49,150.

The project resulted in annual CO_2 emission reduction of 38 t, Energy savings of 211 MWh/year.

Additional resources

- Practical guidance for application low temperature hot water boilers from the Carbon Trust, which is an organisation helping to accelerate the move to a low carbon economy through carbon reduction and energy-saving strategies

- National Energy Foundation provides guidance on Condensing Boilers.

- Energy Efficiency Best Practice in Housing on Domestic Condensing Boilers (by Energy Saving Trust).

- Practical guidance for application renewable energy, including biomass heating and heat pumps from the Carbon Trust.

5.2.1.4 Heat pumps and geothermal heat pumps in buildings

Heat pumps ([126]) combine high energy conversion with the capability of utilising aerothermal, geothermal or hydrothermal heat at useful temperature levels. Heat that is extracted from the environment by a heat pump (ambient heat) is considered renewable as long as a minimum Seasonal Performance Factor (SPF) for the unit is met ([127]).Heat pumps present a versatile energy technology that can provide both heating and cooling in a great variety of building contexts and applications, which can be combined with smart technologies and storage. Heat pumps can also provide for flexibility in the electricity system and contribute to the management of the variability of heating and cooling demand. For these reason, heat pumps have the potential to become a mainstream technology in the heating and cooling sector, including at the building level.

Heat pumps are composed by two heat exchangers. In winter the heat exchanger located outdoors will absorb heat from the environmental air. The heat is transferred to the indoor exchanger to heat the building. In summer the role of each part is inverted. The outdoor unit must transfer heat in summer and absorb it in winter so that a heat pump's performance is highly influenced by the outdoor temperature. In winter (summer), the heat pump's performance will decrease according lower (higher) temperatures. Since the performance of heat pumps depends on both the indoor and the outdoor temperatures, it is convenient to reduce the difference between them as much as possible to increase performance. Accordingly, in the winter season, an increase of temperature in the heat pump's cold side (outside) will improve the performance of the cycle. The same reasoning can easily be applied to the hot (outside) side in summer.

In addition, a possible solution to increase typical performance values is to use ground water as a source of heat in winter and source of cold in summer. This can be done due to the fact that, at a certain depth, the ground temperature does not suffer significant fluctuations throughout the year. Generally, the coefficient of performance (COP) or energy efficiency ratio (EER) values can be improved by 50%. Seasonal Performance

(126) Further information available at *http://www.egec.org* and *http://www.groundmed.eu*
(127) Directive 2009/28/EC Annex VII, Accounting of energy from heat pumps *http://data.europa.eu/eli/dir/2009/28/oj*

Indicators can be improved by 25% ([128]) with respect to an air-water cycle. This leads to the conclusion that the electricity consumption in this case could be 25% lower than the case of an air-water conventional heat pump.

The heat transfer process between the Ground Heat Exchanger (GHE) and surrounding soil is dependent on local conditions such as the local climatic and hydro-geological conditions, the thermal properties of soil, soil temperature distribution, GHE features, depth, diameter and spacing of boreholes, shank spacing, materials and diameter of the pipe, fluid type, temperature, velocity inside the pipe, thermal conductivity of backfill and finally the operation conditions, such as the cooling and heating load and heat pump system control strategy. Geothermal energy systems can be used with forced-air and hydronic heating systems while also designed and installed to provide "passive" heating and/or cooling. Passive heating and/or cooling provide cooling by pumping cool/hot water or antifreeze through the system without using a heat pump to assist the process.

(128) Geotrainet Project Webpage, *http://www.geotrainet.eu*

5.2.2 Local electricity production

Local electricity production can be supported by photovoltaic electricity generation, wind power, hydroelectric plants and mini-hydro, as well as the power output of cogeneration. These options are overviewed based on technical aspects to guide policy support and the key measures that are being used to promote these options based on best practices.

5.2.2.1 Photovoltaic electricity generation (PV)

Photovoltaic modules permit the conversion of solar radiation to electricity by using solar cells. The electricity produced has to be converted from direct current to alternating current by means of an electronic inverter. As the primary energy used is the solar radiation, this technology does not emit CO_2 to the atmosphere.

According to an International Energy Agency study ([129]) the PV solar collectors´ lifespan is estimated at around 30 years. During the lifetime of the modules the potential for CO_2 mitigation in Europe can reach in the specific case of Greece 30.7 tCO_2/kWp in roof-top installations and 18.6 tCO_2/kWp in façade installations. If we focus on the life-cycle period of the module, the energy return factor ([130]) varies from 8 to 15.5 for roof-top mounted PV systems and from 5.5 to 9.2 for PV facade installations.

The integration of solar modules has been improved by manufacturers over the past few years. Information about PV building integration can be found in the document "Building integrated photovoltaics. A new design opportunity for architects" of the EU PV Platform.

Box 50. Solar Energy Campaign, Hannover, Germany

The city of Hannover started a solar campaign, which was launched to significantly increase the share of renewable energies in the city. The goal is to install one million square metres of solar modules by 2020. This is quite a challenge because it means increasing the area seventeen fold. A solar atlas was published on the internet. All home owners will be able to look and see whether their homes within the city's boundaries are suitable for a solar system. Investors can also draw on further support offerings free solar checks or the support of a photovoltaic pilot financed by the proKlima fund. The project is co-financed by Intelligent Energy Europe (IEE) in the frame of the Leadership for Energy Action and Planning (LEAP) project.

http://www.eumayors.eu/about/covenant-community/signatories/key-actions.html?scity_id=1610

5.2.2.2 Wind Power

Similar to PV systems, the use of electricity that is generated based on wind power systems displaces the electricity demand that would have otherwise been supplied by the local utility. Since no emissions are associated with the operation of wind turbines, the emission reductions from this mitigation measure are equivalent to the emissions that would have been produced had electricity been supplied by the local utility.

For this reason, municipalities such as Eskilstuna in Sweden are mobilizing resources to enable the use of a greater share of electricity from wind turbines in the local energy mix. Other policy measures in support of wind power include wind farms with citizen cooperation, promotion of locally owned wind turbines, public procurement of municipality owned wind turbines, co-ownership of wind-power plants, attraction of

([129]) "Compared assessment of selected environmental indicators of photovoltaic electricity in OECD countries" report of the International Energy Agency PVPS task 10. www.iea-pvps-task10.org
([130]) Energy Return Factor: ratio of the total energy input during the system life cycle and the yearly energy generation during system operation.

companies to generate electricity from wind energy, prioritized case handling and licencing of wind turbines, and land use planning for wind energy among other measures.

Box 51. Municipality Owned Wind Turbines in Eskilstuna (SE)

Eskilstuna municipality has ordered 4 x 3.3 MW wind turbines, which would be directly owned by the municipality. One more turbine is optional. The turbines were installed in 2015 in Sollefteå in the north of Sweden. The order is the biggest public procurement of wind turbines in Sweden so far. The power production will match the municipality's own electricity consumption and the energy production of the windmills is expected to be around 37 500 MWh per year, which covers about 40% of the municipality's own electricity consumption on an annual basis.

5.2.2.3 Hydroelectric plants and mini-hydro

Hydropower represents an essential example of the energy-water nexus in which the availability of water resources based on rainfall affects the amount of energy production. Different types of hydroelectric plants have different capacities, including run-of-the-river hydro plants that do not require a dam, or if so, only a very small one.

While large-scale hydropower technology is one of the most mature renewable energy technologies, research is ongoing to better adapt turbines and facilities to the head flow to optimize the techno-economic performance of small hydropower applications [75]. Best practices that involve hydropower technologies include those to attract or allocate investment.

Box 52. Investments in Local Hydro Power Projects in Bremen (DE)

Getting investors interested in the new project to replace the old hydropower facility took years but finally could be achieved. The hydro power plant in Bremen is now Europe's largest in-stream tidal hydro power plant (10 MW) based on water plunges between 2-6 meters. Around 10% of the budget was spent for fish protection measures.

Source: http://www.eumayors.eu/about/covenant-community/signatories/key-actions.html?scity_id=1603

5.2.2.4 Bioenergy for electricity generation (biomass, biogas)

Combustion followed by a steam cycle is the main technology for utilizing biomass for electricity generation. Newer technological alternatives include the use of biomass in organic Rankine cycle (ORC) plants and gasification systems. Biomass is used as the main fuel but can also be co-combusted with coal or peat. Biogas from anaerobic digestion is mainly used on-site for co-generation applications while biogas can also be upgraded into biomethane towards injection into the existing natural gas grid.

Best practices for the use of bioenergy for electricity generation include biogas cogeneration based on anaerobic digestion, anaerobic digestion in the public waste recovery and treatment company, biogas cogeneration based on zootechnical wastewater and silage cereals, and biogas driven district heating networks. Other best practices include public-private partnerships between the municipality and waste management utility for anaerobic digestion of biowaste for CHP-based district heating, the recovery of methane gas from landfills to produce electricity based on gas engines, and consortiums for cogeneration plants driven by sustainable certified biomass based on waste produced locally or from local consortium companies.

5.2.3 Local heat/cold production

Local production of heat and/or cold is an important component of enabling local energy demands to be met with sources of energy supply that may involve lower levels of energy quality (exergy) as an alternative to the combustion of fossil fuels. Below, the developments for local thermal energy production are given under the headings of large solar thermal systems, thermal energy storage, and district heating and/or cooling. The advantages of district energy networks in smart energy systems are also underlined.

This chapter is aimed at providing examples of municipal strategies for district heating/cooling systems (DHC) and use of RES to produce thermal energy. It also provides examples of policies to promote local electricity production, including renewable electricity production.

DHC ([131]) can bring many benefits when it is well managed: it can reduce emissions, enhance energy security and promote economic development. Many district heating systems in countries of CoM Eastern Partnership are approaching or have exceeded their operational life time and require modernisation or replacement. DHC might also require restructuration as it usually faces challenges of competiveness, reforms on tariffs and regulations. In addition, DHC provides a proven solution to make efficient use of the many kinds of RES (biomass, geothermal, solar thermal) on a large scale and recycle surplus heat (from electricity production, fuel and biofuel-refining, waste incineration and from various industrial processes).

Box 53. Heat metering in Moldova

In Moldova, the Energy law mandated heat metering (on a building level) and installation of metering devices by suppliers. The HCAs and TRVs are mandated in new buildings by the building codes. Nevertheless, the legislation was not clear on who should pay for the metering devices and their installation, and end-users were charged for these.

Renewable energy technologies offer the possibility to produce energy with a very low impact on the environment. DHC and cogeneration (or CHP) offer an energy-efficient way of producing heat and electric power for urban areas. To be cost effective and maximise impact, policies should focus on measures targeting areas with high heating and cooling loads.

Distributed electricity generation allows reductions in electricity transport and distribution losses and the use of microcogeneration and low-scale renewable energy technologies. Distributed energy generation associated with unpredictable (cogeneration, solar PV, wind, biomass, etc.) RES is becoming an important issue in the European Union (EU). The electricity grid must be able to distribute this energy to the final consumers when the resources are available, and rapidly adapt the demand or cover the energy required using more adaptable (e.g. hydro or biomass) technologies when the former are not available.

5.2.3.1 Large solar thermal systems

Large solar thermal systems have experienced a strong growth over recent years. Large scale solar thermal process can heat applications for industrial and agricultural processes. Solar district heating systems with and without large seasonal heat storages are relevant for district energy systems. For example, the Marstal District Heating in Aeroe, Denmark provides a large scale solar thermal solution for district heating systems.

Large solar heating systems can also be integrated into an existing district heating system in which heat is supplied by a cogeneration plant [76]. Collective systems that are used in multi-family homes, hospitals, hotels and retirement homes are other

([131]) IEA, *Coming in from the Cold. Improving District Heating Policy in Transition Economies*, 2004 (http://www.iea.org/textbase/nppdf/free/2004/cold.pdf) and IEA, *Cogeneration and District Energy – Sustainable energy technologies for today ... and tomorrow*, 2009 (http://www.iea.org/files/CHPbrochure09.pdf).

options [132]. Such installations can be well-suited for ESCO schemes due to the positive effect of profitability and the effect of economies of scale [133].

5.2.3.2 Thermal energy storage (TES)

Thermal energy storage (TES) addresses the key bottleneck against the widespread and integrated use of renewable energy sources, since the renewable supply does not always coincide with demand for heating or cooling. Numerous technologies in sensible, latent or thermochemical form can time shift renewable energy supply to periods of greatest demand, each of them characterised by different specifications and specific advantages.

5.2.3.3 District Heating and Cooling (DHC)

District heating [134] and/or cooling [135] (DH/C) consists of using a centralised plant to provide thermal energy for external customers. The energy input may be supplied by fossil fuels or a biomass boiler, solar thermal collectors, a heat pump, cooling systems (thermally driven or compression chillers) or from a CHP plant. A combination of the mentioned technologies is also possible and may even be advisable depending on the technologies, the fuel used and other technical issues. The characteristics of the market and demand in the heating and cooling sectors place DH/C as a viable technological option [136].

District energy infrastructure that is based on cogeneration enables the integration of the power and thermal energy sectors so that energy can be supplied to urban energy systems more efficiently. The multiple benefits of district energy systems involve up to a 50% lower primary energy usage, related reductions in greenhouse gas emissions, and increased opportunities to integrate renewable energy sources into the heating and cooling sector [137]. Urban energy infrastructure that benefits from the use of district energy systems can simultaneously contribute to reducing energy imports and provide a means to make use of residual heat sources and/or sources of free cooling, such as those provided by seawater, river, lake or aquifer water using a heat exchanger. The district heating and cooling capacity in 45 cities that are identified as champions in this field has exceeded over 36 GW and 6 GW, respectively, with about 12,000 km of district energy networks [138]. In addition, district energy infrastructure can provide an opportunity for demand response and balancing in the power system when there is excess variable electricity production from renewable energy sources. For example, electricity generation from wind or solar energy can be used in large-scale heat pumps in support of the district energy infrastructure or even power-to-gas options in times of oversupply [139].

Energy efficiency benefits and advantages of DH/C are based on high SPF (Seasonal Performance Factor) due to an intensive operation of the installation, introduction of highly efficient equipment, proper insulation of the distribution network, and on efficient operation and maintenance. For example, the seasonal performance that is defined as the total amount of supplied heat over the total primary energy consumption can be improved from 0.62 for individual heat pumps to 0.85 for district heating heat pumps. Absorption chiller seasonal performance can be improved from 0.54 for an individual

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(132) SOLARGE Project Good Practice Database (Enlarging Solar Thermal Systems in Multi-Family-Houses, Hotels, Public and Social Buildings in Europe), *http://www.solarge.org/index.php?id=2*
(133) Large scale solar thermal systems in ESCo models, *http://www.buildup.eu/en/learn/tools/large-scale-solar-thermal-systems-esco-models-energy-service-companies*
(134) SOLARGE project database contain good examples of large solar district heating. Most of them are located in Denmark and Sweden. http://www.solarge.org/index.php?id=2
(135) ECOHEATCOOL project www.euroheat.org. Supported by Intelligent Energy Europe / Danish Board for District Heating www.dbdh.dk
(136) ECOHEATCOOL: European Heating and Cooling Market Study, *https://www.euroheat.org/our-projects/ecoheatcool-european-heating-cooling-market-study/*
(137) UNEP (2015) District Energy in Cities - Unlocking the Potential of Energy Efficiency and Renewable Energy, *http://staging.unep.org/energy/portals/50177/DE_Executive%20Summary_lowres_double.pdf*
(138) Ibid.
(139) Ibid.

absorption chiller and boiler to 0.61 for the same type of installation in a district heating network [77]. Since each installation operates under different conditions, detailed engineering studies are necessary to evaluate the percentage of distribution losses in the network and overall efficiency. In addition, the use of environmentally-friendly energy resources, such as biomass or solar energy, will determine any CO_2 emission reductions.

District energy networks thus enable a powerful solution for cities by enabling the connection of multiple thermal energy users through a piping network to environmentally optimum energy sources, such as CHP, industrial waste heat, and renewable energy sources (RES) ([140]). The energy and exergy savings benefit of such options in comparison to alternative heating technologies depends on the annual energy request, the population density, and the efficiency of heat production [78]. Since district energy networks can better exploit existing local energy sources, such as surplus heat from electricity production and industry, the need for new thermal (condensing) capacities are effectively reduced. Similarly, District Heating (DH) can offer synergies between energy efficiency, renewable and CO_2 mitigation by serving as hubs to utilize residual heat that otherwise would be wasted. DH can provide significant contributions to the reduction of both CO_2 emissions and particulate matter leading to air pollution while increasing energy security.

The decarbonisation of DH/C networks requires the integration of much higher shares of RES and waste heat, the reduction of the end-user connection costs and the development of low-temperature heating networks. For example, cases that involve renewable energy options can be found to provide significant cost advantages among cases for district heating systems [79]. In Sweden, the current focus for district heating systems is given to be renewable heat, heat recycling and their combination [80]. Synergies between waste-to-energy processes and district heating/cooling could also provide a secure, renewable, and in some cases, more affordable energy in displacing fossil fuels. DH/C networks can offer flexibility to the energy system by cheaply enabling the storage of thermal energy.

District Cooling (DC) can make usage of alternatives to conventional electricity cooling from a compression chiller. The resources can be natural cooling from deep sea, lakes, rivers or aquifers, conversion of surplus heat from industry, CHP, waste incineration with absorption chillers or residual cooling from re-gasification of LNG. District cooling systems can greatly contribute to avoiding electricity peak loads during summer. **Table 36** compares different DC components based on the supply and distribution structure.

([140]) IEA (2008) IEA Implementing Agreement on District Heating and Cooling, Including the Combined Heat and Power ANNEX VIII.

Table 36. Components in different district cooling systems ([141])

Type of District Cooling (DC)	Components in Each Type of District Cooling Design				
	Supply	**Distribution**	**Extra Steps in the Hybrid System**		**Units in the Building**
Conventional DC	Large-scale heat pumps/chillers	Cold pipes	-	-	Substations for cold
Natural Cooling	Natural cooling, usually from the sea or a river	Cold pipes	-	-	Substations for cold
Hybrid Cooling	Heat	Heat pipes	Central absorption heat pumps	Cold pipes	Substations for cold
Sorption Cooling (SCH)	Heat	Heat pipes	-	-	Individual sorption heat pumps

Large-scale district cooling systems can radically reduce the specific capacity costs (€/kW) that have to be invested when compared to individual systems per household. The investment reduction is due to the avoidance of redundant investments and variances in customer's peak load across time (simultaneity factor). Cities with district cooling are estimated to have a 40% reduction in total installed cooling capacity ([142]).

Best practices from the signatories include contract to connect municipal buildings and schools to the DH network, integrated heating systems between public buildings, initiative to increase the purchased volume of energy from the DH network, including subsidies and/or obligations for connection to DH networks, modernization and rehabilitation of DH/C networks, remote monitoring of pipelines and insulation to reduce heat losses, and installation of thermal energy distributors and thermostatic radiator valves in the DH network. The connection of low energy houses to a low-temperature DH network in Västerås, Sweden is also a promising solution.

