EUROPEAN UNION

European Missions

100 Climate-Neutral and Smart Cities by 2030

Info Kit for Cities

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INFO KIT FOR CITIES INTERESTED IN PARTICIPATING IN THE CALL FOR EXPRESSION OF INTEREST (EOI)

Date: 29/10/2021

Doc. Version: V2.0

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PART I – UNDERSTANDING THE CITIES MISSION – Guide to help cities prepare for the Call for Expression of Interest

1 The Climate-Neutral and Smart Cities Mission

1.1 Introduction

Cities play a pivotal role in achieving climate neutrality. They take up only 4% of the EU land area, but are home to 75% of EU citizens. This number is expected to rise to 85% by 2050. Worldwide, cities account for more than 65% of energy consumption and for more than 70% of CO2 emissions.

The targets of the European Green Deal – reducing emissions by 55% by 2030 and becoming the first climate-neutral continent by 2050 – will be impossible to achieve without cities in the vanguard of concerted efforts. And many European cities are already doing fantastic work towards climate neutrality. A number of cities have made commitments to reduce Green House Gas (GHG) emissions. Yet only a handful of cities have so far adopted a target of climate neutrality by 2030.

The Mission on Climate-Neutral and Smart Cities (the "Cities Mission") will mobilise local authorities, citizens, businesses, investors as well as regional and national authorities to achieve two objectives:

1) Deliver at least 100 climate-neutral and smart cities by 2030,
2) Ensure that these cities act as experimentation and innovation hubs to enable all European cities to follow suit by 2050.

Cities already have access to a wide range of programmes at regional, national, European and global level. The added value of the Cities Mission is that it takes a cross-sectoral and demand-led approach, creating synergies between existing initiatives. It bases all of its activities on the actual needs of cities in reaching the Mission objectives.

The Cities Mission is part of the EU Missions initiative - one of the main novelties of the Horizon Europe programme. Rooted in research and innovation (R&I), the Missions aim to address societal challenges and to closely engage and involve citizens in this work. Horizon Europe will invest around EUR 360 million in research and innovation actions linked to the Cities Mission (e.g., in mobility, energy, urban planning) just in the period 2021-23. Some calls for proposals are already open in the Commission's Funding & Tender Portal and a first full work programme will be published there by the end of the year.

The Cities Mission will have as its central feature the "Climate City Contracts". Each participating city will develop and implement such a contract. While not legally binding, these contracts will constitute a clear and highly visible political commitment not just to the Commission and the national and regional authorities, but also to their citizens. They will set out plans for the city to achieve climate neutrality by 2030 and they will include an investment plan. Climate City Contracts will be co-created with local stakeholders and citizens, with the help of a Mission Platform. The Mission Platform will provide the necessary technical, regulatory and financial assistance to cities.

To achieve the climate neutrality objective of the Cities Mission, a wide array of funding and financing instruments both from private and public sources will be needed. On top of access to EU funds, where appropriate, the Cities Mission will help cities develop an Investment Plan as part of the contract process, and in particular to find access to the broader finance community, notably through the InvestEU Programme, the European Investment Bank Group, national promotional banks and other private capital markets. Availability of private financing for green investment will play a key role. The EU sustainable finance agenda offers new opportunities in this regard, including the example the possibility for people to directly contribute to the financing of sustainable projects with a positive impact on their local environment.

It is important to stress that the Cities Mission aims not only to speed up the journey of the most advanced cities toward climate neutrality. It also aims for geographical balance and to be inclusive in the sense of involving cities that are only just beginning their transition towards climate neutrality. For a climate-neutral Europe by 2050, major efforts will be needed from all cities, no matter their level of preparedness.

All cities that are interested in participating in the Mission will be invited to respond to a Call for Expression of Interest (EOI), which will be launched in November 2021 (see Section 2.1 below).

This document is intended to provide cities with all the practical information they need ahead of the publication of this Call for Expression of Interest. Part I of the document describes eligibility conditions, the selection process, the functioning of the different building blocks of the Mission and the obligations and benefits connected with participation in the Mission. Part II describes pathways towards climate neutrality, setting out in detail where and how cities can take action in different sectors.

The Call for Expression of Interest, which will consist of an online questionnaire to be filled in by the interested city, will contain specific guidance as to what is expected in response to each question.

Further detailed information can be found in the Implementation Plan for the Cities Mission, available on the Cities Mission website: http://ec.europa.eu/mission-cities. On this website, there is also a "Questions and Answers" document with replies to questions that were asked by participants of a webinar for cities, organised on the occasion of the launch of the Cities Mission.

1.2 The main building blocks of the Cities Mission

The central focus for cities seeking to become climate-neutral by 2030 as part of the Cities Mission will be the **Climate City Contract**, and the initial phase of work of the Mission will be centred on helping the selected cities develop these contracts. The Climate City Contract will be non-binding, in the form of a Memorandum of Understanding signed by the Mayor or political representative of the city and witnessed by the Commission. Use of the word "contract" is intended to indicate a clear political commitment on the part of the city to its citizens as well as to the Commission and to the national and regional authorities. The contract will encompass a range of activities including setting up large scale EU R&I demonstrators, establishing innovative models for city governance and citizens' engagement and an Investment Plan.

A **Mission Platform** will be the main initial basis for supporting cities in the transition towards climate neutrality, integrating innovative support for cities as they start to develop Climate City Contracts. The platform will offer a range of support activities for cities including a window for large-scale demonstrators, support for the development of tailor-made investment plans, innovative city governance models and citizens' engagement and a common framework for monitoring, reporting and verification. Support for the plan will include use of financial and technical advisory services to access public and private funding and financing. The Mission will collaborate closely with the European Investment Bank Group and national promotional banks, as well as with private investors. The Mission Platform will also support cities through networking and twinning activities.

Climate-neutral cities will need to be able to access other EU funding programmes, particularly as cities will be urged to take advantage of the opportunities to build in cumulative, complementary synergies with other EU projects. A **Mission label** will be awarded to the selected cities that have signed a Climate City Contract, recognising the quality and feasibility of their commitments under the contract. This label will facilitate the creation of targeted funding opportunities in EU funding programmes by making explicit reference to the label in their award procedures (calls for proposals, prizes etc.). For example, this could give cities participating in the Mission additional "points" in the award criteria under the evaluation process. The Mission label will also offer an opportunity for regions and Member States (and other public actors) to support highly visible activities on climate neutrality to help carry forward their overall efforts to meet European Green Deal targets.

Cities participating in the Cities Mission will also explore **innovative governance methods**. They should include the involvement of local key stakeholders such as civil society platforms to engage with citizens and actively involve them to develop, implement and monitor progress of the Climate City Contracts. The aim is to reduce "silo mentality" that causes fragmentation and to build inclusiveness, trust and legitimacy of the necessary actions. In particular by linking local actions for climate neutrality with some of their co-benefits such as better air quality, reduction of energy bills and road safety, it should also help develop "ownership" of the overall climate neutrality objective and thereby induce stronger local commitment and behaviour change, e.g., in mobility behaviour. These local social innovations will in turn contribute to the important process of gaining sufficient "buy-in" from local, regional, national and EU level for both the preparation and the implementation of the Climate City Contracts.

National, regional and local authorities will need to be fully involved in the co-creation and implementation of the Climate City Contracts. A dedicated **network of national contacts** will be established to prepare for the transition of cities to climate neutrality in their respective countries.

1.3 The role of research and innovation

To deliver accelerated climate neutrality, local governments, academia, private sector and civil society organisations need to form cohesive partnerships, as no single piece of the puzzle, however innovative or impactful, can accomplish all the transformational change alone. In this context, R&I is a cross-cutting social and technical enabler for deep transformation and a catalyst for holistic thinking.

It is therefore critical that cities can bridge the gap between ambition and implementation by drawing not just on the pool of existing R&I solutions but also by piloting emerging solutions.

Through the Mission as a whole, cities will be able to participate in research and innovation pilots and will draw from ongoing R&I efforts. The overall goal is to:

- ensure smart, customised access to the best available research, expertise, tools, and technologies;
- and help to engage deeply with citizens and critical stakeholders and apply systemic innovation principles and methods to identify and remove transformation barriers, establish partnerships for long-term collaboration, and foster co-production of knowledge.

Through the Mission, large scale R&I pilots will be launched to act as demonstrators for the deployment of R&I and other off-the-shelf solutions in lead European cities and districts. The pilots will test and implement innovative approaches to rapid decarbonisation, working across thematic areas and functional silos in support of transforming systems. The pilots will seek to address all urban systems, including mobility, energy systems and the built environment, material and resource flows, natural areas, cultural/social/financial/institutional systems, and accessible public spaces. Pilot projects will have the potential of being scaled up and replicated in other cities participating in the Mission to eventually enable all European cities to become climate-neutral by 2050. These pilots will also illustrate a wide range of social, environmental and economic co-benefits, such as clean air and lower congestion, which are often more directly relevant for citizens.

Examples of planned R&I actions include, but are not restricted to:

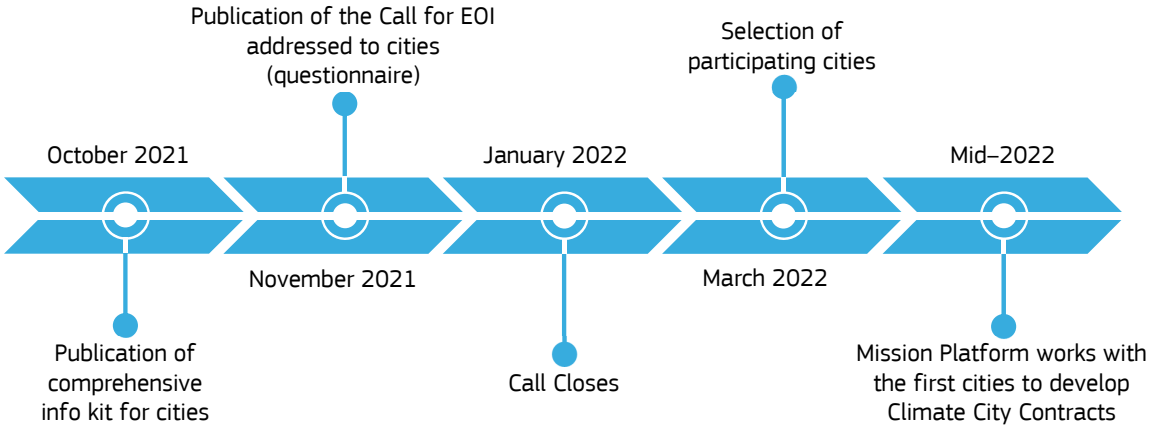
- **Large-scale demonstration projects** to prove in a real world environment the feasibility and cost-effectiveness of energy-efficient and energy-flexible urban areas or groups of connected buildings fully integrated in the city context at all levels - the so-called Positive Energy Districts (PED) - which produce net-zero GHG emissions and actively manage an annual local or regional surplus production of renewable energy (including for example smart grids and synergies with smart water and waste management). These demonstrators will involve a large consortium of cities to ensure replicability and facilitate the scaling-up of the innovative solutions to a broad range of cities;
- **Innovation actions** to develop state-of-the-art knowledge, tools, practices and decision support systems for human-centred urban planning and design that balances high tech, smart, traditional and nature-based solutions and fosters coordination among different sectors (e.g., infrastructures, transport, energy, water, built environment and environment) for cross-sectoral policies and measures for urban sustainability, road safety, climate resilience and climate neutrality;
- **Investigation, testing and experimentation** of new forms of multi-level and silo-breaking governance, new business and finance models empowering citizens and stakeholders to promote inclusive and evidence-based decision and policy making and collaborative design and rolling out of transformative transitions towards urban sustainability and climate neutrality;
- **"Living labs"** and local experimentations to unleash the innovation potential and enhance use of public transport as a backbone of sustainable mobility – helping develop viable alternatives for private vehicle ownership to increase inclusiveness of mobility, alleviating mobility poverty, reducing congestion and contributing to decarbonisation of urban transport and mobility (including via the use of digital and smart tools e.g., for traffic management);
- **Assessment and experimentation** with social innovation, digitisation, artificial intelligence, big data and information and communications technologies (ICT) to enhance the efficiency and optimisation of underlying urban processes and to serve co-creation, communication, public consultation, etc.