([141]) AREA, 2014. Guidelines How to approach District Cooling http://area-eur.be/sites/default/files/2016-05/Guidelines%20District%20Cooling%20140131.pdf

([142]) Possibilities with More District Cooling in Europe, ECOHEATCOOL Work Package 5, *https://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/ecoheatcool_more_district_cooling_in_europe.pdf*

Box 54. Example from Ukraine District Heating Systems

Heat Metering and Consumption-Based Billing

District heating plays a critical role in meeting basic heating needs in Ukraine, but the sector faces serious challenges that must be resolved to avoid collapse.

Heat metering and consumption-based billing has been a critical steps needed to address these challenges, as well other reforms such as building energy efficiency improvements and regulatory reform of the past 15 years. Some of the accomplishments included:

Better quality of service: Building-level meters are typically installed along with a building-level substation package (ITP) which allows supply to be matched with demand through better temperature control at the building level.

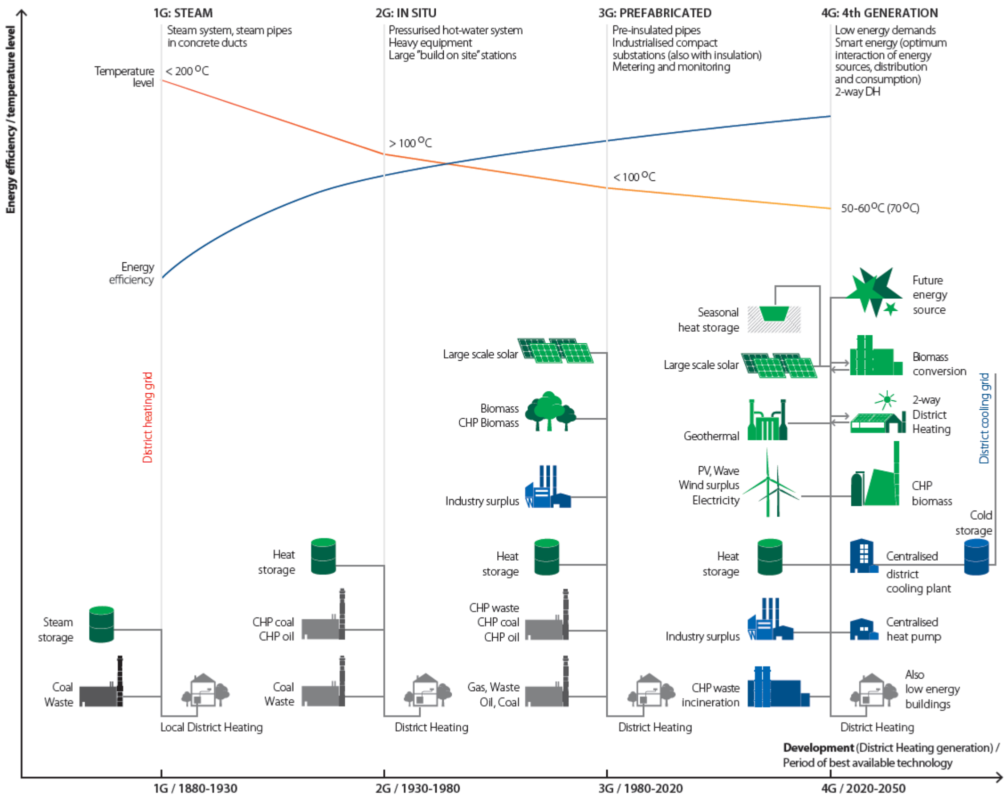
Lower cost: These investments reduce heating demand by roughly 15-25 percent, thereby, combined with consumption-based billing, decreasing average household expenditure on heating.

Improved transparency: Consumption-based billing provides information about customers' heat consumption and how it relates to their bills as well as provides the incentive to balance heat supply and demand.

In comparison to previous generations, developments towards "fourth generation" district heating networks (4GDH) addresses the integration of sectors in the energy system based on smart electricity, thermal and gas grids [81].

In smart energy systems, smart electricity grids involve generators, consumers, and those that function in both domains as prosumers to provide a sustainable, economic, and secure supply of electricity. Smart thermal grids act as an interface between centralized as well as decentralized production units and all connected facilities to satisfy heating and/or cooling demands. This includes low-temperature district heating networks that have low supply temperatures. The operation of the distribution network at lower supply temperatures reduces transfer losses and improves grid efficiency. **Figure 20** compares the four generation of district heating developments based on energy supply, energy efficiency, and temperature level.

Figure 20. District heating generations by supply, efficiency, and temperature level



Source: Lund, et al. 2014 [81]

In addition, two-way district heating involves the possibility that residual sources of heat can be shared in the network, including residual heat from data centres ([143]). Smart gas grids address the need for gas supplies and storage, which also have an important role in contributing to the above grids and vice versa [82]. **Table 37** summarizes the progression of heat production and integration with the electricity supply towards 4GDH networks [81].

Table 37. Generations of Production and System Integration in District Heating Networks

Generations	1st Generation	2nd Generation	3rd Generation	4th Generation
Label	Steam	In situ	Prefabricated	4GDH
Period of best available technology	1880-1930	1930-1980	1980-2020	2020-2050
Heat production	Coal steam boilers and some CHP plants	Coal and oil based CHP and some heat-only boilers	Large-scale CHP, distributed CHP, biomass and waste, or fossil fuel boilers	Low-temperature heat recycling and renewable sources
Integration with electricity supply	CHP as heat source	CHP as heat source	CHP as heat source, and some large electric boilers and heat pumps in countries with temporary electricity surpluses. Some very few CHP plants on spot market as exception	CHP systems integrated with heat pumps and operated on regulating and reserve power markets as well as spot markets

([143]) Two-way district heating creates a heat trading market for the customer *https://www.euroheat.org/news/two-way-district-heating-creates-heat-trading-market-customer/*

In such a cross-sectoral approach, there remains an important role for energy savings so that the increased penetration of variable renewable energy technologies is integrated in an optimal way. For this reason, the promotion, planning, cost, and operation of smart energy systems must be supported by a sufficient institutional framework, including analytical tools based on geographical information systems (GIS) and tariff policy.

Different energy sources that are involved in various generations of DH networks, including those in 4GDH, can have different advantages and disadvantages. For this reason, it is important that the design of such systems take into account aspects of availability and possible environmental impacts as summarized in the table below. **Table 38** compares the advantages and disadvantages of various energy sources [83].

Table 38. Comparison of the advantages and disadvantages of energy sources

Source	Description	Advantages	Disadvantages
Geothermal or ground source heat pumps [84]	Built in locations above large geothermal sources, typically those with naturally occurring hot springs, geysers or aquifers	Provides year around low cost heating and cooling using district energy technology	Geologically limited and usually only efficient in moderate temperature zones
Biomass [85]	Often using wood or energy crop based material to provide heat	Renewable resource that has strong advantages in a sustainable energy future	Low availability in many places in Europe
Waste Incineration [86]	Combustion of urban waste to provide heating to nearby buildings	Utilization of heat generated from burning waste	Potential health effects from emissions when improperly managed
Waste heat [87]	Industrial and commercial process waste heat is used	Provides excess heat to nearby buildings and is able to offset some of the normal district heating fuel costs	Usually cannot provide sole source heating, but can be coupled with an existing DH system
Fossil fuels [88]	Burning of coal, oil and natural gas to provide heat	Processes and infrastructure often already in place, reducing fuel transport costs	Large source of greenhouse gas emissions, non-renewable energy source
Solar thermal [89]	Using sunlight and solar collectors to provide high temperature water for heating and cooling purposes	Passive and active systems with the option to also provide cooling during warmer seasons using absorption chillers.	Geographic assessments as well as proper planning are necessary; variations in peak demand may significantly influence performance

Source: Lake A., Rezaie B., Beyerlein S. 2017 [83]

A systematic approach for synthesizing options for more sustainable heating and cooling supply has been put forth by the EU-funded Stratego Enhanced Heating & Cooling Plans project ([144], [145]). The approach involves five steps that are oriented to guiding local authorities in overcoming challenges in drafting heating/cooling plans based on local opportunities and assessments involving stakeholder engagement as summarized in **Table 39 and Table 40**.

([144]) Stratego Enhanced Heating & Cooling Plans (2016). Insights from drafting local heating cooling action plans. Summary Report on WP 3: National plan - local action: supporting local authorities, p. 5.
([145]) Stratego Enhanced Heating & Cooling Plans (2016). Insights from drafting local heating cooling action plans. Summary Report on WP 3: National plan - local action: supporting local authorities, p. 41-42.

Table 39. Five step approach to support local authorities to draft heating/cooling plans

Steps	Challenges	Lessons Learned
Mapping local heating and cooling demand supply - Mapping the heating and cooling infrastructure - Mapping the energy saving potential - Mapping the excess heat potential - Mapping the renewable heat potential	Mapping of cooling demand, energy saving potential and diffuse renewable heat sources	Simple maps already can provide inspiration for projects
Identification of areas of priority for intervention - Adding heat savings - Comparing heat network solutions - Comparing individual heating solutions - Integrating more excess and renewable heat - Integrating more renewable electricity in the heating sector - Heat roadmap	Assessment of costs and benefits	The list of categories gives good guidance to define projects
Business models for local partners	Developing business models to the level of investment grade plans	Business models put the end-consumer at the heart of the projects
Involvement of local stakeholders	Involvement of a wider range of stakeholders	An early involvement of a wider range of stakeholders smoothens the path for the implementation of the projects
Input to local heating / cooling action plans	Reaching the level of a strategic heating / cooling action plan	A strategic master plan at local level puts single projects into a wider context

Source: Stratego Enhanced Heating & Cooling Plans

Table 40. Consideration for the identification of areas of priority for intervention

Projects to consider	Areas of priority to look for
Reduce heating and cooling demand at end-consumers	Areas with a higher specific heat or cooling demand than average Areas with buildings with a poor energy label Areas suffering from energy poverty
Improve and expand existing heating and cooling networks or build new ones in areas with a substantial heating and cooling density	Areas where there is currently a district heating or cooling grid (DH/C grid) Areas currently without a heating or cooling grid but close to an existing DHC grid and with a high enough heat or cooling density or with a cluster of large heat or cooling customers Areas with a high enough heat density: • DH grid high feasible: > 300 TJ/km² • Current DH grid feasible: 100-300 TJ/km² • 4th gen. DH grid feasible: 30 – 100 TJ/km² Clusters of large heat consumers Clusters of large cooling consumers
Look for more sustainable individual heating and cooling solutions in areas with a limited heating and cooling density	Areas where roofs are suited to install solar water boilers Areas where there is enough free land around the building to install heat pumps Areas with a supply of biomass sources
Tap excess heat from thermal power stations, waste-to-energy installation, energy-intensive industry, etc.	Installations that can supply excess heat and that are nearby potential heating (eventually cooling) consumers
Tap renewable heating and cooling sources (geothermal, bio-energy, solar thermal)	Areas where large solar hot water boilers can be installed Areas where large heat pumps can be installed Areas with favorable geologic conditions to install (deep) geothermal wells Related to the previous point: water purification stations or large sewers nearby potential heating (eventually cooling) consumers from which heat can be extracted Areas with a supply of biomass resources
Improving conversion of fossil fuels to heat or cooling	Areas with a gas grid or where a gas grid can be expanded and where existing, currently less efficient, boilers can be replaced by • Cogeneration units • Condensing boilers

Source: Stratego Enhanced Heating & Cooling Plans

Exergy principles can also guide local authorities in structuring an optimized energy supply structure ([146]). Exergy is the part of an energy flow that can be transformed into any other form of useful energy [90] and is a measure of the potential of a given amount of energy to perform useful work. Different energy supply systems can be considered to satisfy energy demands in more efficient ways based on the exergy levels on the supply and demand sides.

There are multiple opportunities to satisfy low-exergy demands for space heating and cooling as well as domestic hot water with energy resources other than those that represent high exergy resources capable of being combusted and producing electricity.

Even in the case of renewable energy, an exergy based approach can promote a more efficient energy supply structure since renewable energy sources also need to be allocated to matching exergy demands whenever possible.

Table 41 provides practical advice through a comparison of technological options that represent a mismatch between a high exergy resource and a low-exergy demand (left column) and a technological option that represents a better exergy match (right column). At the local level, the Canton of Geneva has required the application of an exergy concept from buildings and city projects, particularly to increase heating and cooling efficiencies based on various technological options [91]. The use of exergy principles can also be applied to direct districts towards net-zero targets [92].

Table 41. Comparison of Options with and without Exergy Matches

Options without exergy matches (mismatch)	**Options with better exergy matches**
Electric heaters, natural gas boilers or combustion of renewable energy resources (biomass) to satisfy space heating demands in buildings	Utilization of high energy resources in CHP-based district heating networks – Including biomass/biogas Utilization of lower exergy resources in district heating/cooling networks – Solar energy – Geothermal energy – Seawater heat pumps – Residual heat: Industrial processes; Wastewater; Data centers – Use of solar collectors and/or PV-thermal panels in buildings

5.2.4 CHP – Combined heat and power generation

A cogeneration or CHP plant is an energy production installation that simultaneously generates thermal energy and electrical and/or mechanical energy from a single input of fuel ([147]). Combined heat and power generation represents about 11.22% of the gross electricity generation in member states ([148]). The necessity to "substantially increase the uptake of high efficiency cogeneration, district heating and cooling" to reinforce an efficient energy supply has an immediate impact for urban energy systems ([149]). Signatories have implemented measures towards high-efficiency cogeneration power plants in close collaboration with local utilities for sustainable energy systems [4]).

CHP plants are usually very close to the electricity consumer, thereby avoiding network losses during transmission and distribution to the end-users. CHP plants can be part of distributed generation schemes in which several smaller CHP plants produce energy

([146]) IEA EBC Annex 64 LowEx Communities - Optimised Performance of Energy Supply Systems with Exergy Principles https://www.annex64.org/
([147]) Directive 2004/8/EC of the European Parliament and of The Council of 11 February 2004 on the Promotion of Cogeneration based on a useful heat demand in the internal energy market and amending Directive 92/42/EEC, http://data.europa.eu/eli/dir/2004/8/oj
([148]) Eurostat, Combined heat and power generation http://ec.europa.eu/eurostat/web/products-datasets/-/tsdcc350
([149]) Communication from the Commission to The European Parliament, The Council, The European Economic and Social Committee and The Committee of the Regions, Energy 2020 A strategy for competitive, sustainable and secure energy, COM(2010) 639 final.

being consumed nearby. Cogenerated heat may also be used to produce cold through absorption refrigeration chillers. Other types of thermally driven chillers are commercially available although their market presence is more limited than that of absorption chillers.

Plants that simultaneously produce electricity, heat and cooling are known as trigeneration ([150]) plants. A part of the trigeneration units offer significant relief to electricity networks during the hot summer months. Cooling loads are transferred from electricity to gas networks. This increases the stability of the electricity networks, especially in Southern European countries that undergo significant peaks in summer ([151]).

CHP leads to a reduction of fuel consumption at least 10 % when compared to conventional electricity and separate heat production ([152]). The reduction of atmospheric pollution follows the same proportion. The power range and efficiencies of CHP technologies are summarized in **Table 42.** CHP may be based on gas turbines, reciprocating engines, Stirling engines, or fuel cells. The electricity produced in the process is consumed by the users of the grid and the useful thermal energy may be used in industrial processes, space heating or in a chiller for the production of cold water.

Table 42. Power Range and Efficiencies of Cogeneration Technologies

Technology	Power range	Electric Efficiency	Global efficiency
Gas turbine with heat recovery	500 kWe - >100 MWe	32 – 45%	65 – 90%
Reciprocating engine	20 kWe -15 MWe	32 – 45%	65 – 90%
Micro gas turbines	30 - 250 kWe	25 – 32%	75 – 85%
Stirling engines	1 - 100 kWe	12 – 20%	60 – 80%
Fuel cells	1 kWe - 1 MWe	30 – 65%	80 – 90%

Source: COGEN Challenge Project ([153])

Small-scale heat and power installations can play an important role in the energy efficiency improvement in public, residential and commercial buildings, including hotels, swimming pools, hospitals and multi residential dwellings. As compact systems, they are convenient to install. The dimensioning of the micro-cogeneration installation will depend on the heat loads. Combined electrical and thermal efficiency varies between 80% and well above 90%. Similar to electrical efficiency, unit capital costs per kW_{el} depend on the electrical capacity of the system. A significant decline of capital costs due to scale effects are observed particularly as systems reach the 10 kW_{el} range [93]). CO_2 emissions of natural gas driven micro-cogeneration systems are in the range 300-400 g/kWh.

Box 55. Cogeneration Plant and Roof-Top PV, Fürstenfeldbruck, Germany

In 2014, the public utility company of Fürstenfeldbruck, Germany (Stadtwerke Fürstenfeldbruck GmbH) added a new cogeneration plant at "Energiezentale West". Correspondingly, they extended their district heating infrastructure. The plant not only supplies households with almost CO_2-free heat, but also provides district heating and cooling to several large companies. The roof of the plant is home to photovoltaic collectors. Source: www.energieatlas.bayern.de

([150]) POLYSMART - Polygeneration with advanced small and medium scale thermally driven air-conditioning and refrigeration technology, http://www.cordis.europa.eu/project/rcn/85634_en.html
([151]) CAMELIA - Concerted Action Multigeneration Energy systems with Locally Integrated Applications, http://cordis.europa.eu/project/rcn/87901_en.html
([152]) Methodology for Determining the Efficiency of Cogeneration Process (Annex II). Directive 2012/27/EU of the European Parliament and of the Council, http://data.europa.eu/eli/dir/2012/27/oj
([153]) http://www.cogeneurope.eu/challenge/

5.2.5 Waste and water management

Local waste management strategies are particularly crucial for enabling the minimization of the amount of waste generated through waste prevention, the diversion of waste from landfills through recycling, reuse, and composting, and the utilization of environmentally-conscience waste-to-energy options ([154]). Water management also has a direct impact on energy usage at the local level through the electricity that is used for the preparation of tap water and its pumping through pressurized water distribution systems to reach end-users. Minimizing water leakages in the water distribution system and reducing water usage through conservation can thus reduce the level of energy usage for water services. In addition, the selection of water supply reservoirs in proximity to the city, which can reduce extraction and transport costs, can be directly affected by the effectiveness of water management practices at the local level. Especially in cases where desalination may be required for water supply, including those in islands, the integration of renewable energy sources can support the energy loads of the energy intensive infrastructure [94].

In the aspect of wastewater treatment, opportunities for local energy generation involve the combustion of digester gas or its use for cogeneration as well as the extraction of residual heat from wastewater based on heat exchangers and heat pumps. The integration of renewable energy, such as solar and geothermal energy to assist in covering the energy requirements of the wastewater treatment plant, is another option. Cases in which wastewater treatment plants (WWTPs) have reached energy self-sufficiency based on the utilization of such options take place among the best practices. At the same time, the heat generation potential in WWTPs often exceeds the amount that is required on-site, which provides opportunities to satisfy other local heat demands in the vicinity, including those of buildings and industries [95]. In the context of the energy system as a whole, WWTPs can offer opportunities for demand response, particularly in the sludge processing equipment, thereby assisting in any power load levelling [96].