2 How can my city participate and what comes next?

2.1 The process explained briefly

If a city has the ambition to participate in the Cities Mission and be among the first 100 European climate-neutral cities, the first step it has to undertake is to participate in the **Call for Expression of Interest** (EOI) coming up in November. In the Call for EOI, each city will have to demonstrate that it meets the eligibility criteria in terms of its number of inhabitants (see Section 2.2.1 below) and that it is committed to the central Mission objective, meaning to reach climate neutrality by 2030 (see Section 2.2.2 below). The next subchapters (Part I of this document, specifically Section 2.3 below) describe in detail the eligibility conditions and what kind of information cities are expected to present at the time of expressing their interest to join the Mission.

Figure 1. Timeline of the Expression of Interest and selection process



Source: Own work.

The selected cities will move on to the next phase, which will consist in the development of the **Climate City Contract** (see Section 1.2 above). Part II of this document gives an outlook to the different steps and measures cities can envisage and implement later on in the context of the Mission when developing and implementing these Climate City Contracts.

2.2 In more detail: who can participate?

There are two specific eligibility criteria proposed, i.e., that cities MUST fulfil in order to express their interest in joining the Mission:

2.2.1 Eligibility criterion – city size and typology

European cities may participate in the Cities Mission if they have at least 50 000 inhabitants. For countries with a lower number of larger cities, this population threshold is lowered to 10 000 inhabitants[1]. In the context of the Cities Mission, the term city is used to refer to a geographical subnational jurisdiction ("local administrative unit") such as a town or a city that is governed by a local government as the legal entity of public administration, understanding that the institutions of local governments may vary from country to country and terminology used in national contexts may differ.

[1] Specifically, cities from countries with less than 5 cities of more than 100 000 inhabitants may express their interest if they have more than 10 000 inhabitants. Those countries are: Croatia (HR), Cyprus (CY), Estonia (EE), Ireland (IE), Latvia (LV), Lithuania (LT), Luxembourg (LU), Malta (MT), Slovenia (SI) and Slovakia (SK).

Box 1. Which cities may express their interest?

Entities will be eligible to express their interest to participate in the Cities Mission if their local authorities or their mandated representatives represent one city defined as a Local Administrative Unit (LAU), or a "greater city" or metropolitan region. Entities of more than 50 000 inhabitants qualify.[2]

However, in order to maximise the impact in terms of reducing GHG overall, **we are keen to encourage expressions of interest in particular from cities where the majority of the population lives in an urban centre of at least 100 000 inhabitants**.

By default, the participating city would commit the whole city or entity to become climate-neutral. However, where duly justified, the city may propose to exclude one or more district(s)[3] from the 2030 deadline, but in this case should commit to a strategy of climate neutrality for these districts as soon as possible, and of course no later than 2050.

In addition, in order to ensure maximum inclusiveness, for entities coming from Member States with five or less cities above 100 000 population, a lower threshold of 10 000 inhabitants will apply.

Source: Mission Implementation Plan

Inclusiveness is a central principle followed by the Cities Mission. The Mission wants to bring cities of different sizes and from all corners of Europe within its scope. Specifically, it is the intention of the Mission to have at least one city from each Member State. Hence the selection approach will also include criteria based on inclusiveness (cities of different sizes and typologies) and geographical balance (cities from all Member States and climatic zones).

Large cities are especially encouraged to join the Mission because of their potential big impact on emission reduction. Groupings of cities of smaller size are generally not encouraged. To be nevertheless considered for participation, those cities would have to be geographically contiguous and demonstrate that they can in fact act in a coordinated manner, with a single coordinating entity having authority to make decisions and commitments for the whole grouping. In all cases, it is important that the entity participating in the EOI has a legal personality and the relevant competencies to commit the territory in question to the Cities Mission.

Cities from countries with Association Agreements with Horizon Europe may participate in the Mission, and will be eligible for funding under Horizon Europe programmes.

2.2.2 Eligibility criterion – ambition

The second eligibility criterion is linked to the main objective of the Cities Mission. Cities in the Mission must state clearly their ambition to become climate neutral within this decade, meaning to reach net-zero GHG emissions by the year 2030. A detailed definition of how climate neutrality is understood in the Mission context can be found in Section 3 below.

In principle, this ambition applies to the whole city, i.e., a city expressing its interest to join the Mission would commit the whole city to become climate-neutral. However, where duly justified, the city may propose to exclude one or more district(s) from the 2030 deadline. In line with the possibility to exclude districts (see **Box 1** above), a city may propose to exclude specific emission sources or zones of specific interest from the 2030 target (for example a port), if there are compelling and duly justified reasons. Source of emission in this context refers to a point source of emission, like a specific site or plant. This could be the case either if it is financially or technically not viable to fully eliminate emissions by 2030 or if the zone does not fall under the city's jurisdiction. If the city proposes to exclude specific sources of emissions by 2030, it still needs to commit to and outline a strategy for reaching climate neutrality including these sources as soon as possible.

2.3 What else will be assessed?

Diversity is another central principle followed by the Cities Mission. The Mission seeks to ensure that we have a fully diverse group of cities and wants to bring on board cities with very different starting points in terms of climate neutrality. Hence the selection approach will also include criteria based on diversity (cities starting their

[2] Functional Urban Areas (FUA) may be taken into account where relevant.

[3] In this context, districts will be considered as neighbourhoods or zones of special interest of a city administered or governed by some type of "district council".

transition from different levels of preparedness and with different decarbonisation efforts and pathways), impact and value added of the Mission.

Besides demonstrating that a city meets the eligibility criteria in terms of size and ambition, the Call for Expression of Interest should be therefore understood as an opportunity for cities to provide an accurate reflection of their current situation. The Mission aims not only to speed up the journey of the most advanced cities, but will be inclusive and involve cities that are just beginning their transition towards climate neutrality. Cities should not be discouraged in case they cannot provide some of the information requested in the Call for EOI, indeed the contrary. More challenging circumstances, like high levels of current emissions or existing barriers do not limit a city's chances to be part of the first 100 cities. In the second phase, Mission Cities will receive specific support according to their needs, in the form of tailored technical, regulatory and financial advice depending on their individual starting points.

This is an important point because the Mission's second main target is to prepare the way for all cities to be climate-neutral by 2050. So we want to include cities with a diverse range of starting points, with different levels of preparedness for climate neutrality.

As part of their Expression of Interest, cities will have the opportunity to

- demonstrate their high level of ambition and their strong political commitment to climate neutrality
- outline their starting point for embarking on the climate neutrality transition, including
    - their current levels of emissions and the decarbonisation effort required across different sectors,
    - their level of preparedness, including existing plans and policies, targets, governance structures and administrative capacity
- describe their commitment to involve citizens and other stakeholders in planning and implementing their climate neutrality plans

The questionnaire which cities should respond to, to express their interest to join the Mission, will cover the elements outlined in **Table 1** below, with the main aim to gather relevant information for the next phases of Mission implementation, including the services to be provided through the Mission Platform (see Section 1.2 above and Section 2.4 below).

The notes in Table 1 below are intended to give early guidance on the type of issues which will be covered in the Call for Expression of Interest. None of the categories below should be seen as qualifying – or excluding – criteria. It is important to underline that the Call for Expression of Interest is looking to gather as much information as possible about the cities to ensure diversity amongst participating cities.

Table 1. Indicative elements of the Call for Expression of Interest

Indicative group of questions	Information to be provided by cities expressing their interest
Eligibility criteria	

Indicative group of questions	Information to be provided by cities expressing their interest
Eligibility criteria and information about the city expressing its interest	At the beginning of the questionnaire, cities are asked to confirm their commitment to join the Cities Mission with the ambition to reach climate neutrality (as defined for the Cities Mission, see Section 3 below) by 2030. This has to be supported by a Council resolution, letter of the Mayor or similar type of official document. Aside from gathering the relevant administrative information like location and number of inhabitants, the questionnaire will enable cities to describe and justify if applicable any proposed exclusions from the target of climate neutrality by 2030. This could involve as outlined in Section 2.2.1, the exclusion of specific districts or sources of emissions, Cities may also here explain why they propose to *include* a larger Functional Urban Area, when applicable. If the EOI is on behalf of a group of entities, information on the group composition and the group's coordinating entity has to be provided.
Other EOI elements	
The climate-neutrality target and vision for closing the gap to net-zero by 2030	At the moment of expressing their interest to join the Mission, cities are not expected to have fully defined their plans on how to reach climate neutrality by 2030. Some cities will have a clear picture already. Others may not be so advanced in their planning for climate neutrality. As outlined above (see Sections 1.2 and 2.1), these details will be elaborated in the process of drawing up the Climate City Contract in the next phase. This section gives cities however the chance to confirm that they understand and are aligned with the scope of the Mission and the required level of ambition and to outline their vision on how they can accelerate and close the gap to be climate neutral in 2030. Cities are encouraged to include in this section aspects that go beyond sector-specific or technological aspects, and outline their initial thinking on elements like governance (see below, partnerships and citizens engagement), digitalization, system integration, impacts and co-benefits. In addition to the overall vision, cities also have the opportunity to outline the main directions for eliminating emissions in all sectors covered by the Mission.
Current level of emissions	This section gathers information from cities on their current level of GHG emissions. Again, this is not intended to be an excluding criterion. Cities are not expected to have performed at this point a comprehensive GHG emissions inventory of all sectors and scopes covered by the Cities Mission (see Section 3 below, as well as Section 2.4 in Part II of this document), but are encouraged to share information that has been gathered in the past (irrespective of the methods followed) as an approximation of their current level of emissions and the GHG emissions reduction effort required. Where available, cities are asked to provide an estimation of their overall and sectoral annual GHG emissions. The methodology applied to assess GHG emissions, as well as studies or other documentation supporting the assessment, can be presented.

Indicative group of questions	Information to be provided by cities expressing their interest
Existing initiatives and plans	In this section, cities are invited to showcase their past performance on climate action and cities have the opportunity to describe any official targets already in place, i.e. the currently envisaged trajectory of the city prior to joining the Mission. Again, this is not intended to be a qualifying – or excluding - criterion. The questions allow cities to provide details on past and existing initiatives regarding GHG emissions reduction and their experience in designing and implementing mitigation strategies, as well as monitoring their progress. This covers cross-sectoral and sectoral climate change mitigation/GHG emissions reduction strategies or plans already adopted by cities and should enable an overview of where those will bring cities in terms of emission reduction by 2030. Additionally, this block of questions collects information on the degree of involvement in other relevant initiatives at EU, national or local levels.
Current key policies	In this section, cities will answer questions on their current policies, e.g. energy, transport, waste and wastewater management, giving a more detailed picture of their starting point in the most relevant sectors for urban climate action. Cities will provide information on how much of the energy consumed in the city is currently covered by Renewable Energy Sources (RES) and how much energy is generated from RES within the city boundaries. Another set of questions explores the cities' experience and preparedness for enabling and implementing digitalisation strategies and other smart city solutions. If applicable, cities can describe any open innovation approaches and innovation procurement strategies they have used.
Partnerships and citizens engagement	The questions in this section explore the partnerships that cities have in place and how they are conducive to reaching the climate neutrality target by 2030. Cities are asked to outline how they collaborate with other levels of government and the private sector to advance the development and implementation of their climate policies. A particularly important point is to hear plans, if already in place, for engaging citizens in the design and implementation of climate policies. Cities are further invited to describe how they are collaborating and sharing experience across city and national boundaries.
Investment needs and strategy	Cities expressing their interest to join the Mission are by no means expected to have an investment plan ready at the time of joining the Mission. As outlined above (see Section 1.2), investment plans will form integral parts of the Climate City Contracts that will be developed in the next phase. The questions in this section explore where cities stand in estimating their investment needs and encourage participating cities to reflect on their investment readiness by looking at past experience and currently available advisory services.

Indicative group of questions	Information to be provided by cities expressing their interest
Governance and capacities of the administration	In this section cities can outline how the climate agenda and specifically actions to move towards climate neutrality is dealt with within their administration, by describing the structures in place or planned and the human resources allocated or planned to be allocated in the next phase. Cities are then asked to outline the systems they have put in place to collect the relevant data and ensure effective monitoring of GHG emissions and reporting on climate action.
Synergies/Horizontal aspects	In this section cities are invited to reflect on potential synergies and trade-offs in specific fields linked to the scope of the Cities Mission, including air pollution and energy poverty, and to outline if and how these are currently addressed.
Barriers, risks and assistance needs	In the final block of questions cities are encouraged to reflect on the critical barriers, risks and challenges they face to achieve climate neutrality by 2030. Cities will be able to set out in this section the type and extent of assistance they will likely require to develop and implement their plans. Again, any information presented here does not constitute a qualifying – or excluding – criterion but it will be relevant both to the city's efforts in the next phases of implementation towards climate neutrality but also to the Mission as a whole, and the services to be provided through the Mission Platform.