5.2.5.1 Utilization of biogas resources at the local level

Biogas is a naturally occurring by-product of the decomposition of organic waste in sanitary landfills or from sewage and residual waters. It is produced during the degradation of the organic portion of waste. Biogas essentially contains methane (CH_4), which is a highly combustible gas. Therefore, biogas is a valuable energy resource that has wide range of uses for biogas for heating, electricity, and transport fuel [97]. Biogas can be used as in a gas turbine or a reciprocating engine, as a supplementary or primary fuel to increase the production of electric power, as a pipeline quality gas and vehicle fuel, or even as a supply of heat and CO_2 for nearby greenhouses and various industrial processes. Biogas is mostly produced based on sewage sludge while production from landfill, food-processing residues and wet manure are expected to increase ([155]). In contrast, methane is a greenhouse gas (GHG) with a global warming potential (GWP) that is 21 times higher than CO_2. The use of methane content that would otherwise be released without being utilized as an energy source is a valid climate mitigation option.

Local policies can promote low-carbon waste practices and the recovery of its energy content when appropriate either as biogas or incineration. Through municipal initiatives or private–public partnerships, waste-to-energy can be promoted as a potential source for heat and electricity, including possible interventions is wastewater treatment plants (Box 56). The use of biogas as an energy source has a role in upholding circular economy principles in which outputs are streamlined to provide inputs for other systems [97].

([154]) Waste Framework Directive 2008/98/EC, *http://ec.europa.eu/environment/waste/framework/*
([155]) European Environmental Agency, (2006). How much bioenergy can Europe produce without harming the environment? Copenhagen: EEA, *https://www.eea.europa.eu/publications/eea_report_2006_7*

Box 56. Biogas Options from Waste and Wastewater

— - Organic waste streams used in bioenergy gasification or composted
— - Landfill gas capture
— - Upgrading of biogas to biomethane for distribution via the exiting natural gas grids
— - Methane recovery from the wastewater for reuse
— - Integration of low enthalpy geothermal sources for the digestion of the sewage sludge in the wastewater systems in the process of producing biogas

Best practices in the signatories involve separate waste collection to increase the recycling of municipal solid waste and the use of organic waste for biogas production, the use of green waste for the production of compost and pellets, and a self-sufficient wastewater facility based on a biogas driven CHP plant in Neumarkt in der Oberpfalz, Denmark. Detailed best practices involving a biomethane chain to obtain bioelectricity, bioheat and biofuel in Wielopole, Poland are given in Box 57 and summarized in **Figure 21**.

Box 57. Bioelectricity, Bioheat and Biofuel Opportunities: Wielopole, Poland

The BIOMASTER project has helped Biogazownie Małopolskie in Wielopole, Poland to generate heat and power from manure and agricultural waste, attracting investors for its long term bioenergy ambitions. Bioelectricity has been sold to the local power network and bioheat is used for the heating needs of farms. Opportunities for biomethane and compressed natural gas (CNG) processing for transport fuel is also being undertaken ([156]).

The BIOMASTER project exploited the potential of biomethane production and use for transport in a "waste-to-wheel" partnership, bringing the key components of the biomethane chain into a joint initiative to stimulate investments, remove non-technological barriers and mobilize action for uptake. The project also addressed the available distribution modes and the legal, organisational and financial barriers, focusing on the ambition of enabling biomethane grid injection.

Source: Biomethane as an Alternative Source for Transport and Energy Renaissance (BIOMASTER), https://ec.europa.eu/energy/intelligent/projects/en/projects/biomaster

Box 58 provides another best practice from Helsingborg, Sweden in which the municipal waste treatment company produces biogas as well as biofuel through biogas upgrading.

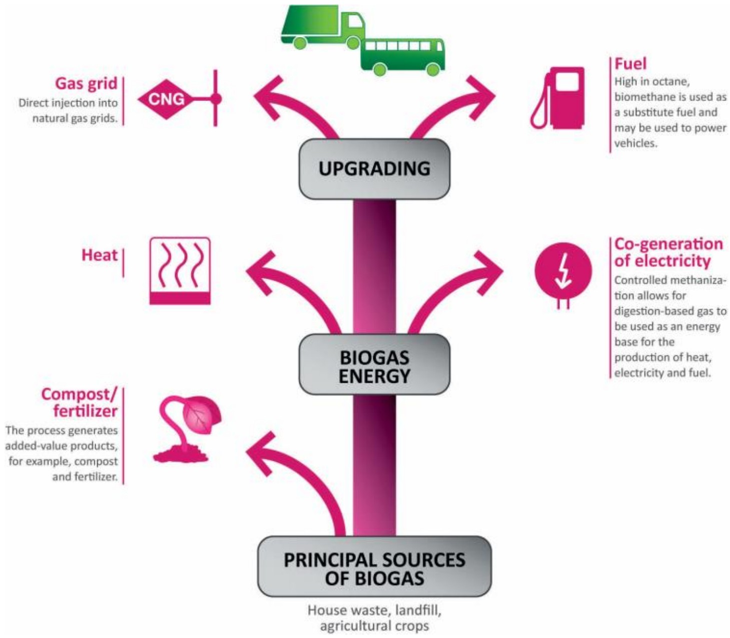
Box 58. Doubled Biogas Production: Helsingborg, Sweden

The municipal waste treatment company started their biogas production in 1996. Since then, several improvements and extensions have been made. In 2014, the latest addition to the plant was taken into service. The capacity for biogas production had then been doubled ending up at 80 GWh. The biogas is upgraded and used as motor fuel. The digestion residue is used as biofertiliser and is transported by pipelines to the farmers.

http://www.covenantofmayors.eu/about/covenant-community/signatories/key-actions.html?scity_id=4878

([156]) Good practice in energy efficiency, Proposal for a Directive of the European Parliament and of the Council amending Directive 2012/27/EU on Energy Efficiency.

Figure 21. Biomethane Chain Involving Compost, Cogeneration and Upgrading



5.2.5.2 Landfill biogas recovery

Waste disposal in landfills can generate environmental problems, such as water pollution, unpleasant odours, explosion and combustion, asphyxiation, vegetation damage, and greenhouse gas emissions ([157]). Landfill gas is generated under both aerobic and anaerobic conditions. Aerobic conditions occur immediately after waste disposal due to entrapped atmospheric air. The initial aerobic phase produces a gas mostly composed of CO_2. Since oxygen is rapidly depleted, a long-term degradation continues under anaerobic conditions, thus producing a gas with a significant energy value that is typically 55% CH_4 and 45% CO_2 with traces of certain volatile organic compounds (VOC) ([158]).

Practices for sustainable landfilling can monitor such indicators as leachate composition, methane production, landfill settlement and in situ waste temperature [98]. Emissions are relatively greater in operating landfills than in closed landfills due to the time of decay and degradation of the landfilled waste [99]. The economic viability of utilizing landfill gas for local energy generation depends on the methane content of the available gas, local energy prices, and the selected equipment based on the engine and turbine [100].

Globally, landfills are estimated to account for 8% of anthropogenic CH_4 emissions as an important source of anthropogenic CH_4 emissions. As mitigation options, Directive 1999/31/EC states in Annex I that "Landfill gas shall be collected from all landfills receiving biodegradable waste and the landfill gas must be treated and used. If the gas collected cannot be used to produce energy, it must be flared" ([159]). Similarly, the Environmental Protection Agency (EPA) of the US presents a method for calculating GHG emissions associated with three different landfill management systems ([160]). These are

([157]) The information given may not be relevant for countries where landfills are no longer allowed.
([158]) IEA Bioenergy – Task 37 Energy from Biogas and Landfill Gas, Methane emissions in biogas plants - Measurement, calculation and evaluation, *http://www.iea-biogas.net/files/member-upload/DRAFT_Methane%20Emissions.pdf*
([159]) Council Directive 1999/31/EC of 26 April 1999 on the Landfill of Waste *http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A31999L0031*
([160]) US EPA, (2006). Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks, Section 6.

landfills that do not capture landfill gas, those that recover methane and flare it, and those that recover methane and combust it for cogeneration. A conservative value for the percentage of methane that is chemically or biologically oxidized is 10 % for landfills with low permeability cover while the default efficiency of methane capture systems is 75 %.

5.2.5.3 Renewable energy in wastewater treatment plants

Another possibility to produce biogas is through the installation of a biodigester in sewage and residual waters facility. The residual waters are conducted to the sewage plant where the organic matter is removed from the wastewater.

Box 59. EE in Water and Sewage Management Yerevan (AM)

In 2000, the Armenian capital's water utility, the Yerevan Water and Sewerage Enterprise (YWSE), entered into a 5-year, performance-based management contract with private operator Acea Spa Utility (Acea). During 2000-2005 the duration of water supply was increased from 6 to 18 hours per day, collection rates improved from 20 to 80 %, and electricity consumption was reduced by 30 %.

Prior to the project, YWSE was in poor financial health with a very dilapidated system. Financially, the utility could not cover its operations and maintenance (O&M) costs and collections stood at a mere 20%. About 80% of those connected to the network only had access to tap water between 2-8 hours a day. Pumps broke down frequently and network leakages were rampant with some 72% of non-revenue water (NRW) (870,000 m^3/day).

To meet water needs, many households purchased storage tanks and apartment buildings installed costly booster pumps. In response, the Government of Armenia (GOA) decided to solicit private sector expertise through a management contract. Acea, a joint venture led by an Italian water operator, won an open and competitive bid to operate YWSE's system for five years. The World Bank and GOA also established an investment fund, for Acea's capital investments in the water utility infrastructure.

Over the course of the contract, Acea invested US$24.07 million for a number of targeted improvements including: establishing water pressure sectors in the distribution network of three districts, purchasing and installing meters, rehabilitating several pumping stations, implementing a water leakage detection and repair program, and increasing gravity-fed water supply. The project demonstrated that, under a conducive legal and regulatory framework, private operators can be effectively engaged using a performance-based management contract to deliver significant improvements in service quality, operational efficiency, financial performance, and energy efficiency in municipal water and sanitation utilities. Due Acea's strong performance and overall project results, GOA subsequently entered into a follow-on 10-year lease contract in 2005 with Veolia, a French international water company. During the years of the lease contract the water-supply and wastewater collection systems of the city improved significantly, they became more efficient and manageable.

Until 2017 significant achievements were observed in the areas of pressure zoning of the distribution network, network management, commercial management of the services, prevention of breakages, leakages and illegal connections, and as a result of all these – the improved quality of services, particularly in terms of duration of water supply. In addition to immense improvements in service quality and reliability, annual energy savings were 13,510 MWh/year, and emission reduction, 3000 tonnes of CO_2/year.

Organic matter then decays in a biodigester in which the biogas is produced through an anaerobic process. Around 40 % to 60 % of the organic matter is transformed in biogas with a methane content of around 50% to 70 % [101]. The biodigester can also be fed by vegetable or animal wastes. Modern plants can be designed to reduce odours to a minimum extent. Biogas plants may be designed to fulfil the prerequisites for approval by the food industry to use the bio-fertilizer in agriculture.

Other best practices include the integration of renewable sources for supplying power to pumping tap water, including photovoltaic electricity generation, while reducing electricity usage for pumping based on reductions in water losses in the tap water distribution network and an information system for energy and water use in the public sector.

Additional Resources

— International Energy Agency (IEA): IEA's Programme of Research, Development, and Demonstration on District Heating and Cooling, including the integration of Combined Heat and Power. http://www.iea-dhc.org/index.html

— ECOHEATCOOL Project: The overall purpose of this project is to communicate the potential of district heating and cooling to offer higher energy efficiency and higher security of supply with the benefit of lower carbon dioxide emissions. www.ecoheatcool.org

— Euroheat & Power: Euroheat & Power is an association uniting the combined heat and power, district heating and cooling sector throughout Europe and beyond, with members from over thirty countries. www.euroheat.org

— COGEN EUROPE: COGEN Europe is the European association representing the cogeneration sector. It aims at promoting the benefits and wider use of cogeneration in the EU and wider Europe. https://www.cogeneurope.eu/

— ELEP Project: ELEP (European Local Electricity Production) is a European Project that offers technical and policies information, tools and best practices on local electricity generation. https://ec.europa.eu/energy/intelligent/projects/en/projects/elep

— Heat Roadmap Europe : Heat Roadmap Europe is a project funded under the European Union's Horizon 2020 programme with the aim of a low-carbon heating and cooling strategy for Europe. http://www.heatroadmap.eu/

— Pan-European Thermal Atlas: The atlas contains mappings of residual heat from industry and renewable energy opportunities for about 90% of the EU's total heat market. http://www.heatroadmap.eu/maps.php; http://www.heatroadmap.eu/peta.php

— ST-ESCOs Project : ST-ESCOs (Solar Thermal Energy Services Companies) offers technical and economical software tools aimed at studying the feasibility of ST-ESCO projects, guiding information and best practices examples. http://www.cres.gr/st-escos/

— PV GIS: PV-GIS is a web-based solar radiation database for the calculation of PV potential in Europe, Africa and Asia: http://re.jrc.ec.europa.eu/pvgis/

PART 3.b.
Policies and initiatives for local adaptation

6. The adaption pillar of the CoM initiative

The adaptation pillar was first introduced through Mayors Adapt, launched in 2014 by the European Commission (DG Climate Action) as a parallel initiative to the Covenant of Mayors, which focused on mitigation. Mayors Adapt was an EU-wide movement of cities committed to adaptation. In 2015, the European Commission merged the two initiatives in an effort to promote an integrated approach to climate and energy action. From 2015 onwards, adaptation and therefore the Mayors Adapt initiative is entirely integrated into the Covenant of Mayors for Climate and Energy (150).

By joining the initiative, signatory cities commit to voluntarily developing a comprehensive local adaptation strategy or integrating adaptation into on-going development plans, as well as to reporting their progress every second year. The Covenant of Mayors fosters peer-to-peer learning, proposes dedicated workshops/webinars and offers twinning programmes to encourage local capacity building and good-practice exchange between cities facing similar issues. COR (2016) points out that small- and medium-size cities are the majority of Covenant of Mayors signatories, reflecting a more pressing need for support and resources than bigger cities [24].

The concerned cities can make many healthy choices in the urban development and municipal infrastructure solutions, which can help them cope with the impacts of climate change in the long run. The local action, however, is closely tied to the national policy frameworks, regulations for local governments and procurement rules. If the national policy framework does not have the appropriate provisions and funding instruments to empower the local governments, the city-level actions can be slowed down or limited in scale.

The cities, networks of cities or other associations of local governments need to identify national policies that conflict with or prevent local climate action, to help spur the discussion of this topic with the national government. Further, a broad dialogue is necessary to ensure that national and regional governments' policy frameworks are well-aligned and work to support city-level action. The national support is necessary in the following key areas:

- establish policy frameworks and minimum standards for climate change mitigation and adaptation,
- help streamline required capacity and financial resources
- support development and distribution of necessary technical information.
- Integrate the national environmental goals and incentives into local government performance indicators and financing mechanisms, apply peer pressure by encouraging competition among cities.

The above dialogue needs to clearly articulate to all levels of the government that investing in low-carbon, climate-resilient urban infrastructure has low incremental costs and provides multiple local benefits, e.g. sustainable urban transport projects can reduce traffic congestion and local air pollution as well as greenhouse gas emissions. National governments also need to understand that the local governments will not fully rely on state/public budget financing for mitigation and adaptation measures, but enrol private sector participation opportunities in green-minded urban infrastructure projects, such as transport, municipal solid waste, water and wastewater networks, etc.

Box 60. Lower Danube green corridor: floodplain restoration for flood protection (2014)

In 2000, the governments of Bulgaria, Romania, Ukraine and Moldova pledged to work together – with the signing of the Lower Danube Green Corridor Agreement - to establish a green corridor along the entire length of the Lower Danube River (~1,000 km).

The construction of dikes reduced the size of the river's floodplains considerably. In addition, large parts of the Danube are experiencing river bed erosion due to gravel extraction, dredging and dams, contributing to a lowering of water tables on adjacent agricultural lands.

- Adaptation Options Implemented in this case:

- Adaptation of flood management plans

- Restoration and management of coastal wetlands

Cut-off from the river by dykes, these floodplain lands were of marginal value for primary industries. Once restored, these lands will be of similar scale as the area inundated in the 2005 and 2006 floods. As of 2012, 600 km2 of floodplain has been restored or is undergoing restoration; and enhancing flood protection and local peoples livelihoods through the strengthening of ecosystem services and nature conservation. Most flood plain restorations have been achieved by removing sections of dykes. During the 2013 flood in the Danube along the lower Danube there was no flooding, although the water level was above average. The flood peak decreased downstream of the Iron Gates dam, which was also due to the dam's operations.

Source: http://climate-adapt.eea.europa.eu/metadata/case-studies/lower-danube-green-corridor-floodplain-restoration-for-flood-protection/#adapt_options_anchor

Source:https://static1.squarespace.com/static/56bb8dd3356fb0f3c74253d0/t/5760271537013b86b6dca799/1465919254790/The+First+Five+Years+of+Climate+Prep+Stories.pdf

Once the topics are harmonized on the national policy frameworks, some regional initiatives may arise, such as joint disaster risk reduction projects, large interstate infrastructure investments (transit roads, renewable power interconnections, transboundary river HPPs, etc.). Some of these real-life examples from the region are summarized below:

Box 61. Flatland Forest Vulnerability Assessment - Ukraine

The Clima East Policy project through its 'Expert Facility' provided an opportunity to conduct a research on climate change impacts and a vulnerability assessment of Ukraine's flatland forests. The outcomes of this assignment support the State Forest Resources Agency of Ukraine in the development of relevant sectoral policies, and help the Ministry of Ecology and Natural Resources by providing input to the National Adaptation Strategy.

Source: http://1067656943.n159491.test.prositehosting.co.uk/wp-content-sec/uploads/2016/09/CE-case-study-Ukraine_FINAL-ENG.pdf

Box 62. UNDP-GEF "Peatlands-2" project - Belarus

UNDP-GEF "Peatlands-2" project helped Belarus to return 52,000 ha of damaged peatlands to their natural condition, turning these lands back into carbon sinks and tackling greenhouse gasses emissions. Climate Change education was launched in universities across the country. This issue was successfully addressed by the UNDP-ENVSEC "Environment and Security" project. A study course "Climate Change: Consequences, Mitigation, Adaptation" has been developed and tested in the universities. The course applies innovative educational approaches to help students and young people to understand, address, mitigate, and adapt to the impacts of climate change.

Source: http://www.by.undp.org/content/belarus/en/home/Blog/2016/11/7/Building-Up-Climate-Resilience-in-Belarus.html

Box 63. Climate Resilient Flood Management Practices in Georgia

Six Georgian municipalities—Oni, Tsageri, Lentekhi, Ambrolauri, Tskaltubo, and Samtredia—were included in the Climate Resilient Flood Management Practices in Georgia Project. The project aims to develop resilience of highly vulnerable communities and regions to climate related hazards. It addresses critical gaps in land use policy and regulatory framework, fundamental to climate resilient flood management.

Source: http://www.adaptation-undp.org/projects/af-climate-resilient-flood-management-practices-georgia

Box 64. Sustainability measures for water-related ecosystems in the Lower Dniester Ramsar Site, Moldova

The project AIMED AT implementing the Ramsar Site Lower Dniester, including in Transdniestria. The project intends to determine priority steps and contribute to solving the problems of water supply systems in Popeasca and Talmaza villages from LDRS. Implementation of the project solves also the problem of protecting a part of Cioburciu Village including school that is affected by floods: an anti-flood system will be rehabilitated. Creation of a regulated spawning place will be done as a pioneer activity in the region, and the second place will be assessed. The forestation works in the biodiversity valuable area of LDRS as well as in riverside protective bands will be done (15-18 ha). A sociological study and awareness raising will be done in favour of strengthening the LDRS and creation of a national park; based on this activities 5 seminars with stakeholders will be conducted, more meetings with focus groups within sociological study will be organised, development of the capacity of local authorities in the field of water use and water protection issues will be done and an information campaign organised that assure ADC and project activity visibility.

Source: http://amp.gov.md/aim/exportActToPDF.do?activityid=7510

Box 65. Integrating climate change risks into water and flood management by vulnerable mountainous communities in the Greater Caucasus region of Azerbaijan

There are likely to be issues on current and future water shortages exacerbated by climate change in some regions in Azerbaijan, including Ganikh, Lenkeran/Southern Caspian, Eastern Lower Kur, and Samur/Middle Caspian basins. The project aims to reduce vulnerability of the mountain communities of the Greater Caucasus region of Azerbaijan to climate change induced water stress and flood hazards by improved water and flood management. This will be accomplished through addressing the management framework at the legislative and policy level, strengthening institutional capacity by introducing new non-structural methods and providing training, and empowering communities to actively participate in water and flood management.

Source:http://adaptation-undp.org/projects/sccf-integrating-climate-change-risk-management-azerbaijan

Box 66. Flood Risk Management in Ukraine

More than 600 pumping stations have been installed in connection with reservoirs. Transboundary Flood Risk Management has been set up, and includes State, regional and local administrative levels. Dykes and river banks have been reinforced after major floods, inter alia, by using biological bank protection. Ukraine has also established an automatic flood forecasting system that has proved very cost effective. It includes:

- Total automatization of regulatory hydro meteorological observation network

- Creation of digital elevation maps with scales of 1:10,000 and 1:5,000 on a GIS platform

- Development of modelling technologies and forecasting of flood hydrographs and zones of inundation

- Integration of meteorological radar data and satellite images into the forecasting and modelling process

- Creation of a flood emergency warning system.

Source:https://www.unece.org/fileadmin/DAM/publications/oes/Transboundary_Flood_Risk_Management_Final.pdf

Additional resources

- Urban adaptation to climate change in Europe - Challenges and opportunities for cities together with supportive national and European policies (2012)

- Cities and Climate Change: National governments enabling local action (2014)

7. Key adaptation measures for climate hazards

Each city is unique but in most cases almost all sectors of the urban infrastructure will be affected by the climate change, creating the need for development of adaptation solutions for every sector. Often the impact can be cross-sectoral. Below is an indicative list of options for adaptation measures by sectors. While it is difficult to separate the impact of the climate adaptation and resilience measures, because these usually have a cross-sectoral impact, many cities in the region have attempted individual and bundled adaptation measures, often as part of their disaster risk reduction strategies.

Figure 22. Indicative list of adaptation options by sectors

Buildings
- enforcing building codes and regulations for resilient buildings, especially prone to climate change in coastal areas and exposed to urban heat island conditions
- investing in upgrades of existing buildings for climate resilience
- promoting green roofs for cooling and local urban agriculture
- effective development control of informal settlements

Transport
- test and adapt transport for functional rapid response ability during emergency situations
- introduce and enforce new design standards for road construction

Energy
- promoting decentralized, distributed generation
- assessing and upgrading energy systems for disaster risk reduction
- reduce dependence on climate sensitive energy sources (e.g. if high dependence on glacier-based hydro-power)
- assessing the sensitivity of existing capacities not matching the future demand, particularly for peak load demands for cooling and heating
- avoid adaptation malpractices, e.g. use of more electricity for cooling to cope with higher temperatures

Water
- changing network infrasturtcures
- demand-side management
- ensuring sufficient water supply and draught protection
- reduction of non-revenue water
- ensuring water quality complies with norms and standards
- increased capacity to deal with reduced freshwaeter availability
- flood risk reduction

Wastewater
- Managing waste-water flows to maintain and improve ecosystem services,
- introducing climae-friendly wastewater infrastructures in new construction/development
- Scheduled checks and funding availability for ad-hoc interventions
- Expanding on-site sewarage and waste disposal systems

Waste
- Integrated solid waste managmenet for climate adaptation
- Upgrading waste sorting facilities for increased resource recovery
- Optimizaiton of collection and transportation, transfer loading stations
- Reduction of waste, composting and recycling
- Waste to Wealth Initiatives

Land Use Planning

- Promoting transit-oriented development that maintains urban green, resilient buildings, disaster-prone transport infrastructures, decentralized, multi-functional communities
- construction of coastal protection structures (e.g. groynes, sea walls, geofabric sand bags and beach nourishment schemes to minimize coastal erosian, inundation and flooding)
- development of better drainage systems and improvement of strom-water protection infrastructure
- Relocating sensitive economic infrastructures along the coastal buffer zones
- adapt planting dates and irrigation practices to changing temperature regimen
- promotion of higher densities within the resilience limitations to reduce pressure on ecological infrastructures

Agriculture & Forestry

- Assessing risks and developing warming systems for extreme temperatures, extreme precipitation, damaging cyclone, drying trend, flooding, snow cover, sea level rise, storm surge
- maintaining and developing urban green to help mitigate and adapt to climate change
- deveopment of better iriigation and drainage systems

Environment (Ecosystems & Biodiversity)

- assessing and mitigating lack of public awareness
- regular information gathering and updating for up-to-date monitoring of the state of the environment
- developing a conservation plan to protect representative and persistent ecosystems and locla biodiversity
- mitigating and/or removing non-climate risks (e.g. invasive species)

Health

- developing adaptation measures for water supply and quality, air quality, food safety, waste and wastewater management, sanitation and health safety services and insurance to population with particular focus on vulnerable groups (elderly, children, people with chronic illnesses, low-income population)
- maintaining and expanding vector control
- ensuring the ability to deal with large-scale disasters via inter-agency and inter-sectoral coordination

Civil Protection & Emergency

- increasing social safety nets for food and other vital supplies in case of emergencies
- promoting local markets
- building the emergence response capacities
- educating the public about emergence responses
- building the public trust for the city government emergence services

Tourism

- Diversification of tourism services if tourism built on climate-sensitive services
- Locate and protect vulnerable infrastructures on coastal areas, including tourist attractions and ports
- Focus on co-benefits of "green" and "eco" tourism

Other

- Decentralized and local communication systems for early warning and adaptation
- empowering local communities to address climate chaneg problems
- Focus on locating and protecting vulnerable economic sectors, including coast-lying businesses, petro-chemicals, etc.
- Use of climate adaptation to create new businesses and jobs
- Competence, capacity and willingness within local government to act on adaptation

Climate change will increase the frequency and intensity of extreme weather and climate events in different regions of the world; hence, more extensive damages and losses from weather-related disaster are expected. There are, at least, nine types of climate hazards that could potentially affect negatively societies, its economies and the environment: extreme heat, extreme cold, extreme precipitation, floods, sea level rise, droughts, storms, landslides, and forest fires (however, other hazards may also be listed, such as vector-borne diseases).

These hazards may be considered a climatic risk only if something of value is at stake, such as demographic, financial, infrastructure, cultural and heritage assets, among others. The gravity of risks depends on the vulnerability of the impacted system and its adaptive capacity. For example, whilst urban inhabitants may be all equally exposed to extreme heat, those inhabitants living in poorly isolated buildings would be more vulnerable than those living in bioclimatic houses.

The exposed/vulnerable sectors - such as buildings, transport, energy, water, waste, agriculture and forestry, biodiversity, health, among others - may be possibly impacted with different levels of severity (low, medium, high) and over different time periods (e.g.: short-term, medium-term, long-term).

Whilst mitigation climate action is meant to reduce greenhouse gases emissions and, therefore, oriented to reduce global warming and hence the potential climatic hazards, adaptation action is focused on improving the resilience of the systems at stake through target investments in infrastructure development, planning, monitoring and early warning system, awareness and education, amongst other. The following boxes present several examples of successful adaptation actions, accompanied by a table summarising examples found in the literature.

Providing ventilation corridors and green spaces helps to lower the temperature and, hence, to deal with **heat waves**.

Box 67. Green spaces and urban corridors in Stuttgart (DE)

Due to Urban Heat Island effect, the inner city is 0.9 degrees Celsius hotter than its surroundings – an effect that is likely to increase in the future. In order to reduce the average temperatures and help dilute airborne pollutants and smog, ventilation corridors have been provided.

Ventilation corridors are basically areas without buildings. The open corridors allow for the inflow of cooler air from surrounding areas to the inner city.

The positive effects of the 'cooling corridors' have led to implementation of this strategy in the local Land Use Plan. At this moment green areas cover more than 60 percent of the Stuttgart's surface area and 39% of the total area of the city is protected through landscape and nature conservation laws.

Source: http://climate-adapt.eea.europa.eu/metadata/case-studies/stuttgart-combating-the-heat-island-effect-and-poor-air-quality-with-green-ventilation-corridors

On the contrary, a **cold wave** is a rapid fall in temperature that for example may lead to ice formation on road infrastructure which reduces the road safety by increasing the number of crashes.

Box 68. Fixed in-road Anti-icing Spray Systems in Minnesota (US)

To reduce ice formation on road infrastructure a control computer with specific software has been connected to temperature values. The control computer continuously polls the environmental sensors to gather data used to predict or detect the presence of black ice or snow. When predetermined threshold values are met, the computer automatically activates flashing beacons on bridge approach ramps to alert motorists, checks the chemical delivery system for leaks, and initiates one of 13 spray programs. Each program activates different valves, in various spray sequences, at different spray frequencies based upon prevailing environmental conditions. An average spray cycle dispenses 34 gallons (128.7 litres) of potassium acetate (i.e., 12 gallons or 45.4 litres per lane mile) over ten minutes. At the end of each winter season the anti-icing system is inspected and reconfigured to spray water instead of potassium acetate. Over the summer, the system is manually activated on a monthly basis to ensure proper operation of the pump and delivery. The system is re-inspected in the fall before being configured for anti-icing during winter operations. In the first year of operation the automated anti-icing treatment strategy significantly improved roadway safety through a 68-percent decline in winter crashes. Mobility enhancements resulted from reduced traffic congestion associated with such crashes. Installing the bridge anti-icing system also improved productivity by lowering material costs and enhancing winter maintenance operations throughout the district. Source: U.S. Department of Transport

Floods can be produced from many sources caused by multiple mechanisms. Climate change is expected to significantly impact on extreme precipitation events frequency and magnitude and on temperature (important for snowmelt). Moreover, human modifications of the basin areas, land use change and anthropological pressure on the rivers are consistently impacting on the retention and drainage capacity of the catchment areas which may lead to an increase of surface runoff ([161]). Between 1998 and 2009, Europe suffered over 213 major damaging floods. Severe floods in 2005 further reinforced the need for concerted action. In order to integrate the measures into new and existing developments in the flood prone areas, spatial planning approaches have been used, especially when a holistic, risk-based approach is taken. Spatial planning is not only useful in developing flood risk management plans, but also to facilitate communication between stakeholders, enhance participation and reduce conflicts and improve the urban environment.

Box 69. Climate Resilient Flood Management Practices in six municipalities in Georgia

Six Georgian municipalities—Oni, Tsageri, Lentekhi, Ambrolauri, Tskaltubo, and Samtredia—were included in the Climate Resilient Flood Management Practices in Georgia Project. The project aims to develop resilience of highly vulnerable communities and regions to climate related hazards. It addresses critical gaps in land use policy and regulatory framework, fundamental to climate resilient flood management.

Source: http://www.adaptation-undp.org/projects/af-climate-resilient-flood-management-practices-georgia

Drought has been a recurrent feature of the European climate. From 2006–2010, on average 15 % of the EU territory and 17 % of the EU population have been affected by meteorological droughts each year. The severity and frequency of meteorological and hydrological droughts have increased in parts of Europe, in particular in south-western and central Europe. Droughts have severe consequences for Europe's citizens and most economic sectors, including agriculture, energy production, industry and public water supply. Measures aimed at reducing water demand and increasing public awareness are decisive in advancing resilience to future droughts and water scarcity associated with climate change ([162]).

Box 70. Drought and water scarcity in Zaragoza (ES)

Zaragoza stands on a semi-arid region with an average annual precipitation of only 314 mm, with water shortage and drought being a problem (e.g. early 1990's droughts). In the future, the number of consecutive dry days is projected to increase significantly in southern Europe, in particular in summer, thus possibly exacerbating the problem of water scarcity in this region. With the aim of reducing water demand and the leakage from the distribution networks, awareness campaigns and economic incentives were set up for behavioural change. Water restrictions and consumption cuts and leakages from the city's aging water supply pipeline were reduced. A progressive reduction of water consumption was obtained: from 180 l per capita per day (lpcd) in 1980, through 136 lpcd in 2000, to just under 100 lpcd in 2010. In terms of the overall water savings, the city exceeded its own target: in 2009 total water consumption was 59.9 Mm3. Thus, 15 years after the start of the campaign, the city achieved a reduction of water consumption by almost 30 %, despite a 12 % population increase in the same time. The approximate cost of the awareness campaigns between 2002 - 2010 was around 2.5 million euros.

Source: https://climate-adapt.eea.europa.eu/metadata/case-studies/zaragoza-combining-awareness-raising-and-financial-measures-to-enhance-water-efficiency

Fire risk depends on many factors, including climatic conditions, vegetation, forest management practices and other socio-economic factors. Climate change projections suggest substantial warming and increases in the number of droughts, heat waves and dry spells across most of the Mediterranean area and more generally in southern Europe. These projected

([161]) https://climate-adapt.eea.europa.eu/metadata/adaptation-options/adaptation-of-flood-management-plans/#websites
([162]) https://www.eea.europa.eu/

changes would increase the length and severity of the fire season, the area at risk and the probability of large fires ([162]). Actions such as reforestation and tree planting can prevent fires.

Box 71. Forest Fires, Cascais (PT)

Forest Fires are very common in Portugal and in this municipality. In the future, increasing temperatures and decreasing precipitations can increase the fire danger conditions. To reduce the fire hazard conditions and prevent the occurrence of forest fires, Cascais considered as key measures planting and reforestation actions to prevent the spread of invasive species and reduce fire hazard and implementing fire hazards plans. These measures are ongoing and the approximate investment costs between 2016-2030 should be around 6.8 million euro.

Source:https://www.covenantofmayors.eu/about/covenant-community/signatories/action-plan.html?scity_id=1869

Landslides are a major hazard in most mountainous and hilly regions as well as in steep river banks and coastlines. Their impact depends largely on their size and speed, the elements at risk in their path and the vulnerability of these elements. Every year landslides cause fatalities and result in large damage to infrastructure and property. Landslides occur in many different geological and environmental settings across Europe, population expansion into landslide-prone areas is raising landslide risk in Europe. In addition, an increase of landslides associated to extreme rainfall events is expected in the future due to climate change ([163]).

Box 72. Multi-Hazard approach to early warning system in Sogn og Fjordane (NO)

Sogn og Fjordane is a coastal, mountainous region of Norway that boasts hundreds of thousands of tourist visits annually. Several communities in Sogn og Fjordane are facing numerous hazards such as flooding, avalanches, rock slides and other extreme weather events that might be exacerbated by climate change. Great distances between peripheral communities and not accessible transport and communication infrastructure can make accessibility inadequate, thus making communities more vulnerable to extreme weather events. The potential for an effective, reliable and cost-efficient early warning system that has a multi-hazard approach and makes use of location and population-based communication technologies, such as mobile phones and social media has been explored. In order to establish a cost-effective and sustainable early warning system, multi-hazard approach is a prerequisite, to share the costs among different scopes. The system and operational activities must be established within a framework that considers the warning needs of all undesirable events and hazards and the requirements of various end-users. The system is based on already available modern technology and infrastructure, and anchored to existing legislative and institutional frameworks. This project demonstrated how an existing county-encompassing organization could be used to issue the population warning. As this organization is closely coordinated with the police whilst being an inter-municipal organization, it is suited for the issuing of both non-emergency and emergency warnings with a multi-hazard approach. Moreover, it has been investigated how modern technology can help reduce the negative consequences of weather related hazards in current and climate changed conditions, thus also helping to prevent the loss of lives. The action implementation costs are about 105.000 euros.

Source: https://climate-adapt.eea.europa.eu/metadata/case-studies/multi-hazard-approach-to-early-warning-system-in-sogn-og-fjordane-norway

Additional resources

— European Climate Adaptation Platform for Cities and towns — Climate-ADAPT: climate-adapt.eea.europa.eu/countries-regions/cities

— Report on Urban adaptation to climate change in Europe 2016 — Transforming cities in a changing climate

— Climate-Friendly Cities: A Handbook on the Tracks and Possibilities of European Cities in Relation to Climate Change. (2011)

([163]) https://esdac.jrc.ec.europa.eu/themes/landslides

- Guide to Climate Change Adaptation in Cities - World Bank Group
- Example of disaster-resilient building design solutions for mountain areas (adapted for floods and avalanches) Sources: https://link.springer.com/article/10.1007%2Fs12665-011-1410-4 and http://www.sven-fuchs.de/links/Fuchs_et_al_2012d.pdf; http://www.interpraevent.at/palm-cms/upload_files/Publikationen/Tagungsbeitraege/2012_2_675.pdf
- Flood resistance and resilience of buildings: new build and retrofit, https://www.e3s-conferences.org/articles/e3sconf/pdf/2016/02/e3sconf_flood2016_13004.pdf
- Retrofitting for flood resilience and energy efficiency, CLASP:
- 5th Assessment Report by Intergovernmental Panel on Climate Change (IPCC)
- United Nations Office for Disaster Risk Reduction (UNISDR) Report on Disaster risk reduction tools and methods for climate change adaptation
- Community-Based Disaster Risk Management Field Practitioners' Handbook, ADPC.
- Establishing Community Based Early Warning System Practitioner's Handbook
- The Hyoho Framework for Action, 2005-2015, post-2015 focusing on increasing the capacities of local government and their accountability for DRR, available at http://www.unisdr.org/eng/hfa/hfa.htm
- The Yokohama Strategy and Plan of Action for a Safer World at with Guidelines for Natural Disaster Prevention, Preparedness and Mitigation
- European Environmental Agency on *Green Economy*
- Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication. UNEP (2011)
- Standards developed by International Standards Organization (ISO) on Resilient and Smart cities:
- ISO 37101 – Sustainable development in communities avahttps://www.iso.org/publication/PUB100394.html
- ISO 37120 - Sustainable development & resilience of communities - Indicators for city services & quality of life
- ISO/TR 37150 - Smart community infrastructures - Review of existing activities
- relevant to metrics
- ISO 37101 - Sustainable development of communities -- Management systems : Requirements with guidance for resilience and smartness
- ISO 37102 - Sustainable development & resilience of communities – Vocabulary
- ISO/TR 37121 - Inventory & review of existing indicators on sustainable development & resilience in cities
- ISO/TS 37151 - Smart community infrastructures: Principles and requirements for performance metrics
- ISO/TR 37152 - Smart community infrastructures: Common framework for development & operation
- The Green City Action Plan Methodology by The European Bank for Reconstruction and Development (EBRD)
- Compilation of Green Building Standards and Certification Systems

PART 3.c
Financing sustainable energy and climate action plans

8. Financing sustainable energy and climate action plans

A SECAP´s successful implementation requires the sufficient financial resources. It is therefore necessary to identify available financial resources, as well as the schemes and mechanisms for getting hold of these resources in order to finance the SECAP actions.