2.4 What are the benefits of becoming a Mission City?

Many cities and city organisations report that, while they want to go further and faster on their journey to climate neutrality, they face barriers in generating the necessary operational capacity and capability, financing the upfront costs and developing political support both with their voters and with their governments.

Against this backdrop, adopting the goal of climate neutrality by 2030 within the context of the Mission brings specific benefits. While existing programmes for cities are often top-down and/or are often technology-based or focused only on specific sectors, the Mission starts with the perspective of the city and takes a bottom-up, demand led approach. The Mission will help cities make the best use of existing programmes, to develop and benefit from cross-sectoral complementarities and synergies, to take up and scale up research and innovation solutions and to find ways of overcoming regulatory barriers.

In particular, the main benefits of being among the cities joining the Mission and fully committing to the climate neutrality target by 2030 and the Climate City Contract process are:

— Tailor-made advice and assistance from the Mission Platform

The Mission Platform will work with each participating city and support them with technical, regulatory and financial advice. The Platform will assist cities in developing and subsequently implementing their Climate City Contract. The Climate City Contract will set out the definitive plans for the city to achieve climate neutrality by 2030 and signal the city's firm commitment to mainstream these plans into their overall city planning processes. The contract will include an investment plan to scale up and deploy innovative solutions for delivering on the commitments.

— Unlocking additional funding and financing opportunities through a Mission label

Cities participating in the Mission, after finalising their Climate City Contract, will be awarded a "Mission label" that will recognise the quality and feasibility of their commitments. The label would be intended to help provide additional funding opportunities through other EU programmes (beyond Horizon Europe) as well as facilitate access to finance, via the European Investment Bank, national promotional banks, but also

private investors looking to invest in verified climate neutrality projects. The Mission will also work with Member States to develop further opportunities to use the label also at national and regional level to secure additional resources.

— Research & Innovation

The Horizon Europe Mission Work Programme will provide ample funding opportunities for cities to be part of large innovation actions, pilot projects and demonstrators. Other parts of the Horizon Europe programme will also contribute through for example joint calls. The Mission Platform will also provide opportunities for targeted R&I pilots addressed directly to cities through open calls for proposals to test and implement innovative approaches to rapid decarbonisation, working across thematic areas and addressing all urban systems (including mobility, energy systems and the built environment, material and resource flows, natural areas, cultural/social/financial/institutional systems, and accessible public spaces).

— Support through a national coordination network

A National network, pulling together representatives from the different parts of Member State administrations, together with regional and local authorities, will provide further opportunities for coordination and exchange both within the country and with other Member States, to discuss how to work together, based on best practices, and how to address common challenges. A national coordination network will be set up and will work closely with the European Commission and the Mission Platform to make sure that the horizontal Mission approach translates into concrete cooperation between sectors at all levels. Particular tasks of the network will be to involve national funding programmes and to examine how the national regulatory framework can enable cities to take the necessary steps to become climate-neutral.

— Networking opportunities, learning and exchange of experiences among cities

Through the Mission Platform cities will be able to interact and to benefit from networking and matchmaking for cities and practitioners, in order to stimulate mutual learning between cities and to facilitate knowledge exchange between the Mission Cities and a wider group of twin cities across Europe and beyond.

— High visibility – raised political profile, attractiveness for investment and skilled workers

The first 100 cities to pursue climate neutrality by 2030 will have high political visibility especially in the context of the European Green Deal and the overall EU effort to reduce GHG emissions by 55% by 2020. Participation in the Mission will help give cities a forum from which to demonstrate their vision and ambition, making them more attractive for public and private investments and as a location for new businesses and skilled workers.

2.4.1 What happens if a participating city does not meet the climate neutrality target?

The Climate City Contracts will not be legally binding. So, cities do not need to fear any legal consequences if they do not meet the target of full climate neutrality by 2030. That said, the contracts will be a very visible commitment that the Mayor or political representative of the city will have made towards their national authorities, the Commission and towards the city's inhabitants. Hence the importance of developing solid Climate City Contracts based on sound planning that take possible future difficulties into account.

3 Urban climate neutrality defined in the context of the Mission

The European Climate Law writes into law the goal set out in the European Green Deal for Europe's economy and society to become climate-neutral by 2050. **Climate neutrality means achieving net zero GHG emissions**, to be realised mainly by cutting emissions, investing in green technologies and protecting/enhancing the natural environment.

3.1 Main elements of the urban climate neutrality definition

At the level of cities, there is currently no definitive agreement on how climate neutrality targets are implemented, while differences in the definition of neutrality can lead to very different climate ambitions and action. Since "two net-zero commitments can be dramatically different, aiming for different timelines, covering different kinds of GHG emissions, and relying on offsets to varying extents" (New Climate Institute, 2020), specifying these aspects by identifying gases, scopes and sectors involved in the remainder of this section, will support transparency in the overall process of the Mission.

Achieving climate neutrality will require a Mission City to reduce the GHG emissions from all sectors and sources within the city's boundary to net zero by 2030, **including**:

- Emissions from combustion of fossil fuels in **all buildings and facilities** (known as 'stationary energy'). This includes residential, commercial and industrial buildings as well as municipal buildings and public lighting within the city boundary;
- Emissions from combustion of fossil fuels for **all vehicles and transport** within the city boundary;
- Emissions arising from the **consumption of electricity and district heating/cooling** within the city's boundary, from power plants located within or outside the city boundary;
- Emissions arising from **waste generated within the city boundary**, treated/managed/disposed within or outside the city boundary;
- Emissions from **changes in land use** including agriculture, forestry and other land uses (collectively referred to as 'AFOLU') within the city boundary;
- Emissions from **chemical processes in industry** (collectively referred to as Industrial Process and Product Use or 'IPPU') within the city boundary.

Box 2. Indicators for measuring climate neutrality at the city level

1. Scope 1 GHG emissions (direct emissions) for the city within its geographic boundary (mandatory from the beginning of the Mission). This indicator will be calculated based on the emissions from buildings, facilities, industry, transport, waste treatment (solid waste and wastewater), agriculture and forestry and from other activities.