Energy-efficiency financing decisions must be compatible with public budgeting rules and available resources. The local authority should allocate the necessary resources in the annual budgets and make firm commitments for the years to come. As municipality resources are scarce, there will always be competition for available financial funding. Therefore, efforts should be continuously made to find alternative sources of resources. Regarding multi-annual commitment, different political parties should give their approval by consensus in order to avoid disruption in the development of the SECAP when a new administration is elected.

Successful SECAP actions will reduce the long-term energy costs of the local authority, the inhabitants, companies, and in general all stakeholders. The long-term reduction of costs must be taken into consideration when planning the allocation of resources. Moreover, in considering the costs of SECAP actions, local authorities should also consider their co-benefits: benefits to health, quality of life, employment, attractiveness of the city, etc.

In this perspective, local authorities may be tempted to opt for energy-efficiency projects with short paybacks. However, this approach will not capture the majority of potential savings available through energy retrofits. Instead, it is recommended that all profitable options are included and in particular those that yield a rate of return higher than the interest rate of the investment capital. This approach will translate into greater savings over the long term. As a consequence, attention should be given to proper payback time. Quick paybacks on investments mean too often that organisations do not pay attention to "life-cycle costing". Payback time shall be compared with the lifespan of the goods to be financed. For instance, a 15 years payback time cannot be considered long when it comes to building with a lifespan of 50-60 years.

Moreover, the unprecedented mobilisation of the CoM signatories to contribute to strategic climate and energy policy objectives generates the development of specific financing instruments, aimed at supporting pioneering cities and regions' efforts towards the implementation of measures.

This chapter will attempt to describe the most common financing mechanisms and funding schemes available at EU and international levels to the CoM East signatories in this region. Links and examples are provided as a general guidance to Local authorities and stakeholders. However, due to their diversity, the dissimilar economic situation and a restrictive public finance law currently in place in some of these countries, not all the financing mechanisms and structures described in this chapter are fully applicable to these countries since they are not yet fully established in their markets.

8.1 Donor-fiches

From Moldova to Turkmenistan and from Azerbaijan to Kazakhstan, the financial opportunities available to municipalities can be very different from one country to another. Many international financial institutions (IFIs) are present in the CoM East region with supporting programmes, and some of them have already been contracted by municipalities to develop plans for improving EE and reducing CO_2 emissions at the community level. In some CoM East countries, many financial institutions are active in the field of sustainability, either providing technical support, financial support or green lending products. In order to provide guidance to the municipalities, so called 'donor-fiches' are established for each country with specific information on the donors, IFIs and other supporting organisations. These donor-fiches are available through the CoM East website in the respective local language ([164]), and are updated on a regular basis depending on the availability of new information.

The country-specific donor-fiches attempt to review both public and private funds available for EE and carbon abatement projects, and provide an overview on the possible activities of

([164]) The donor-fiches are available through the CoM East website (www.com-east.eu).

commercial financing institutions supporting the funding of sustainable energy investment programmes related to the CoM. The donor-fiches are not intended to provide a complete and detailed inventory of the existing financing mechanisms for EE, carbon abatement and climate adaptation projects in each country that committed to the CoM East, as it would be impossible to cover all the detailed aspects in a short snapshot such as this. Therefore, they contain a list of the major financial mechanisms and projects that have been implemented and, where available, some information on the ESCOs' market in each country.

The data reported in the donor-fiches for the country sheets comes from various sources, including information provided by experts during CoM East working groups, presentations and comprehensive studies on the topic.

8.2 Financing opportunities and funding initiatives

This point describes the most frequent and general financing mechanism used for renewable energy sources and energy efficiency. Other specific programmes such as European funding are also available. Wide and updated information about these programmes can be found in the webpage of the Covenant of Mayors Office www.eumayors.eu

The contribution of the World Bank: The World Bank generally works at the national level. However, under such national level programs, many of the investments are actually at the city level. These include national energy efficiency programs in Serbia, Bosnia & Herzegovina, Kosovo, Macedonia, Montenegro, Belarus, Kazakhstan, Ukraine, Armenia and elsewhere, where a majority of the beneficiaries are cities. Typically, these projects include renovation of public buildings, replacement of street lighting, upgrading of district heating networks, and other investments. In some cases, these investments include renewable energy, where cost effective, such as solar water heating, biomass boilers, geothermal heat pumps and rooftop solar PV.

Sustainable energy action plans are usually financed by other bilateral donors. However as part of the national programs, Municipal Energy Efficiency Action Plans are reviewed by the Institute.

The Bank has established Energy Efficiency Revolving Funds in a number of countries in the region (e.g., Bulgaria, Armenia) and is seeking to develop several new ones (Kosovo, Macedonia, Ukraine) that can finance such investments and recover the energy cost savings over time. Through the urban sector engagement, a number of programs that support municipal infrastructure investments that include some sustainable energy projects (e.g., Municipal Services Improvement Program in Macedonia, Sustainable Cities Project through Iller Bank in Turkey, the Municipal Development Fund in Georgia) is also offered.

Signatories who are interested in accessing World Bank financing, should contact their Ministry of Finance to discuss (i) if there are existing national programs that could support their investments, (ii) if there are other municipalities interested in similar loans, so a municipal program for sustainable energy could be financed, or (iii) if there is a possibility of securing a guarantee for such a loan. Finally, the Bank has an ongoing Energy Efficient Cities Program, under the Energy Management Assistance Program (ESMAP), which offers technical assistance including a specialized tool to help local authorities identify energy efficiency priorities (TRACE) ([165]).

([165]) Contribution from Jas Singh – The World bank
https://www.ifc.org/wps/wcm/connect/Industry_EXT_Content/IFC_External_Corporate_Site/PPP/Priorities/Cities/
http://esmap.org/node/235

Box 73. The invest4climate platform

Globally, there is a failure to match demand for climate action with supply of finance. Complementary to existing climate financing mechanisms, the Invest4Climate platform provides an opportunity to further mobilize, coordinate and deliver the finance needed to help countries make the transition to a low-carbon resilient future, while creating jobs and building prosperity. The World Bank Group will partner with the UN development system in jointly convening the platform, bringing together key decision-makers in countries and various kinds of financial institutions (including private sector investors and foundations) to identify and support potential transformational climate action in line with the Paris Agreement. The platform will bring together investors with high-impact opportunities in developing countries and will work with national governments to improve policy environments. Invest4Climate will be supported by national finance ministers, climate thought leaders, chief executives of firms, foundations and financial institutions, as well as senior representatives from the UN and the World Bank Group. It will not have its own funding sources but will complement existing climate and development finance initiatives and institutions.

Source: http://www.worldbank.org/en/topic/climatechange/brief/mobilizing-finance-for-climate-action-through-the-invest4climate-platform

EU Funds and programmes: The EU provides funding and grants for a broad range of projects and programmes.

One of the first financial engineering tools created under the drive of the Covenant was the **European Local Energy Assistance (ELENA)** facility, financed by the IEE programme and initially implemented by the European Investment Bank (EIB), with the objective of supporting the technical costs associated with developing, structuring, tendering and launching large sustainable energy investment programmes. The EU together, with the EIB, is currently evaluating the possibility of expanding ELENA towards the east. It will draw on the experience of the existing facility, but should also take into account the needs of the new market.

Horizon 2020 (H2020) is the biggest EU Research and Innovation programme with nearly €80 billion of funding available over 7 years (2014 to 2020). H2020 aims to achieve smart, sustainable and inclusive economic growth. H2020 is organised in thematic sections each dedicated to a specific challenge. Among these particularly relevant for local authorities are the so called Societal Challenges (SC). Through this programme support for SECAP development and implementation and preparation of bankable projects may be addressed. Moreover **Horizon2020 Project Development Assistance (PDA)** is a technical assistance facility. The PDA will support building technical, economic and legal expertise needed for project development and leading to the launch of concrete investments, which are the final aim and deliverable of the project.

Furthermore, there are a number of relevant programmes funded by the EU that support the participation of Eastern Partnership and central Asian cities in the CoM; that is, Inogate that is operational in Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine and Uzbekistan ([166]).

The role played by the EBRD: The EBRD invests to foster sustainable and inclusive growth and promote the transition to market economies. The Bank works in countries from Central and Eastern Europe to Central Asia and North Africa, supporting sustainable investments in cities across the countries of its operation.

The Bank has a proven track record of delivering sustainable city investments. Since Bank's Municipal and Environmental Infrastructure team's activity started in 1994, the team has invested over EUR 7.3 billion in 420 projects while also mobilising EUR 7 billion co-financing and investment grants. Since measurement began in 2006, the projects are delivering expected savings of 5.5 million tonnes CO_2/year, 191 million m^3 of water/year and a reduction of 423,000 tonnes of waste/year.

A key element EBRD's ability to deliver sustainable city infrastructure is the business model. The EBRD's business model combines projects and investments with policy dialogue and

([166]) See http://www.inogate.org/index.php?option=com_content&view=article&id=46&Itemid=72&lang=en online.

technical assistance. This model aims to create the framework conditions for city investments, thereby supporting cities to adopt and transition to sustainable practices during and after the investment project.

The EBRD deploys a range of financial instruments to assist cities in their investments. These instruments include direct lending to governments, municipalities, utilities and private sector/concessionaires and public-private partnerships/ESCOs delivering municipal services as well as intermediated lending via partner banks. In addition to debt instruments, the Bank also can support bonds, structured finance and forfeiting.

It is important to note that the Bank can invest in a wide range of project sizes – from smaller loans of less than €10m to larger loans greater than €100m where we often co-finance/syndicate together with other banks. Furthermore, while the Bank can do sovereign-backed lending, whenever possible the EBRD lends directly to cities/utility companies.

One of the innovative approaches developed recently by the Bank to support sustainable city investments is the Green Cities Framework.

Green Cities Framework

The Bank's Green Cities Framework (GrCF) combines strategic planning, technical assistance and finance to help cities invest in priority environmental infrastructure projects. The Framework's goal is to systematically address cities' most pressing environmental challenges by linking planning to investment, with a keen focus on ensuring that cities' sustainable develop visions are translated into realised projects. EBRD launched the GrCF in launched in November, 2016 as a dedicated window of funding available to all countries of operations.

The Framework's key tool is a Green City Action Plan (GCAP), which helps municipal authorities and key urban stakeholders identify, benchmark, prioritise and guide green city actions and investments. The GCAP methodology, designed in conjunction with the OECD and ICLEI, first conducts a baseline assessment of a city's environmental performance based on a set of indicators and local stakeholder feedback. This assessment identifies a city's priority environmental challenges. A city, working closely with local stakeholder groups, then articulates a long term vision for its green development and lays out a 5-year action plan to address its challenges and realise its visions through investment, policy and other additional measures.

To be eligible for the Framework, cities are required to commit to undertake a GCAP, have a population exceeding 100,000, and sign a 'trigger' investment in a municipal infrastructure sector that addresses climate or environmental issues and initiates a City's participation in the Framework ([167]).

Box 74. Renewal of public transport in Ukraine

The EBRD is supporting the modernisation of public transport in Ukraine with a loan of up to €13 million for the acquisition of up to 72 low-floor trolleybuses for the city of Mariupol. The funds, provided to the communal enterprise Mariupolske Tramvaino-Troleybusne Upravlinnya (MTTU), will also finance spare parts and maintenance equipment as well as the modernisation of the existing trolleybus depot and the reconstruction of the catenary network.

The Bank's investment will reduce the upgraded trolleybus fleet's electricity consumption by approximately 40 per cent, resulting in a reduction in air pollution, CO_2 and nitrous oxides. The project will support the city in reaching its emission reduction targets agreed under the EU Covenant of Mayors programme.

The project is implemented under the Ukraine Public Transport Framework, approved by the EBRD in 2015. The facility helps replace ageing municipal transport with new environmentally friendly rolling stock.

Source: https://www.ebrd.com/news/2018/ebrd-supports-renewal-of-public-transport-in-ukraine-.html

([167]) Contribution from Nigel Jollands - European Bank for Reconstruction and Development (EBRD)

9. Financing mechanisms

9.1 Revolving funds

This is a financial scheme aimed at establishing sustainable financing for a set of investment projects ([168]). The fund may include loans or grants and aims at becoming self-sustainable after its first capitalisation.

The objective is to invest in profitable projects with short payback time, be repaid, and use the same fund to finance new projects. It can be established as a bank account of the owner or as a separate legal entity. The interest rate generally applied in the capitalisation of revolving funds is lower than the market one or even 0%. Grace periods are also frequent for the periodic payment of revolving funds.

There are several parties in a revolving fund: The owners can be either public or private companies, organisations, institutions or authorities. The operator of the fund can be either its owner or an appointed authority. External donors and financiers provide contributions to the fund in the form of grants, subsidies, loans or other types of repayable contributions. The borrowers can be either the project owners or contractors. According to the conditions of the revolving fund, savings or earnings gained from projects should be paid back to the fund within a fixed period of time, at certain time intervals.

Box 75. Green Urban Lighting Revolving Fund in Yerevan (AM)

UNDP-GEF Green Urban Lighting Project, implemented in cooperation with the Yerevan Municipality, has introduced about 500 LED lights to Isakov Avenue, Tairov street, as well as Yerevan Zoo. The initiative, which has been carried out in partnership with the Ministry of Nature Protection, allows energy savings of 63%, reduction of costs by USD 45,000, and carbon emissions by 220 tons per year. The project launched in 2013 and continued until 2017. An additional feature of the project was the requirement to accrue all financial savings from reduced energy consumption to establish a revolving fund which will further be used to expand the street-lighting retrofits.

The first achievements are a great success. The Order #2354-A of the Mayor of Yerevan dated 30.07.2015 approved the EE measures in Yerevan external lighting based on the "Utilization Procedures for the Designated Revolving Fund for Yerevan External Lighting EE Retrofitting", which allowed establishment of a revolving fund which is perpetually replenished from the financial savings accrued as a result of reduced O&M costs resulting from the original investment in the pilot project financed by the joint initiative of the Yerevan Municipality and UNDP–GEF Green Urban Lighting (GUL) Project.

Within the framework of this project the lighting retrofits have started by enhancing the efficiency and replacement of light-bulbs with LEDs with the Isakov Avenue joining the Yerevan center with the airport, followed by the Victory Bridge, Mashtots Avenue, Athens Street, Brazil Square, Tsitsernakaberd Drive, and the road leading to the Genocide Victims' Memorial, and the Arshakunyats Avenue.

9.2 Third-party financing schemes

Perhaps the easiest way for municipalities to undertake comprehensive building energy retrofits is to allow someone else to provide the capital and to take the financial risk. With these alternative methods of financing, high financing costs may be expected to reflect the fact that the debt is registered on someone else's balance-sheet. However, the interest rate is only one factor among many that should be considered in determining the suitability of a project-financing vehicle.

([168]) Further information on the EBRD-Dexia-Fondelec Revolving Fund can be found at http://www.ebrd.com/new/pressrel/2000/17feb15x.htm and in the document *Financing Energy Efficient Homes* of the International Energy Agency (IEA) (http://www.iea.org/Papers/2008/cd_energy_efficiency_policy/2-Buildings/2-FinancialBarrierBuilding.pdf).

Box 76. An example of government-led third party financing IDEA, Spain

An example of government-led third party financing is the Spanish IDAE model, which has been financing renewable projects in Spain since the late 1980s. IDAE identifies a project, provides the capital to a developer to construct it (or install the new energy-efficient equipment), and recovers its investment, plus the cost of its services, out of the energy production or savings. In other words, IDAE finances all the costs and assumes the technical responsibility of the investment. At the end of the contract, the project developer and user of the installation owns all the capital assets. In most instances the government agency IDAE works as an ESCO and has invested 95 M€ in renewable energy projects and leveraged another 104 M€ for 144 projects under the third-party finance mechanism

9.3 Leasing

The client (lessee) ([169]) makes payments of principal and interest to the financial institution (lessor). The frequency of payments depends on the contract. The stream of income from the cost savings covers the lease payment.

It can be an attractive alternative to borrowing because the lease payments tend to be lower than the loan payments; it is commonly used for industrial equipment. There are two major types of leases: capital and operating.

— Capital leases are instalment purchases of equipment. In a capital lease, the lessee owns and depreciates the equipment and may benefit from associated tax benefits. A capital asset and associated liability appears on the balance sheet.

— In operating leases the owner of the asset owns the equipment and essentially rents it to the lessee for a fixed monthly fee. This is an off-balance sheet financing source. It shifts the risk from the lessee to the lessor, but tends to be more expensive for the lessee.

9.4 Public private partnerships (PPP)

In this case the local authority uses a concession scheme under certain obligations. For instance, public administration promotes the construction of a zero-emission swimming pool, or a district heating and cooling installation, by allowing a private company to run it revolving the profits on the initial investment. This kind of contract should be flexible in order to allow the private company to extend the contract in case of unexpected payback delays. Moreover, a frequent due diligence is also recommended in order to follow up the evolution of incomes ([170]).

9.5 Energy cooperatives

Energy cooperatives ([171]) play an important role for consumers who want to take action but are not confident or interested in acting alone. By becoming members of an energy cooperative, consumers can overcome such inhibitions and become members of a local community taking energy-related actions.

Different types of energy cooperatives exist. Some operate their own generation assets (such as wind or solar parks). Others can act as aggregators or intermediaries, ensuring optimal operation and management of their members' generation installations (such as roof-top PVs on houses). Yet others can act as financial actors, pooling their members' resources and investing them in larger-scale generation or helping to fund low-carbon renovation/construction works in public facilities. In all cases they have important advantages not only for their members but also for local energy systems. They contribute to decarbonising electricity generation, they involve citizens who can easily understand and, hence, play a role in the energy market and help the energy transition. They can also potentially reduce energy bills or bring revenues to the shareholders. Energy cooperatives can therefore support a municipality's plans to reduce

([169]) Leaseurope (http://www.leaseurope.org/) is an association of car leasing European companies.

([170]) Successful worldwide Public-Private Partnerships example can be found in the document "Public-Private Partnerships: Local Initiatives 2007" on http://websdit.ypes.gr/fileadmin/documents/ppp_booklet.pdf

([171]) Covenantofmayors.eu (2018). Fact-sheet Citizen cooperative [online]. Available at http://www.covenantofmayors.eu/support/funding.html#guide_25

GHG emissions and implement sustainable energy measures within the CoM framework ([172],[173]).

9.6 Soft loans

Financing the energy retrofitting of buildings is a great challenge. Since investments may be perceived as expensive, financial incentives such as grants, guarantees or soft loans for energy renovation could motivate homeowners to make the investment decision more easily. Local and regional authorities in cooperation with financing institutions can play a key role in driving the change by offering to homeowners of private residential buildings soft loans. These are loans with interest rates below standard market conditions and longer payback periods, including eventually other advantages (e.g. grace period, lower administrative or insurance costs) ([174]).

([172]) Covenantofmayors.eu. (2018). Newsletter Covenant of Mayors. [online]
Available at: http://www.covenantofmayors.eu/New-deal-for-consumers-How-can.html

([173]) CITYnvest.eu (2017). Cooperatives and local authorities [video]. Available at http://citynvest.eu/content/citynvest-cooperative-model

([174]) See also https://www.covenantofmayors.eu/support/funding.html and CoM Guidebook "How to develop a Sustainable Energy and Climate Action plan" Part III-C.