2. Scope 2 GHG emissions (indirect emissions) for the city (mandatory from the beginning of the Mission). This indicator will be calculated based on the emissions from indirect emissions due to consumption of grid-supplied electricity within the geographic boundary and indirect emissions due to consumption of grid-supplied heat or cold within the geographic boundary.

3. Scope 3 GHG emissions (out-of-boundary emissions) for the city are not required for inclusion at this stage (except in respect of waste, see table 2 below). The Mission is however interested in looking further into Scope 3 emissions with participating cities as ultimately, of course, by 2050, they will need to be fully factored into climate neutrality. This indicator will be calculated based on the emissions from out-of-boundary emissions from treatment of waste produced within the geographic boundary, out-of-boundary emissions from transmission and distribution of energy consumed within the geographic boundary, out-of-boundary emissions from transportation of citizens living within the geographic boundary, out-of-boundary emissions from consumption made within the geographic boundary (food, clothes, furniture, materials, etc.) and other indirect emissions.

The most important elements of the definition of climate neutrality that is applied in the Mission context are summarised in **Table 2** below.

Table 2. Elements of the definition of climate neutrality as applicable in the Mission

Elements of a climate neutrality definition	Recommended approach
GHGs covered by the target boundary[1]	Mission Cities should account for emissions of the following gases (expressed as CO_2 equivalents): carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). If emissions from the IPPU sector are present, cities also have to cover emissions of hydro fluoro carbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF6) and nitrogen trifluoride (NF3).
Sectors/sources of emissions covered by the target boundary	Scope 1 and Scope 2 from stationary energy, transport, waste (including in this case. Scope 3, i.e., at point of disposal/treatment), IPPU, AFOLU mandatory
ETS plants	Any large-scale energy generation or industrial facilities located within the city boundary which are registered under the EU Emissions Trading Scheme (EU ETS) will be exempt from the Mission on the basis that municipalities have very limited influence over their operation and there is a dedicated EU process to reduce emissions from these sources. It is optional for cities to include them if measures are foreseen.
Local energy generation measures[2]	Reflect local energy generation measures through the local emission factor (Scope 2 emissions), splitting on-site consumption and what is provided to the grid.
Share of residual emissions	Residual emissions should be reduced to the minimum possible, with a recommended maximum level of residual emissions (20%) and mandatory compensation of residual emissions and rules for compensation (see next 4 lines)
Offsetting – type and location	Offsetting is only possible for emissions which are very difficult or impossible to mitigate (i.e., for residual emissions). Limited eligibility depending on project types (i.e., projects within the country/EU, and with high additionality, high co-benefits)
GHG emission removal (within the territory)	Pilot projects on carbon capture and storage (CCS) allowed, i.e., to account for negative emissions through GHG removal to address residual emissions. Only applications which result in permanent sequestration of the CO2 (i.e., injected into geological structures) will be allowable.
Sinks	Allowed to account for negative emissions through the enlargement or enhancement of natural sinks within the territory to address residual emissions (taking into account all changes in the carbon stock)
Certified renewable energy purchases (Renewable energy credits)	Allowed for the reflection of certified renewable energy purchases in the calculation of the local emission factor to address Scope 2 emissions
Local Emission Factors (see Box 8 in Part II of this document)	Allowed to use of locally estimated Emission Factors (EF) for electricity and heat (double-counting through dynamic national/regional EF has to be avoided).[3]

Elements of a climate neutrality definition	Recommended approach
Reflect grid decarbonisation	Change Emission Factor over the years (reflecting changes in the national/regional/local mix) (double-counting through locally weighted EF has to be avoided).[3]
Other methodological considerations	Biomass: Zero emission factor only if sustainability criteria are respected (a principle) No negative emissions allowed for biomass energy.

[1] The inclusion of gases needs to be aligned with the sectors covered.

[2] The CoM EU presents criteria to define what can be considered as local energy generation, to be included in the calculation of the local emission factor.

[3] Local renewable electricity generation when shared with the electricity grid contributes to lowering the overall EF. At the same time, local emission factors taking into account local renewable energy generation will be important for urban areas, especially to represent their efforts to decarbonize the energy system in an amount that is equivalent to their local renewable energy generation.

Source: Own work.

3.2 Residual emissions and offsetting

While cities will be required to reduce all sources of GHG emissions to the extent feasible, it is acknowledged that depending on local circumstances there may be certain emission sources (e.g., specific industrial processes) which cannot be fully mitigated by 2030 due to technological or financial constraints. Subsequently, compensating for any 'residual emissions' will be possible, to an extent, to account for those emissions sources which cannot be fully eliminated.

To ensure that cities achieve maximum emission reductions within their territory, the Mission recommends as a guideline to aim for a level of 'residual emissions' within the city boundary in 2030 that does not exceed 20% of the baseline GHG inventory, with the possibility that the remainder could be accounted for using carbon sinks or credits.[4] In any case this is not encouraged, i.e., residual emissions should be reduced to the minimum possible and any form of offsetting should only be considered for emission sources which are very difficult or impossible to mitigate.

Ultimately, between direct reduction and offsetting of residual emissions, a net-zero emission balance must be achieved by 2030, meaning the amount of GHGs emitted from a city territory is completely neutralised. This is in line with the European Climate Law, which recognises that while GHG emissions should be avoided at source as a priority, removals of GHGs will be needed to compensate for remaining emissions from sectors where decarbonisation is the most challenging.

There will be two ways for a city to deal with its residual emissions in order to reach net-zero:

- **Carbon sinks**, i.e., removals through natural and technological solutions, within the city boundary
- **Carbon Credits** from outside the city's boundary and subject to certain rules and restrictions to be able to credibly demonstrate a city's climate neutrality (i.e., using formal credits/certificates verified and/or validated under rigorous standards by certified third-party auditors).

As some form of offsetting is likely to be required by participating cities to cancel out residual emissions. Mission Cities should gain a good understanding early in the process, as integral part of developing their City Climate Contract, of the likely level of residual emissions and devise a strategy for addressing them. Participating cities have to separately report gross and net emissions to ensure transparency regarding residual emissions cancelled out through offsetting mechanisms.

[4] The recommended minimum 80% reduction is in line with the Communication "A Clean Planet for all" (often referred to as the "long-term decarbonisation strategy") which confirms Europe's commitment to lead in global climate action and presents a vision that can lead to achieving net-zero greenhouse gas emissions by 2050 through a socially-fair transition in a cost-efficient manner (European Commission, 2018b). The in-depth analysis underpinning the long-term decarbonisation strategy presents eight different scenarios, all compatible with the Paris Agreement, that are based on different levels of ambition in terms of GHG emission reduction. All of the scenarios are based on a reduction of GHG emissions of at least 80%.

Further details on the accounting of GHG emissions for the Mission are included in Sections 2.4 and 2.5 in Part II of this document.

PART II – A SHORT GUIDE TO URBAN CLIMATE NEUTRALITY

1 The challenge and the global and European policy context

In line with the EU commitment to global climate action under the Paris Agreement (hereinafter the Agreement), the strategic long-term vision of the European Commission for a prosperous and climate-neutral economy has determined that GHG emissions must be drastically reduced by 2050 (European Commission, 2018b). Accordingly, the European Green Deal (EGD), presented in December 2019, sets a reduction target of 50%-55% by 2030 and the objective of becoming climate-neutral by 2050 while transforming the EU into a modern, resource-efficient, and competitive economy (European Commission, 2021a). The EU Climate Law, as part of the Green Deal, will enact the 2050 objective in EU legislation (European Commission, 2021b) and the Fit for 55 package of proposals will bring the EU climate and energy legislation in line with the 2030 GHG emission reduction target and 2050 ambition.

Against this backdrop, sub-national players, with cities at the forefront, are the envisioned game-changers in stimulating and delivering the means for a climate-safe future. According to the key findings of the Working Group I (WGI) contribution to the IPCC's Sixth Assessment Report (AR6) published on August 9, 2021 (IPCC, 2021a), we reached a 'code red' for human-driven global warming with cities exacerbating the effects at the local scale. Urbanization and more frequent hot extremes will increase the severity of heatwaves, the magnitude of precipitation over and/or downwind of cities, and the resulting runoff intensity, with alarming consequences especially for coastal cities. As climate systems respond to the interplay between human influence, natural drivers and internal variability, knowledge of the climate response and calibrated actions at regional and sub-regional level will be critical to tackle these challenges and harness the opportunities associated with the transition.

What cities achieve locally will not only carry a large part of both the national and the European load in meeting the Agreement, it can also encourage greater uptake of sustainable solutions outside cities, setting a trend for their Member States to follow and a leading international example. Many cities are now starting to embrace the policies needed for climate neutrality, and the concept of doing so by 2050 is taking hold, as seen in the new commitments taken by the signatories of the Covenant of Mayors just in April of this year (Covenant of Mayors, 2021).

Overall, translating a mayoral commitment to reality in the short haul, as championed by the Cities Mission with its objective of reaching climate neutrality by 2030, represents an unequalled opportunity for rapid transition, workforce development, increased climate resilience and leadership, but it also requires navigating unprecedented political, technical and financial challenges. Looking ahead to the Climate City Contract development and implementation phase under the Mission (see Section 1.2 above), this **Part II** of the document illustrates a compendium of resources and strategies towards climate neutrality at city level. Possible pathways are identified concerning both demand and supply side and involving different sectors, while illustrating the cross-cutting benefits of holistic thinking and twin green and digital transition.

Please note that the information provided in the following sections is meant as guidance throughout the implementation process of the Mission and cities are not expected to have already developed strategies or undertaken initiatives in all of these areas at the stage of expressing their interest.

2 Planning for net zero emissions by 2030

Given that climate and environmental challenges span across sectors and administrative boundaries, it is increasingly clear that these issues need to be tackled through an integrated approach. Cities are often the places where severe environmental pressures are concentrated, as well as the places that are on the front line

in terms of solutions. Therefore, climate neutrality policies pursued in relation to urban areas have a wider significance for the EU as a whole (European Commission, Urban development, n.d.).

Urban challenges are addressed on various policy levels, from local action to national urban policy frameworks, and global agendas. The European Union (EU) is relevant to this context, as it has consolidated a common integrated approach towards sustainable urban development over recent decades, thanks to milestones such as the Leipzig Charter of 2007 and its revision in 2020, and as well as the Urban Agenda for the EU launched by the Pact of Amsterdam in 2016. Moreover, EU's Cohesion Policy provides operational tools and funding to reinforce a common approach to sustainable urban development[5].

For the programming period 2014-2020 a large majority of the EC Sustainable Urban Development (SUD strategies included at least one of the following thematic objectives: 'Shift towards a low-carbon economy', 'Environment and resource efficiency', 'Climate change adaptation, risk prevention and management', and/or 'Sustainable transport and network infrastructures'. At the same time, keywords such as 'low carbon', 'air quality', 'climate adaptation' and 'circular economy' are often indicated to describe the strategy's main focal point(s) (see European Commission, STRAT-board, n.d.).

2.1 The building blocks for an integrated approach to climate neutrality

While there is no 'one size fits all' guidance on strategies to support climate neutrality in an integrated and sustainable way, **six main principles** can be highlighted. Even though these building blocks might have specific common challenges and pitfalls, they can support both the preparation and execution of integrated climate neutrality plans.[6]

1) For starters, when planning an urban strategy aimed at climate neutrality, it is crucial to bridge between (national and regional) programmes and local projects, as well as to create synergies with different policy frameworks. A strong **strategic dimension** can align goals and objectives. In this respect, special consideration must be given to the policy architecture, going from good design to good implementation (see sections 2.2 and 2.3 for further information). A guiding principle to strategic approach is the place-based one advocated in the Barca Report (2009). There are different tools designed to help the planning process, one of these is the URBACT Toolbox, tailored to address the different stages of strategic public action-planning.

2) Furthermore, strategies must have the appropriate **territorial focus**, whereas urban planning strategies that target climate neutrality can address areas that transcend administrative boundaries, focusing on the real spatial dimension of needs and opportunities. Choosing the implementation area is a policy decision, which can depend on policy agendas and available governance tools. The Functional Urban Area (FUA) approach is applicable to areas formed by multiple municipalities, where a specific interdependence (or function) occurs. It allows projects to maximise local potential, especially when it enhances a coherent mobilisation of urban actors, encouraging territorial democracy, and giving rise to new cooperation structures across municipal borders. A wider territorial focus can also be used to promote urban-rural linkages (e.g., labour market flows/commuting, public service provision, mobility, etc.) that blur the distinction between urban and rural, especially for small- and medium-sized cities and towns. For example, Gothenburg (SE) proposed an integrated territorial investment strategy where, under the Thematic Objective 'Low-carbon economy', urban-rural linkages are fostered through hubs to test innovative solutions and the Sustainable Food Strategy. The aim of integrating the targeted area into a larger context, and the project into a wider strategic framework, requires flexibility. In Berlin (DE) for instance the Future Initiative City District contributes to the Berlin 2030 strategy, building an overarching framework for neighbourhood regeneration strategies, and establishing five action areas with 'flexible' perimeters.