10. Energy Services Companies (ESCOs)

The Energy Saving Companies (ESCOs) usually finance the energy-saving projects without any up-front investment costs for the local authority. The investment costs are recovered and a profit is made from the energy savings achieved during the contract period. The contract guarantees a certain amount of energy savings for the local authority, and provides the possibility for the city to avoid facing investments in an unknown field. Once the contract has expired, the city owns a more efficient building with less energy costs.

Often, the ESCO offers a performance "**guarantee**" which can take several forms. The guarantee can revolve around the actual flow of energy savings from a retrofit project. Alternatively, the guarantee can stipulate that the energy savings will be sufficient to repay monthly debt service costs. The key benefit to the building owner is the removal of **project non-performance risk,** while keeping the operating costs at an affordable level.

Financing is arranged so that the energy savings cover the cost of the contractor's services and the investment cost of the new and more energy efficient equipment. The repayment options are negotiable.

Measurements and verification of the energy and savings produced are critical for all the parts involved in the project. Therefore, a protocol ([175]) aimed at working with common terms and methods to evaluate performance of efficiency projects for buyers, sellers and financiers will be essential. As mentioned in a previous chapter, the International Performance Measurement and Verification Protocol (IPMVP) is an international set of standardised procedures for the measurement and verification (M&V) of savings in Energy-Efficiency projects (also in water efficiency). This protocol is widely accepted and adapted.

Box 77. Renewable Resources & Energy Efficiency (R2E2) Fund, Armenia

R2E2's experience in public building EE retrofits made obvious that the limited funds can have a multiplier effect revolving through repaid loans from energy savings generated. R2E2 provided loans to public buildings for comprehensive energy efficiency improvement package including insulation of walls/finishing, replacement of doors and windows, replacement of windows by walls, and roof insulation, after an efficient heating system has already been put in place.

The 8 million USD credit line of R2E2 has very strict eligibility criteria, and can only finance energy efficiency measures with attractive economic indicators (positive net present value) and only accept applications from public buildings where the comfort level is beyond 50%. As a result, energy efficiency measures which may result in substantial greenhouse gas mitigation but have lower cost-effectiveness or are proposed for suppressed demand conditions will not be eligible for finance. The documented average energy saving has been about 54% in over 100 buildings, and more in the pipeline for the following years.

R2E2 established the lending scheme for public building energy saving investments via energy saving agreements through ESCOs, more than 30 companies are now operating, which provide services such as weatherization, design, installation and maintenance of boiler houses, as well as broader consulting on related issues. However, they still do not share or guarantee amounts of energy saved in accordance with what was preliminarily estimated, neither do they bear direct financial risk (R2E2 functions as a super-ESCO bearing the major risk).

Cross-border ESCO cluster

Cross-border ESCO clusters are large scale projects at national and international levels in the areas of the following energy resources: oil, gas, coal, electricity, emission quotas, transportation, EE and energy savings, demand response services, renewable energy services, smart autonomous energy supply systems.

([175]) May be downloaded free from www.ipmvp.org

Amongst the CoM East countries, the main international players in the ESCOs market can be considered as being Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan. The benefits of the successful operation of ESCOs in some of these developing countries have been highlighted by the following aspects: the reduction of payments for energy resources, the increase in EE and a decrease in energy consumption, the optimisation of equipment performance, and a quality improvement in the products and services.

ESCO Interacting model or Public Internal Performance Commitments (PICO)

Besides the large private ESCO sector, a public ESCO sector called "Interacting model", or Public Internal Performance Commitments (PICO), has mainly been used in Germany ([176]). In the PICO model a department in the public administration acts as a unit similar to an ESCO in function for another department. The ESCO department organises, finances and implements energy-efficiency improvements mostly through a fund made up of municipal money, and using existing know-how. This allows larger cost savings and implementation of less profitable projects, which would be ignored by a private ESCO ([177]). However, these projects lack the energy savings guarantee, because there are no sanction mechanisms within a single organisation (even though PICO includes saving targets). This can result in lower effectiveness of the investments. Nevertheless, this scheme increases activity for energy savings.

Box 78. Specific example in the City of Stuttgart (DE)

The internal contracting was set up in 1995 under the direction of the Stuttgart Environmental Agency with the specific aim of establishing pre-financing for measures to conserve energy and water more rapidly, as well as implementing the measures themselves. The costs saved through these measures flow back to the Environmental Agency from the energy cost budgets of the individual departments and locally-owned utilities until the investments have been paid off. After this, the funds then become available again.
Since the concept was launched, more than 220 measures have been implemented and 8.1 million Euro invested. Both small (improvements to control technology) and large-scale (building of wood-pellet heating systems) projects have been implemented. The average period of return on invested capital is 7 years. Annual savings meanwhile amount to over 1.2 million Euro, which represents some 32,000 m^3 of water, 15,000 MWh of heat energy and 2,000 MWh of electricity. In addition to an increase in energy efficiency, city-internal contracting has also allowed the construction of systems for the use of renewable energy sources (27% of investments) ([178])

([176]) See http://www.eceee.org/EEES/public_sector/PROSTappendix8.pdf *online.*
([177]) Irrek et al. 2005 – PICOlight project is a project supported by the European Commission through the programme SAVE. More information on http://www.iclei-europe.org/?picolight
([178]) Example from a publication: Solutions for Change - How local governments are making a difference in climate protection (Climate Alliance 2008)

Annexes

Annex 1. Possible indicators to monitor the SECAP implementation

Table 43. Possible indicators to monitor the SECAP implementation

SECTOR	INDICATORS	DATA COLLECTION DIFFICULTY	DATA COLLECTION
Transport	Number of public transport passengers per year	1	Agreement with a public transport company. Select representative lines to monitor.
	Kms of biking ways	1	City Council
	Kms of pedestrian streets / Kms of municipal roads and streets	1	City Council
	Number of vehicles passing fixed point per year/month (set a representative street/point)	2	Install a car counter on representative roads/streets
	Total energy consumption in public administration fleets	1	Extract data from fuel suppliers' bills. Convert to energy.
	Total energy consumption of renewable fuels in public fleets	1	Extract data from biofuels suppliers' bills. Convert to energy. Sum this indicator with the previous one and compare values.
	% of population living within 400 m of a bus service	3	Carry out surveys in selected areas of the municipality.
	Average Kms of traffic jams	2	Perform an analysis of traffic fluidity in specific areas.
	Tonnes of fossil fuels and biofuels sold in representative selected gas stations	1	Sign an agreement with selected gas stations located within the municipality.
Buildings	% of households with energetic label A/B/C	2	City Council, national/regional energy agency, etc.
	Total energy consumption of public buildings	1	City Council
	Total surface of solar collectors	3	City Council, regional/national public administrations (from grants) and selected areas for door-to-door surveys.
	Total electricity consumption of households	2	Selected areas for door-to-door surveys.
	Total gas consumption of households	2	Selected areas for door-to-door surveys.
Local energy production	Electricity produced by local installations	2	Regional/national public administrations (feed-in tariffs of certificates).

SECTOR	INDICATORS	DATA COLLECTION DIFFICULTY	DATA COLLECTION
Involvement of the private sector	Number of companies involved in energy services, energy efficiency and renewable energies business Number of employees in these businesses, turnover	2	City Council and regional/national public administrations.
Citizen involvement	Number of citizens attending to energy efficiency/renewable energies events	1	City Council and consumers associations.
Green public procurement (GPP)	Establish an indicator for each category and compare with the typical value before implementing GPP. For example, compare kg CO_2/kWh of green electricity with the previous value. Use the data collected from all purchases to produce a single indicator.	2	City Council

Data collection frequency may be every 12 months by default.

This data can be collected from utilities, tax offices (calculation of electricity consumption patterns analysing taxes paid for electricity) of the public administration or performing surveys in selected areas. Data collection from taxes can be feasible or not depending on the taxing mechanisms of each country.

** 1-EASY, 2-MEDIUM, 3-DIFFICULT

Annex 2. How estimating the emission reduction needed to achieve the 2030 target

a) Setting the target on the basis of a BAU scenario.

The national coefficients provided in **Table 44**, which also account for the urbanization level of the country, have to be applied by local authorities to the BEI inventories in order to estimate their 2030 CO_2 and GHG emissions based on estimates from [8] [10] [102].

The methodology, assumptions, data sources and use of these default emission factors and BAU coefficients can be found in JRC Technical reports.

Because regular updates are foreseen, we recommend checking for the latest version of this document in the Covenant website Library.

Table 44. BAU coefficients to apply to BEI emissions in order to assess the 2030 emissions in CoM East countries

BEI Year	AM	AZ	BY	GE	MD	UA
2005	1.24	1.98	1.09	1.60	1.17	1.00
2006	1.25	1.96	1.09	1.60	1.19	1.00
2007	1.27	1.94	1.09	1.60	1.21	1.00
2008	1.28	1.91	1.10	1.61	1.23	1.01
2009	1.30	1.89	1.10	1.61	1.25	1.01
2010	1.31	1.87	1.10	1.61	1.27	1.01
2011	1.29	1.83	1.10	1.58	1.26	1.01
2012	1.28	1.78	1.09	1.55	1.24	1.01
2013	1.26	1.74	1.09	1.52	1.23	1.01
2014	1.25	1.70	1.08	1.49	1.22	1.01
2015	1.23	1.65	1.08	1.46	1.20	1.01
2016	1.22	1.61	1.07	1.43	1.19	1.01
2017	1.20	1.57	1.07	1.40	1.18	1.01
2018	1.19	1.52	1.06	1.37	1.16	1.01
2019	1.17	1.48	1.06	1.34	1.15	1.01
2020	1.16	1.44	1.05	1.31	1.14	1.01
2021	1.14	1.39	1.05	1.27	1.12	1.00
2022	1.12	1.35	1.04	1.24	1.11	1.00
2023	1.11	1.30	1.04	1.21	1.09	1.00
2024	1.09	1.26	1.03	1.18	1.08	1.00
2025	1.08	1.22	1.03	1.15	1.07	1.00
2026	1.06	1.17	1.02	1.12	1.05	1.00
2027	1.05	1.13	1.02	1.09	1.04	1.00
2028	1.03	1.09	1.01	1.06	1.03	1.00
2029	1.02	1.04	1.01	1.03	1.01	1.00
2030	1.00	1.00	1.00	1.00	1.00	1.00

b) 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:

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

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:

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

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

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

The targeted maximum 2030 absolute emissions are calculated as follows:

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

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

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

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

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

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:

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

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 3. 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.

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 ([179]).

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 5.4.1. 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 MWfuel

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

New parameters included in the calculation of Local Emission Factor for Electricity:

— 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 MWfuel

([179]) 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 5.4.1. 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 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/emissions 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)

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

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/

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 proposed, based on the data availability.

The method allocates the emissions based on the energy input required to produce separately (not in cogeneration) the same amount of output of heat and electricity (as in the CHP power plant output) as follows ([180]):

$$CO_{2_{CHPH}} = \frac{\frac{P_{CHPH}}{\eta_h}}{\frac{P_{CHPH}}{\eta_h} + \frac{P_{CHPE}}{\eta_e}} * CO_{2_{CHPT}} \qquad (a)$$

$$CO_{2_{CHPE}} = CO_{2_{CHPT}} - CO_{2_{CHPH}} \qquad (b)$$

with

- $CO_{2_{CHPT}}$: total amount of CO_2 emissions in the CHP power plant [tCO_2]
- $CO_{2_{CHPH}}$: amount of CO_2 emissions from heat production [tCO_2]
- $CO_{2_{CHPE}}$: 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
- η_h: typical efficiency of separate heat production. The recommended value to be used is 90 %.

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

Annex 6. Conversion factors and indicative emissions by country

Table 45 Basic conversion factors

To	TJ	Mtoe	GWh	MWh
From	Multiply by:			
TJ	1	2.388×10^{-5}	0.2778	277.8
Mtoe	4.1868×10^{4}	1	11 630	11 630 000
GWh	3.6	8.6×10^{-5}	1	1 000
MWh	0.0036	8.6×10^{-8}	0.001	1

A unit converter is available on the website of the International Energy Agency (IEA) (http://www.iea.org/stats/unit.asp).

Table 46. CO_2 emissions per capita [18]

ISO_CODE	ARM	AZE	BLR	GEO	MDA	UKR
1990	5.81	7.34	10.60	6.39	7.31	15.30
1991	6.11	7.06	10.23	4.94	5.87	14.32
1992	3.16	5.59	9.23	3.93	4.65	12.59
1993	1.51	4.84	7.97	3.21	3.95	11.00
1994	0.84	4.26	6.81	2.10	3.21	9.14
1995	1.09	4.10	6.16	1.68	2.78	9.05
1996	0.81	3.40	6.24	1.35	2.41	7.79
1997	1.06	3.20	6.28	1.21	2.21	7.55
1998	1.11	3.18	6.17	1.09	2.01	7.28
1999	1.00	3.26	5.97	1.02	1.71	7.32
2000	1.16	3.43	5.82	1.10	1.59	7.33
2001	1.19	3.23	5.73	0.80	1.67	7.37
2002	1.02	3.17	5.78	0.71	1.71	7.44
2003	1.15	3.44	5.88	0.78	1.84	7.98
2004	1.24	3.37	6.45	0.86	1.86	7.64
2005	1.49	3.54	6.60	1.07	2.01	7.52
2006	1.51	3.56	7.10	1.19	1.95	7.62
2007	1.77	3.20	6.77	1.41	1.96	7.82
2008	1.95	3.48	7.09	1.26	1.93	7.51
2009	1.57	2.88	6.86	1.44	1.88	6.23
2010	1.43	2.72	7.44	1.36	2.03	6.75
2011	1.64	3.04	6.96	1.67	2.06	7.09
2012	1.64	3.16	7.06	1.71	2.05	6.94
2013	1.53	3.20	7.09	1.76	1.81	6.77
2014	1.52	3.30	7.05	2.03	1.95	5.97
2015	1.53	3.51	6.29	2.12	1.97	4.83
2016	1.57	3.45	6.61	2.19	2.03	5.25

Table 47 Conversion of fuels from mass to energy units (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
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

Annex 7. Emission factors tables

IPCC (1995) and IPCC (2007) GWP values

		IPCC (1995)	**IPCC (2007)**
Greenhouse gas	Mass of GHG in (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

a) CO_2 emission factors for fuels

The emission factors for the fuels that are most commonly used within the territories of the local authorities are presented in Table 48 are based on 2006 IPCC Guidelines and the ELCD ([181]) [16] [18].

Because regular updates are foreseen, we recommend checking for the latest version of this document in the Covenant website Library.

Table 48 Emission factors for fossil fuels and municipal wastes

Energy carriers		IPPC 2006		LCA (up to 2007)	LCA (2008-2015
SECAP template	IPCC denomination	tCO_2/MWh	tCO_2-eq /MWh	tCO_2-eq /MWh	tCO_2-eq /MWh
Natural gas	Natural gas	0.202	0.202	0.237	0.240
Liquid gas	Liquefied petroleum gasses	0.227	0.227	n.a.	0.281
	Natural gas Liquids	0.231	0.231	n.a.	0.272
Heating oil	Gas/Diesel oil	0.267	0.268	0.305	0.360
Diesel	Gas/Diesel oil	0.267	0.268	0.305	0.360
Gasoline	Motor gasoline	0.249	0.250	0.307	0.314
Lignite	Lignite	0.364	0.365	0.375	0.375
Coal	Anthracite	0.354	0.356	0.393	0.370
	Other-Bituminous Coal	0.341	0.342	0.380	0.358
	Sub- Bituminous Coal	0.346	0.348	0.385	0.363
Other non renewable fuels	Peat	0.382	0.383	0.392	0.390
	Municipal Wastes (non-biomass fraction)	0.330	0.337	0.174	0.295

The emission factors for the renewable fuels that are most commonly used within the territories of the local authorities are presented in Table 49 are based on 2006 IPCC Guidelines and the ELCD ([182]) [16] [18].

The term "Carbon neutrality" ([183]) 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

([181]) http://lca.jrc.ec.europa.eu/lcainfohub/index.vm
([182]) The emission factors for fuel combustion are expressed as t/MWh_{fuel}. Therefore, the corresponding activity data to be used must also be expressed as MWh_{fuel}, which corresponds with the net calorific value (NCV) of the fuel.

due to the end-user consumption are entirely compensated by the CO_2 removal on the productive land.

If the local authority uses *activity-based* approach*,* the emission factor should be reported zero if the biofuels/biomass meet 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.

Table 49. Emission factors for renewable energy sources

Renewable Energy			IPPC 2006		LCA (up to 2007)	LCA (2008-2015
SECAP template	IPCC denomination	Carbon neutrality	tCO_2 /MWh	tCO_2-eq /MWh	tCO_2-eq /MWh	tCO_2-eq /MWh
Plant oil	Other Liquid Biofuels	cn	0	0.001	0.182	0.182
		ncn	0.287	0.302	0.484	0.484
Biofuel	Bio-gasoline	cn	0	0.001	0.207	0.207
		ncn	0.255	0.256	0.462	0.462
	Biodiesels	cn	0	0.001	0.156	0.156
		ncn	0.255	0.256	0.411	0.411
Other biomass	Biogas	ncn	0.197	0.197	n.a.	0.284
	Municipal Wastes (biom.fraction)	cn	0	0.007	0.106	0.106
	Wood/Wood waste	cn	0	0.007	0.013	0.017
		ncn	0.403	0.410	0.416	0.420
	Other primary solid biomass	ncn	0.360	0.367	n.a.	n.a.
Solar thermal			0	0	n.a.	0.040
Geothermal			0	0	n.a.	0.050

([183]) Stands for the terms "Sustainable / non sustainable" as currently reported in the 2016 CoM on-line templates

Table 50 CO_2 emission factors for fuels (IPCC, 2006)

Fuel type	CO_2 emission factor [kg/TJ]	CO_2 emission factor [t/MWh]
Crude Oil	73 300	0.264
Orimulsion	77 000	0.277
Natural Gas Liquids	64 200	0.231
Motor Gasoline	69 300	0.249
Aviation Gasoline	70 000	0.252
Jet Gasoline	70 000	0.252
Jet Kerosene	71 500	0.257
Other Kerosene	71 900	0.259
Shale Oil	73 300	0.264
Gas oil / diesel	74 100	0.267
Residual Fuel Oil	77 400	0.279
Liquefied Petroleum Gases	63 100	0.227
Ethane	61 600	0.222
Naphtha	73 300	0.264
Bitumen	80 700	0.291
Lubricants	73 300	0.264
Petroleum Coke	97 500	0.351
Refinery Feedstocks	73 300	0.264
Refinery Gas	57 600	0.207
Paraffin Waxes	73 300	0.264
White Spirit & SBP	73 300	0.264
Other Petroleum Products	73 300	0.264
Anthracite	98 300	0.354
Coking Coal	94 600	0.341
Other Bituminous Coal	94 600	0.341
Sub-Bituminous Coal	96 100	0.346
Lignite	101 000	0.364
Oil Shale and Tar Sands	107 000	0.385
Brown Coal Briquettes	97 500	0.351
Patent Fuel	97 500	0.351
Coke Oven Coke and Lignite Coke	107 000	0.385
Gas Coke	107 000	0.385
Coal Tar	80 700	0.291
Gas Works Gas	44 400	0.160
Coke Oven Gas	44 400	0.160
Blast Furnace Gas	260 000	0.936
Oxygen Steel Furnace Gas	182 000	0.655
Natural Gas	56 100	0.202
Municipal Wastes (non-biomass fraction)	91 700	0.330
Industrial Wastes	143 000	0.515
Waste Oil	73 300	0.264
Peat	106 000	0.382

b) Emission factors for electricity consumption

The NEFEs using the IPCC approach and accounting for CO_2 emissions (tCO_2/MWh) are provided in **Table 51**, whereas the GHG factors (in tCO_2 eq/MWh), which include CO_2, CH_4 and N_2O emissions, are provided in **Table 52**. The NEFEs using the LCA approach (**Table 53**) were obtained applying the LCA emission factors to the IEA input energy carriers (see for details [18]).

Because regular updates are foreseen, we recommend checking for the latest version of this document in the Covenant website Library.

Table 51. CO_2 emissions from Electricity consumption (IPCC approach, tCO_2/MWh) in CoM East countries

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Armenia	0.396	0.406	0.240	0.215	0.174	0.200	0.172	0.195	0.190	0.130	0.136	0.179	0.278	0.243
Azerbaijan	0.966	0.819	0.769	0.766	0.691	0.685	0.652	0.762	0.724	0.744	0.669	0.699	0.741	0.706
Belarus	0.462	0.466	0.457	0.444	0.533	0.516	0.517	0.503	0.556	0.513	0.862	0.477	0.433	0.441
Georgia	0.267	0.180	0.079	0.076	0.103	0.118	0.189	0.232	0.112	0.181	0.112	0.129	0.140	0.094
Moldova	0.663	0.571	0.515	0.523	0.445	0.436	0.415	0.457	0.446	0.550	0.627	0.603	0.599	0.473
Ukraine	0.614	0.630	0.622	0.698	0.554	0.613	0.654	0.632	0.624	0.605	0.713	0.637	0.673	0.660

Table 52. GHG emissions from Electricity consumption (IPCC approach, tCO_2 -eq/MWh) in CoM East countries

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Armenia	0.396	0.407	0.240	0.215	0.174	0.201	0.172	0.195	0.190	0.130	0.136	0.179	0.279	0.243
Azerbaijan	0.969	0.821	0.770	0.768	0.692	0.687	0.653	0.763	0.724	0.745	0.670	0.700	0.742	0.707
Belarus	0.463	0.466	0.458	0.444	0.533	0.516	0.518	0.504	0.556	0.514	0.863	0.478	0.433	0.441
Georgia	0.268	0.180	0.079	0.076	0.103	0.118	0.189	0.232	0.112	0.181	0.113	0.129	0.140	0.095
Moldova	0.664	0.571	0.516	0.523	0.445	0.437	0.415	0.458	0.446	0.550	0.628	0.603	0.599	0.473
Ukraine	0.616	0.632	0.625	0.701	0.556	0.615	0.657	0.635	0.627	0.608	0.716	0.640	0.676	0.663

Table 53. GHG emissions from Electricity consumption (LCA approach, tCO_2-eq/MWh) in CoM East countries

Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Armenia	0.471	0.483	0.285	0.255	0.206	0.238	0.204	0.231	0.226	0.155	0.161	0.213	0.331	0.289
Azerbaijan	1.116	0.959	0.900	0.896	0.812	0.803	0.767	0.897	0.856	0.883	0.795	0.830	0.880	0.837
Belarus	0.548	0.552	0.542	0.527	0.632	0.612	0.613	0.599	0.660	0.606	1.027	0.569	0.515	0.525
Georgia	0.315	0.213	0.093	0.090	0.121	0.138	0.224	0.275	0.132	0.214	0.133	0.153	0.166	0.112
Moldova	0.782	0.674	0.609	0.617	0.529	0.518	0.493	0.543	0.530	0.653	0.745	0.716	0.711	0.562
Ukraine	0.660	0.682	0.670	0.752	0.598	0.655	0.697	0.675	0.666	0.644	0.769	0.679	0.715	0.702

Annex 8. Adaptation case studies per type of climate risks

Table 54. Adaptation case studies per type of climate risks

Hazard	**Sector impacted**	**Action**	Case study	**Source**
Extreme heat	Environment & Biodiversity	Green spaces and corridors in urban areas	Barcelona	http://climate-adapt.eea.europa.eu/metadata/case-studies/barcelona-trees-tempering-the-mediterranean-city-climate
			Stuttgart	http://climate-adapt.eea.europa.eu/metadata/case-studies/stuttgart-combating-the-heat-island-effect-and-poor-air-quality-with-green-ventilation-corridors
				CIRCLE-2, 2013
			Antwerp	CoM SECAP of Antwerp
			Bologna	CoM SECAP of Bologna
			Kamen	CIRCLE -2, 2013
	Buildings	White roof, innovative solar shading and bioclimatic design	Madrid	http://climate-adapt.eea.europa.eu/metadata/case-studies/white-roof-innovative-solar-shadings-and-bioclimatic-design-in-madrid
		Green roofs	Copenhagen	CIRCLE -2, 2013
		Green walls	Nijmegen	CIRCLE -2, 2013
		Green roofs subsidy	Ghent	CoM SECAP of Ghent
		More energy efficient building codes and more renewable sources	California	Vine, 2012
		Awareness raising demonstrations and exhibitions	Antwerp	CoM SECAP of Antwerp
		Room acclimatisation with plants	Eferding	CIRCLE -2, 2013
	Transport	Improve indoor climate conditions in public transportation	Bologna	CoM SECAP of bologna
		Temperature resistant road surface	Stuttgart	SECAP template
	Civil Protection & Emergency	Early heat warning systems and emergency plans	Kassel	http://climate-adapt.eea.europa.eu/metadata/case-studies/heat-hotline-parasol-2013-kassel-region

Hazard	**Sector impacted**	**Action**	Case study	**Source**
			Tatabánya	http://climate-adapt.eea.europa.eu/metadata/case-studies/tatabanya-hungary-addressing-the-impacts-of-urban-heat-waves-and-forest-fires-with-alert-measures
				CIRCLE -2, 2013
	Health	Creating and/or repairing fountains for drinking and cooling; Cooling by water spray (fountains); Cooling by wetting streets.	London	http://climate-adapt.eea.europa.eu/metadata/adaptation-options/water-uses-to-cope-with-heat-waves-in-cities
		Web-site information on heatwaves and air quality	Bologna	CoM SECAP of Bologna
Storm	Agriculture & Forestry	Cover crops, minimum tillage (planting in the stubble), furrow pressing, spreading manure on top of the soil and adjusting the crop rotation	Vombsänken	Riksen and De Graaff, 2001
	Water	Storm surge gates	London, Rotterdam, Venice, &	http://climate-adapt.eea.europa.eu/metadata/adaptation-options/storm-surge-gates-flood-barriers
			St. Petersburg	CoM SECAP of Antwerp
Extreme cold	Transport	Fixed in-road Anti-icing Spray Systems	Antwerp	U.S. Department of Transport
Sea level rise	Green Infrastructur e	Restauration and management of Coastal wetlands	Minnesota	http://climate-adapt.eea.europa.eu/metadata/case-studies/lower-danube-green-corridor-floodplain-restoration-for-flood-protection
		Cliff stabilization	Danube Estuary	http://www.eacg.org.uk/default_smp.asp
		Restauration of dunes and sand spreading	East Anglia	http://climate-adapt.eea.europa.eu/metadata/case-studies/implementation-of-the-integrated-master-plan-for-coastal-safety-in-flanders
			Flanders	https://www.government.nl/latest/news/2011/01/17/province-of-zuid-holland-expands-seawards

Hazard	**Sector impacted**	**Action**	Case study	**Source**
	Grey infrastructure	Construction/Improvement of dykes, dams, seawalls, jetties	Zuid-Holland	http://climate-adapt.eea.europa.eu/metadata/case-studies/an-integrated-plan-incorporating-flood-protection-the-sigma-plan-scheldt-estuary-belgium/#adapt_options_anchor
			Scheldt Estuary	
		Floating and mobile barriers	New York	https://www.mosevenezia.eu/
		Depolderisation (via tidal gate) and coast realignment	Venice	https://www.ice.org.uk/knowledge-and-resources/case-studies/managed-realignment-at-medmerry-sussex
		Amphibious and floating housing	Medmerry	http://www.deltacities.com/cities/rotterdam/climate-change-adaptation
	Civil Protection & Emergency	Modelling, Monitoring, Flood Risk Management Plans (FRMPs)	Rotterdam	http://climate-adapt.eea.europa.eu/metadata/case-studies/an-integrated-plan-incorporating-flood-protection-the-sigma-plan-scheldt-estuary-belgium/#adapt_options_anchor
			Scheldt Estuary	http://climate-adapt.eea.europa.eu/metadata/case-studies/integrating-climate-change-adaptation-into-coastal-planning-in-sibenik-knin-county-croatia
	Transport	Floated or elevated roads	Šibenik-Knin County	http://www.iiinstitute.nl/sites/default/files/FloatingRoad_343.pdf
	Civil society, education & health	Participatory process with local representatives for adaptation education, planning and action	Nederland	https://coastadapt.com.au/sites/default/files/information-manual/IM09_community_engagement.pdf
		Health care plans including Climate Change concerns as cause of psychological distress	Waitakere City	http://climate-adapt.eea.europa.eu/metadata/publications/climate-change-and-mental-health-in-the-uk-impacts-of-changes-in-temperature-precipitation-and-uv
	Water and Wastewater	Water quality monitoring networks	UK	http://medcraveonline.com/MOJES/MOJES-03-00061.pdf
		Hydraulic barriers, desalinisation, aquifer storage and recovery	Purba Midnapur	http://scwd2desal.org/Page-PreventSWIntrusion.php
	Insurance	Risk-transfer tools	Santa Cruz and Soquel	http://www.deltacities.com/cities/new-york-city/climate-change-adaptation
Landslides	Green Infrastructure	Agro-forestry on landslide prone slopes	New York	http://www.rio.rj.gov.br/dlstatic/10112/4402327/4113195/PROGRAMADEPROTECAOCOMUNITARIA.pdf

Hazard	**Sector impacted**	**Action**	Case study	**Source**
			Rio de Janeiro	http://www.100resilientcities.org/wp-content/uploads/2017/10/Quito-Resilience-Strategy-PDF.pdf
	Grey infrastructure	Property rebuilding in safe areas (citizen reallocation)	Quito	http://www.100resilientcities.org/cities/salvador/
		Soil stabilization: soil nails, reinforced walls and deep drainage systems	Salvador	https://www.newcivilengineer.com/latest/lyme-regis-landslip-stabilisation-coastal-conservation/8658793.article
	Civil Protection & Emergency	Early Warning systems; Disaster management planning	Lyme Regis	http://climate-adapt.eea.europa.eu/metadata/case-studies/multi-hazard-approach-to-early-warning-system-in-sogn-og-fjordane-norway
		Vulnerability and Risk Assessment (RVA)	Sogn og Fjordane County	http://www.kas.de/wf/doc/kas_47229-1522-4-30.pdf?161128211634
	Civil society, Education & Health	Strengthening community risk management	Belo Horizonte	http://www.100resilientcities.org/strategies/medellin/
	Transport	Hazard control and forecasting system	Medellin	https://www.comune.ancona.gov.it/ankonline/act-life-adapting-to-climate-change-in-time/
			Ancona (FSI railways)	http://climate-adapt.eea.europa.eu/metadata/case-studies/building-railway-transport-resilience-to-alpine-hazards-in-austria
Droughts	Water Supply	Establishment of the "regional water association network of Lavant Valley; Early warning system in place providing daily updated data about the drinking water situation (Wolfsberg)	Austrian Railway	http://climate-adapt.eea.europa.eu/metadata/case-studies/securing-future-water-supply-on-regional-and-local-level-in-the-river-lavant-valley-carinthia
		Develop the water leakage detection program	Lavant Valley/Carinthia (AT)	http://climate-adapt.eea.europa.eu/metadata/case-studies/private-investment-in-a-leakage-monitoring-program-to-cope-with-water-scarcity-in-lisbon/#adapt_options_anchor

Hazard	Sector impacted	Action	Case study	Source
		Awareness-raising campaign to reduce water consumption and implementation of 50 examples of water efficient technologies and practices in parks, gardens, public buildings and industry.	Lisbon (PT)	http://climate-adapt.eea.europa.eu/metadata/case-studies/zaragoza-combining-awareness-raising-and-financial-measures-to-enhance-water-efficiency
	Agriculture, Forestry and Natural Habitats	Promoting use of more drought-tolerant tree species and establishing more climate-resilient mixed forest stands.	Zaragoza (ES)	http://climate-adapt.eea.europa.eu/metadata/case-studies/securing-future-water-supply-on-regional-and-local-level-in-the-river-lavant-valley-carinthia
		Water retention measures ("Watermachine" concept): natural area divided into several compartments mutually interconnected. These compartments are periodically filled with water coming from the Elsebeek River, rainfall and the wastewater treatment plant.	Lavant Valley/Carinthia (AT)	http://climate-adapt.eea.europa.eu/metadata/case-studies/the-watermachine-multifunctional-area-for-flood-protection-and-improved-water-quality-kristalbad-enschede
		Improve water retention and reduce water needs; Agroforestry and crop diversification measures	Enschede, Hengelo (NL)	http://climate-adapt.eea.europa.eu/metadata/case-studies/autonomous-adaptation-to-droughts-in-an-agro-silvo-pastoral-system-in-alentejo
		Water Retention Landscapes (WRL) for the restoration of the full water cycle by retaining the water in the areas where it falls as rain.	Montemor-o-novo (PT)	http://climate-adapt.eea.europa.eu/metadata/case-studies/tamera-water-retention-landscape-to-restore-the-water-cycle-and-reduce-vulnerability-to-droughts
	Transport	In case of drought screw pumps are pumping up water lost by the passing from the ship through the lock. In case of an excess of water, mainly in	Odemira (PT)	http://climate-adapt.eea.europa.eu/metadata/case-studies/new-locks-in-albertkanaal-in-flanders-belgium

Hazard	Sector impacted	Action	Case study	Source
		winter, the screws are used as a bypass to get rid of the excessive amount.		
	Urban Green Areas	Installation of underground storage tanks under the pavements and the associated water collection and distribution system (Gomeznarro Park) Removal of impervious pavements and their replacement with permeable surfaces, thereby facilitating water drainage and collection; Replacement of the eroded and compacted soil and Re-vegetation of the eroded areas.	Antwerp (B)	http://climate-adapt.eea.europa.eu/metadata/case-studies/the-refurbishment-of-gomeznarro-park-in-madrid-focused-on-storm-water-retention
Forest Fires	Forest and Natural Habitats	Adaptation of fire management plans and Adaptive management of natural habitats	Madrid (ES)	http://climate-adapt.eea.europa.eu/metadata/case-studies/financial-contributions-of-planning-applications-to-prevention-of-heathland-fires-in-dorset-uk
		Awareness campaigns; Monitoring, forecasting and early warning systems	Dorset (UK)	http://climate-adapt.eea.europa.eu/metadata/case-studies/tatabanya-hungary-addressing-the-impacts-of-urban-heat-waves-and-forest-fires-with-alert-measures
Flood	Green Infrastructure	Rain gardens and woodlands	Tatabánya (HU)	https://somersetnewsroom.files.wordpress.com/2014/03/20yearactionplanfull3.pdf
			Somerset County	https://www.ngu.no/en/topic/urban-groundwater
		River restoration and rehabilitation: green corridors, wetlands and floodplains	Trondheim	http://climate-adapt.eea.europa.eu/metadata/case-studies/lower-danube-green-corridor-floodplain-restoration-for-flood-protection

Hazard	Sector impacted	Action	Case study	Source
	Grey infrastructur e	Fixed and mobile barriers and safety valves	Lower Danube	http://climate-adapt.eea.europa.eu/metadata/case-studies/realisation-of-flood-protection-measures-for-the-city-of-prague
			Prague	https://www.gov.uk/guidance/the-thames-barrier
			London	http://climate-adapt.eea.europa.eu/metadata/case-studies/room-for-the-river-waal-2013-protecting-the-city-of-nijmegen
		Amphibious and floaing housing	Nijmegen	http://climate-adapt.eea.europa.eu/metadata/case-studies/amphibious-housing-in-maasbommel-the-netherlands
	Civil Protection & Emergency	Flood control system, Flood Risk Management Plans (FRMPs)	Maasbommel	http://climate-adapt.eea.europa.eu/metadata/case-studies/realisation-of-flood-protection-measures-for-the-city-of-prague
		Vulnerability and Risk Assessment (VRA)	Prague	http://www.kas.de/wf/doc/kas_47229-1522-4-30.pdf?161128211634
	Civil society, Education & Health	Participatory process with local representatives for adaptation education, planning and action	Belo Horizonte	http://www.duurzaamrivierenland.nl/documents/WieWatWater.pdf
		Health care plans including Climate Change concerns as cause of psychological distress	Tiel	http://climate-adapt.eea.europa.eu/metadata/publications/climate-change-and-mental-health-in-the-uk-impacts-of-changes-in-temperature-precipitation-and-uv
	Transport	Critical node hardening and green roof infrastructure	UK	http://eprint.ncl.ac.uk/file_store/production/237503/F42C93B2-11FC-42D9-AADB-D1F7E15967EE.pdf
		Improving drainage standards of railway networks	Newcastle	http://climate-adapt.eea.europa.eu/metadata/case-studies/implementing-climate-change-allowances-in-drainage-standards-across-the-uk-railway-network

References

[1] P. Bertoldi, R. Raveschoot Piers De, F. Paina, G. Melica, G. Janssens-Maenhout, A. Meijide Orive, and A. Iancu, "How to develop a Sustainable Energy Action Plan (SEAP) in the Eastern Partnership and Central Asian Cities - Guidebook." 2014.

[2] P. Bertoldi, "Guidebook: How to develop a Sustainable Energy Climate Action Plan (SECAP)," Publications Office of the European Union, Luxembourg, 2018.

[3] E. Croci, B. Lucchitta, G. Janssens-Maenhout, S. Martelli, and T. Molteni, "Urban CO2 mitigation strategies under the Covenant of Mayors: An assessment of 124 European cities," *J. Clean. Prod.*, vol. 169, pp. 161–177, 2016.

[4] A. Kona, G. Melica, P. Bertoldi, S. Rivas Calvete, B. Koffi, A. Iancu, P. Zancanella, G. Janssens-Maenhout, and J. F. Dallemand, "Covenant of Mayors in figures : 8-year assessment," Publications Office of the European Union, Luxembourg, 2017.

[5] S. Rivas, G. Melica, A. Kona, P. Zancanella, T. Serrenho, A. Iancu, B. Koffi, I. Gabrielaitiene, G. Janssens-Maenhout, and P. Bertoldi, "The Covenant of Mayors : In-depth Analysis of Sustainable Energy Actions Plans." Publication Office of the European Union, Luxembourg, 2015.

[6] J. Barnett and S. O'Neill, "Maladaptation," *Glob. Environ. Chang.*, vol. 20, pp. 211–213, 2010.

[7] S. Juhola, E. Glaas, B.-O. Linnér, and T.-S. Neset, "Redefining maladaptation.," *Environ. Sci. Policy(55), 135-140.*, vol. 55, pp. 135–140, 2016.

[8] U. M. Doering, G. Janssens-Maenhout, J. A. van Aardenne, and V. Pagliari, "Climate Change and Impact Research in the Mediterranean Environment: Scenarios of Future Climate Change, CIRCE report D.3.3.1, IES report 62957," 2010.

[9] A. Pozzer, P. Zimmermann, U. M. Doering, J. van Aardenne, H. Tost, F. Dentener, G. Janssens-Maenhout, and J. Lelieveld, "Effects of business-as-usual anthropogenic emissions on air quality.," *Atmos. Chem. Phys. Discuss*, vol. 12, pp. 8617–8676, 2012.

[10] P. Russ, T. Wiesenthal, D. van Regenmorter, and J. C. Ciscar, "Global Climate Policy Scenarios for 2030 and beyond. Analysis of Greenhouse Gas Emission Reduction Pathway Scenarios with the POLES and GEM-E3 models." Publication Office of the European Union, Luxembourg, p. EUR 23032, 2007.

[11] L.-Y. Shen, A. Platten, and X. P. Deng, "Role of public-private partnerships to manage risks in the public sector project in Hong Kong," *Int. J. Proj. Manag.*, vol. 24, pp. 587–594, 2006.

[12] A. K. Cerutti, A. Iancu, G. Janssens-Maenhout, G. Melica, F. Paina, and P. Bertoldi, "The Covenant of Mayors in Figures 5-Year Assessment," Publications Office of the European Union, Luxembourg, 2013.

[13] G. Janssens-Maenhout, A. Meijide-Orive, D. Guizzardi, V. Pagliari, and A. Iancu, *An approach with a Business-as-Usual scenario projection to 2020 for the Covenant of Mayors from the Eastern Partnership*, EUR 25315. Luxembourg: Publication Office of the European Union, 2012.

[14] A. R. Neves, L. Blondel, K. Brand, S. Hendel-Blackford, S. R. Calvete, A. Iancu, G. Melica, B. Koffi, P. Zancanella, and A. Kona, "The Covenant of Mayors for Climate and Energy Reporting Guidelines," Publications Office of the European Union, Luxembourg, 2016.

[15] R. Sims, R. Schaeffer, F. Creutzig, X. Cruz-Núñez, M. D'Agosto, D. Dimitriu, M. J. F. Meza, L. Fulton, S. Kobayashi, O.Lah, A. McKinnon, P. Newman, M. Ouyang, J. J. Schauer, D. Sperling, and G. Tiwari, "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 [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Sey." Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA., 2014.

[16] B. Koffi, A. Cerutti, M. Duerr, A. Iancu, A. Kona, and G. Janssens-Maenhout, *Covenant of Mayors for Climate and Energy: Default emission factors for local emission inventories - Version 2017*. 2017.

[17] A. Iancu, A. K. Cerutti, G. Janssens-Maenhout, I. Gabrielaitiene, F. Paina, G. Melica, P. Zancanella, and P. Bertoldi, *How to develop a Sustainable Energy Action Plan (SEAP) in the Eastern Partnership and Central Asian Cities Part II. - Baseline emission inventories.*, EUR 25804. Luxembourg: Publications Office of the European Union, 2014.

[18] B. Koffi, A. Cerutti, M. Duerr, A. Iancu, A. Kona, and G. Janssens-Maenhout, "CoM Default Emission Factors for the Eastern Partner countries Dataset Version 2017." 2017.

[19] European Commission, "COM (2013) 0216 final. An EU Strategy on adaptation to climate change." 2013.

[20] "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." 2015.

[21] W. Bank, "The economics of adaptation to climate change. A synthesis report." p. 84, 2010.

[22] European Environmental Agency, "National Adaptation policy processes in European countries." p. 136, 2014.

[23] Loyd' s, "Catastrophe modelling and climate change. Loyd's press." p. 41, 2014.

[24] A. Revi, D. E. Satterthwaite, F. Aragón-Durand, J. Corfee-Morlot, R. B. R. Kiunsi, M. Pelling, D. C. Roberts, and W. Solecki, "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, 2014.

[25] H. M. Fussel, "Review and quantitative analysis of indices of climate change exposure, adaptave capacity, sensitivity and impacts. World Development report 2010 – background note, pp.35." 2009.

[26] IPCC, "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." Cambridge University Press, Cambridge, UK, 2007.

[27] IPCC, "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, p. 34, 2014.

[28] IPCC, "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,." Cambridge University Press, Cambridge, UK and NY, 2012.

[29] UCCRN, "Climate change and Cities: First Assessment report ARC3. Urban Climate Change Research Network." Cambridge press, p. 28, 2011.

[30] Swiss RE, "Mind the Risk. A global ranking of cities under threat from natural disasters." Swiss RE press, p. 39, 2014.

[31] F. Bittencourt, M. Follador, V. Pereira, A. Rocha, C. Vaz, T. Vieira, M. Amoni, and F. Bicalho, "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. In Press." 2017.

[32] C. Tapia, B. Abajo, E. Feliu, M. Mendizabal, J. A. Martinez, J. G. Fernández, T. Laburu, and A. Lejarazu, "Profiling urban vulnerabilities to climate change: An indicator-based vulnerability assessment for European cities," *Ecol. Indic.*, vol. 78, pp. 142–155, 2017.

[33] M. Oppenheimer, M. Campos, R. Warren, J. Birkmann, G. Luber, B. O'Neill, and K. Takahashi, "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, 2014.

[34] S. Weber, N. Sadoff, E. Zell, and A. Sherbinin, "Policy relevant indicators for mapping the vulnerability of urban populations to extreme heat events: a case study of Philadelphia.," *Appl. Geogr.*, vol. 63, p. 231–243., 2015.

[35] OECD and JRC, *Handbook on constructing composite indicators. OECD press*. 2008.

[36] P. S. Karspen and K. Halsenes, "Integrated climate change risk assessment: a practical application for urban flooding during extreme precipitation.," *Clim. Serv.*, vol. 6, pp. 55–64, 2017.

[37] G. Naumann, P. Barbosa, A. Iglesias, and J. Vogt, "Exploring drought vulnerability in Africa: na indicator based analysis to be used in early warning systems.," *Hydrol. Earth Syst. Sci.*, vol. 18, pp. 1591–1604, 2014.

[38] G. Naumann, J. Spinoni, O. J.V., and P. Barbosa, "Assessment of drought damages and their uncertainties in Europe.," *IOP Publ. Environ. Res. Lett.*, vol. 10, 2015.

[39] European Environmental Agency, "Urban adaptation to climate change in Europe 2016. Transforming cities in a changing climate." p. 140, 2016.

[40] R. S. Kovats, R. Valentini, L. M. Bouwer, E. Georgopoulou, D. Jacob, E. Martin, M. Rounsevell, and J.-F. Soussana, "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, 2014.

[41] S. Weber, N. Sadoff, E. Zell, and Alex de Sherbinin, "Policy-relevant indicators for mapping the vulnerability of urban populations to extreme heat events: A case study of Philadelphia," *Appl. Geogr.*, vol. 63, pp. 231–243, 2015.

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

[43] M. Follador, H. Pereira, and A. Abreu, "Analise de vulnerabilidade as mudanças climáticas na cidade de Goiania, Goias. InterAmerican Development Bank report." 2013.

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

[45] "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.," 2016.

[46] "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.," 2017.

[47] S. Cutter, B. Boruff, and W. Shirley, "Social vulnerability to environmental hazards.," *Soc. Sci. Q.*, vol. 84 (2), pp. 241–261.

[48] C40, "Infrastructure interdependencies and climate risk report, pp.56.," 2017.

[49] European Commission, "DG CLIMA, 2017. Mainstreaming of adaptation into the ESIF 2014-2020. European Commission report, pp.130." 2017.

[50] European Commission, "Multiannual Financial Framework 2014-2020 and EU budget 2014." 2014.

[51] European Commission, "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." 2017.

[52] European Environmental Agency, "Urban adaptation to climate change in Europe. Challenges and opportunities for cities together with supportive national and European policies." 2012.

[53] H. M. Fussel, "Vulnerability: a generally applicable conceptual framework for climate change research.," *Glob. Environ. Chang.*, vol. 17, pp. 155–167, 2007.

[54] F. Giordano, F. Rizzitiello, C. Ndong, and A. Scaramella, "'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., 2014.

[55] GIZ, "The vulnerability sourcebook. Concept and guidelines for standardized vulnerability assessments." 2014.

[56] Y. Gonzalez, G. Gomes, and P. Barbosa, "A database for identifying EU climate change adaptation policies." Luxembourg, Publications Office of the European Union, 2017.

[57] O. Heidrich, D. Reckien, M. Olazabal, A. Foley, M. Salvia, S. de Gregorio Hurtado, H. Orru, J. Flacke, D. Geneletti, F. Pietrapertosa, J. J.-P. Hamann, A. Tiwary, E. Feliu, and R. J. Dawson, "National climate policies across Europe and their impacts on cities strategies," *J. Environ. Manage.*, vol. 168, pp. 36–45, 2016.

[58] L. Katzschener, "Urban Climate Maps." 2011.

[59] S. Neumann, F. Crick, B. Harman, G. Schuch, and D. L. Choy, "Maximizing synergies between disaster risk reduction and climate change adaptation: potential enablers for improved planning outcomes.," *Environ. Sci. policy*, vol. 50, p. 46–61., 2015.

[60] Ricardo AEA Ltd, "Adaptation strategies for European Cities. Final Report for DG Clima, pp.148." 2013.

[61] Ricardo AEA Ltd, "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." 2013.

[62] D. Reckien, J. Flacke, R. J. Dawson, O. Heidrich, M. Olazabal, A. Foley, J. J. Hamann, H. Orru, M. Salvia, S. D. G. Hurtado, D. Geneletti, and F. Pietrapertosa, "Climate change response in Europe: what's the reality? Analysis of adaptation and mitigation plans from 200 urban areas in 11 countries," *Clim. Change*, vol. 122, pp. 331–340, 2014.

[63] WHO, "The new European policy for health –Health 2020. World Health Organization, regional office for Europe." p. 174, 2012.

[64] UCCRN, "Second Assessment report ARC3.2 – Summary for policy makers. Urban Climate Change Research Network." Cambridge press, p. 28, 2015.

[65] K. Kern and G. Alber, "Governing Climate Change in Citites: Modes of Urban Climate Governance in Multi-level Systems," *Compet. Citites Clim. Chang.*, no. October, pp. 171–196, 2008.

[66] A. Webb, "Energy retrofit in historic and traditional buildings: a review of problems and methods.," *Renew. Sustain. energy Rev.*, vol. 77, pp. 748–759, 2017.

[67] A. Moschella, A. Salemi, A. Lo Faro, G. Sanfilippo, M. Detommaso, and A. Privitera, "Historic Buildings in Mediterranean area and solar thermal technologies: architectural integration vs preservation criteria.," *Energy Proceedia*, vol. 42, pp. 416–425, 2015.

[68] N. Zografakis, A. N. Menegaki, and K. P. Tsagarakis, "Effective education for energy efficiency," *Energy Policy*, vol. 36, pp. 3226–3232, 2008.

[69] A. Yezioro, I. G. Capeluto, and E. Shaviv, "Design guidelines for appropriate insolation of urban squares," *Renew. Energy*, vol. 31, pp. 1011–1023, 2006.

[70] J. Young and M. Brans, "Analysis of factors affecting a shift in a local energy system towards 100% renewable energy community," *J. Clean. Prod.*, vol. 169, pp. 117–124, 2017.

[71] C. Herbes, V. Brummer, J. Rognli, S. Blazejewski, and N. Gerick, "Responding to policy change: New business models for renewable energy cooperatives – Barriers perceived by cooperatives' members," *Energy Policy*, vol. 109, pp. 82–95, 2017.

[72] V. Verda, M. Caccin, and A. Kona, "Thermoeconomic cost assessment in future district heating networks," *Energy*, vol. 117, 2016.

[73] R. Haas, G. Lettner, H. Auer, and N. Duic, "The looming revolution: How photovoltaics will change electricity markets in Europe fundamentally, Energy 57, pp.," *Energy*, vol. 57, pp. 38–43, 2013.

[74] H. Schnitzer, C. Brunner, and G. Gwehenberger, "Minimizing greenhouse gas emissions through the application of solar thermal energy in industrial processes," *J. Clean. Prod.*, vol. 15, pp. 1271–1286, 2007.

[75] F. Manzano-Agugliaro, M. Taher, A. Zapata-Sierra, A. Juaidi, and F. Montoya, "An overview of research and energy evolution for small hydropower in Europe," *Renew. Sustain. Energy Rev.*, vol. 75, pp. 476–489, 2017.

[76] C. Winterscheid, J. Dalenback, and S. Holler, "Integration of solar thermal systems in existing district heating systems," *Energy*, vol. 137, pp. 579–585, 2017.

[77] Y. Shimoda, T. Nagota, N. Isayama, and M. Mizuno, "Verification of energy efficiency of district heating and cooling system by simulation considering design and operation parameters," *Build. Environ.*, vol. 43, pp. 569–577, 2008.

[78] V. Verda, E. Guelpa, A. Kona, and S. Lo Russo, "Reduction of primary energy needs in urban areas trough optimal planning of district heating and heat pump installations," *Energy*, vol. 48, no. 1, pp. 40–46, 2012.

[79] R. Mikulandrić, G. Krajačić, N. Duić, G. Khavin, H. Lund, B. Vad Mathiesen, and P. Østergaard, "Performance analysis of a Hybrid District Heating System: A Case Study of a Small Town in Croatia," *J. Sustain. Dev. Energy, Water Environ. Syst.*, vol. 3, pp. 282–302, 2015.

[80] S. Werner, "District heating and cooling in Sweden," *Energy*, vol. 126, pp. 419–429, 2017.

[81] H. Lund, S. Werner, R. Wiltshire, S. Svendsen, J. E. Thorsen, F. Hvelplund, and B. V. Mathiesen, "4th Generation District Heating (4GDH) Integrating smart thermal grids into future sustainable energy systems, Energy 68, 1-11.," *Enegy*, vol. 68, pp. 1–11, 2014.

[82] B. V. Mathiesen, H. Lund, D. Connolly, H. Wenzel, P. A. Østergaard, B. Möller, S.

Nielsen, I. Ridjan, P. Karnøe, K. Sperling, and F. K. Hvelplund, "Smart Energy Systems for coherent 100% renewable energy and transport solutions," *Appl. Energy*, vol. 145, pp. 139–154, 2015.

[83] A. Lake, B. Rezaie, and S. Beyerlein, "Review of district heating and cooling systems for a sustainable future," *Renew. Sustain. Energy Rev.*, vol. 67, p. 417–425., 2017.

[84] H. H. Thorsteinsson and J. W. Tester, "Barriers and enablers to geothermal district heating system development in the United States.," *Energy Policy*, vol. 38 (2), pp. 803–813, 2010.

[85] K. Ericsson and L. J. Nilsson, "Assessment of the potential biomass supply in Europe using a resource-focused approach.," *Biomass Bioenergy*, vol. 30 (1), pp. 1–15, 2006.

[86] M. Cordioli, S. Vincenzi, and G. De Leo, "Effects of heat recovery for district heating on waste incineration health impact: a simulation study in Northern Italy.," *Sci. Total Env.*, vol. 44, pp. 369–380, 2013.

[87] J. Ivner and S. Broberg Viklund, "Effect of the use of industrial excess heat in district heating on greenhouse gas emissions: a systems perspective.," *Resour. Conserv. Recycl.*, vol. 100, pp. 81–87, 2015.

[88] D. Su, Q. Zhang, G. Wang, and H. Li, "Market analysis of natural gas for district heating in China.," *Energy Procedia*, vol. 75, pp. 2713–2717, 2015.

[89] T. Urbaneck, T. Oppelt, B. Platzer, H. Frey, U. Uhlig, T. Göschel, D. Zimmermann, and D. Rabe, "Solar district heating in East Germany – transformation in a cogeneration dominated city.," *Energy Procedia*, vol. 70, pp. 587–594.

[90] H. Torío and D. Schmidt, "Low-Exergy Systems for High-Performance Buildings and Communities IEA ECBCS Annex 49 Final Report," 2011.

[91] D. Favrat, F. Marechal, and O. Epelly, "The challenge of introducing an exergy indicator in a local law on energy," *Energy*, vol. 33, p. 130–136., 2008.

[92] Ş. Kılkış, "Energy System analysis of a Pilot Net-zero Exergy District.," *Energy Convers. Manag.*, vol. 87, pp. 1077–1092.

[93] M. Pehnt, M. Cames, C. Fischer, B. Praetorius, L. Schneider, K. Schumacher, and J. Voss, *Micro cogeneration: towards decentralized energy systems.* 2006.

[94] N. Duić, G. Krajačić, and M. Graça Carvalho, "RenewIslands methodology for sustainable energy and resource planning for islands.," *Renew. Sustain. Energy Rev.*, vol. 12 (4), p. 1032–1062., 2008.

[95] R. Kollmann, F. Neugebauer, G., Kretschmer, B. Truger, H. Kindermann, G. Stoeglehner, T. Ertl, and M. Narodoslawsky, "Renewable energy from wastewater - Practical aspects of integrating a wastewater treatment plant into local energy supply concepts," *J. Clean. Prod.*, vol. 155 81), pp. 119–129, 2017.

[96] A. Aghajanzadeh, C. Wray, and A. McKane, "Opportunities for Automated Demand Response in California Wastewater Treatment Facilities,." Berkeley National Laboratory, Berkeley, California, USA., 2015.

[97] S. Achinas, V. Achinas, and G. Euverink, "A Technological Overview of Biogas Production from Biowaste," *Engineering*, vol. 3 (3), pp. 299–307, 2017.

[98] W. van Vossen, "Sustainable landfilling in The Netherlands: Developments, Methodologies and Experiences, Österr Wasser- und Abfallw 62." pp. 141–148, 2010.

[99] X. Lou and J. Nair, "The impact of landfilling and composting on greenhouse gas emissions – A review," *Bioresour. Technol.*, vol. 100, pp. 3792–3798, 2009.

[100] M. Zamorano, J. Pérez, I. Pavés, and A. Ridao, "Study of the energy potential of the biogas produced by an urban waste landfill in Southern Spain.," *Renew. Sustain. Energy Rev.*, vol. 11, pp. 909–922, 2007.

[101] J. Bruno, V. Ortega-López, and A. Coronas, "Integration of absorption cooling systems into micro gas turbine trigeneration systems using biogas: Case study of a sewage treatment plant," *Appl. Energy*, vol. 86, pp. 837–847, 2009.

[102] D. P. van Vuuren, M. G. J. den Elzen, J. van Vliet, T. Kram, P. Lucas, and M. Isaac, "Comparison of different climate regimes: the impact of broadening participation," *Energy Policy*, vol. 37, no. 12, pp. 5351–5362, 2009.

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
EaP	Eastern Partnership
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
EPLCA	European Platform on Life Cycle Assessment
ETS	European Union Greenhouse Gas Emission Trading System
EU	European Union
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
MESHART ILITY	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
NEFE	National Emission Factor for Electricity consumption
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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