3) In addition, good **governance** arrangements contribute to more transparent, inclusive, responsive, and effective decision-making. Broadly speaking, governance refers to how the relevant authorities and stakeholders decide to plan, finance, and manage a specific strategy or plan. Three central components are: multi-level governance, the multi-stakeholder approach, and the bottom-up and participatory approach. The first component refers to the coordination and alignment of actions between different levels of government. The second deals with the inclusion of all relevant actors throughout the whole policy cycle (next to local, regional, national, and EU/supranational administrative bodies and agencies,

[5] Under EU cohesion policy, the European Urban Initiative will be set up in 2022 to offer coherent support to cities, including in the area of integrated sustainable urban development strategies.

[6] This section is largely derived from Fioretti et al., 2020.

governance arrangements may include a wide variety of actors and institutions, such as civil society, Non-Governmental Organisations (NGOs), academia, community-based organisations, social movements, steering groups, and the private sector). The last component concerns the active involvement of citizens through specific territorial instruments, as well as other alternative methods. With regard to citizen engagement, it is important to go beyond 'tokenism' and one-sided dialogue, enabling citizens to have a real say in the policies that will directly affect their lives. In this respect, public officials should recognise citizens' input as meaningful and complementary to the policy process (see Sections 2.2 and 7 below for further information). In short, urban planning strategies targeted at climate neutrality work best when all potential stakeholders including citizens are properly mapped and involved throughout the process. For example, Zagreb (HR) has ensured effective cooperation among many stakeholders by establishing a Partnership Council, comprised of all administrative levels, as well as other public bodies, universities, training and research centres, economic and social partners, businesses, and civil society, to support the preparation, development and implementation of its sustainably urban development strategy.[7]

4) Climate neutrality plans cannot be tackled using sectoral policies alone. The **cross-sectoral** approach aims at overcoming the traditional, so-called 'silo-structure', whereby different sectoral departments do not work effectively together. The goal of the cross-sectoral approach is to ensure coherence in policymaking principles and objectives across policy areas, and to ensure that actors cooperate in creating strategic policies. This approach helps to anticipate the possible negative externalities of one-dimensional policies at the local level, and it allows for multi-dimensional challenges to be tackled. Furthermore, cross-sectoral integration has the ability to boost innovation. A helpful resource to look at is JASPER – Joint Assistance to Support Projects in European Regions. To foster collaboration between different sectors, it is suggested to provide instruments such as pacts, meetings, and sharing moments to guarantee dialogue and to identify the different needs and capacities. Furthermore, joint administrative boards or intermediate management bodies can ease coordination. In addition, it is recommended to actively invest in capacity building in order to enhance officials' understanding of potential cross-sectoral synergies (see Sections 2.2, 2.3 and below for further information).

5) The combination of multiple **funding** sources, and the associated increase in the significance of **financial instruments**, are two long-established trends in urban strategic planning, including climate neutrality plans. The rationale behind the use of multiple funding sources is that this provides efficiency gains by exploiting synergies and mobilises a wider range of actors and resources. Multi-dimensionality of urban issues, such as the transition to climate neutrality and the use of multiple funds, should work hand in hand. The integration might concern ESI (European Structural and Investment) funds, with domestic funds, the involvement of private investors and the third sector. This implies the need to match the administrative requirements and target groups of different types of public funds, and requires that cities produce bankable projects in order to raise investors' interest. Organising projects and multiple funding sources in an 'Investment Programme' format allows local authorities to manage the project pipeline and state aid issues more flexibly, thus facilitating strategy implementation, and boosting investor confidence (please consult section 9 for further information). Athens in this sense offers an example of an integrated investment programme.

6) Finally, effective **monitoring** quantifies the progress of a specific policy, strengthening transparency and legitimacy. Urban planning strategies often require multi-sector monitoring, while also measuring the added effect of having an integrated approach. Key issues related to monitoring are: setting up a coherent and effective monitoring framework; measuring different types of effects; and aligning monitoring to different levels of objectives. In this respect, it is advised to always make sure the monitoring system follows the logical framework, moving from needs (what has to be addressed?), to specific objectives, (what is the desired change?), to indicators (how can this change be measured?). However, for many administrations, a lack of human capacity and/or methodological skills can be an issue. It is therefore recommended to consider collaboration with local/regional universities or research institutes and to explore the options for bringing in external expertise and stakeholders to support with the design of the monitoring framework. A Coruña's SUD strategy, for example, is monitored through an indicator system which measures the behaviour of the city in relation to its own objectives plus, among others, its alignment to the SDG (Sustainable Development Goals).

[7] For more information, see Fioretti et. al. 2020, p. 109.

Furthermore, it is advised to invest in cost-effective data-gathering procedures and methodologies. In this respect, it should be assessed how far data already collected by the city, regional, national or EU statistical sources can be used. Consider using a dashboard to support sharing and monitoring of data might offer an easy-to-read overview that shows current status and progress towards targets for the various indicators in a visual way. Rotterdam with its Social Index platform offers an example on this regard. If possible, the monitoring framework should be designed from a long-term perspective, whereas longitudinal data (repeated measurements over time) is key to high-quality monitoring.

Since high-quality monitoring provides timely information on progress, it allows for a quick identification of issues, and refocusing on priorities when needed. In this sense, monitoring systems are crucial 'early warning systems'. Monitoring also supports policy evaluation, by supplying policy-makers, stakeholders and beneficiaries with important information about effectiveness (see sections 2.4 for further information).

2.2 Governance and stakeholder engagement

Cities aiming to achieve climate neutrality will need strong collaboration across all municipal departments, elected officials and private/public sector stakeholders. Furthermore, the objective to become climate neutral will likely need to be the highest political priority to be realistically achievable. A formal and functional governance structure will also need to be established to lead these efforts with an agreed-upon, common vision. This should be the first task of any city taking on this challenge.

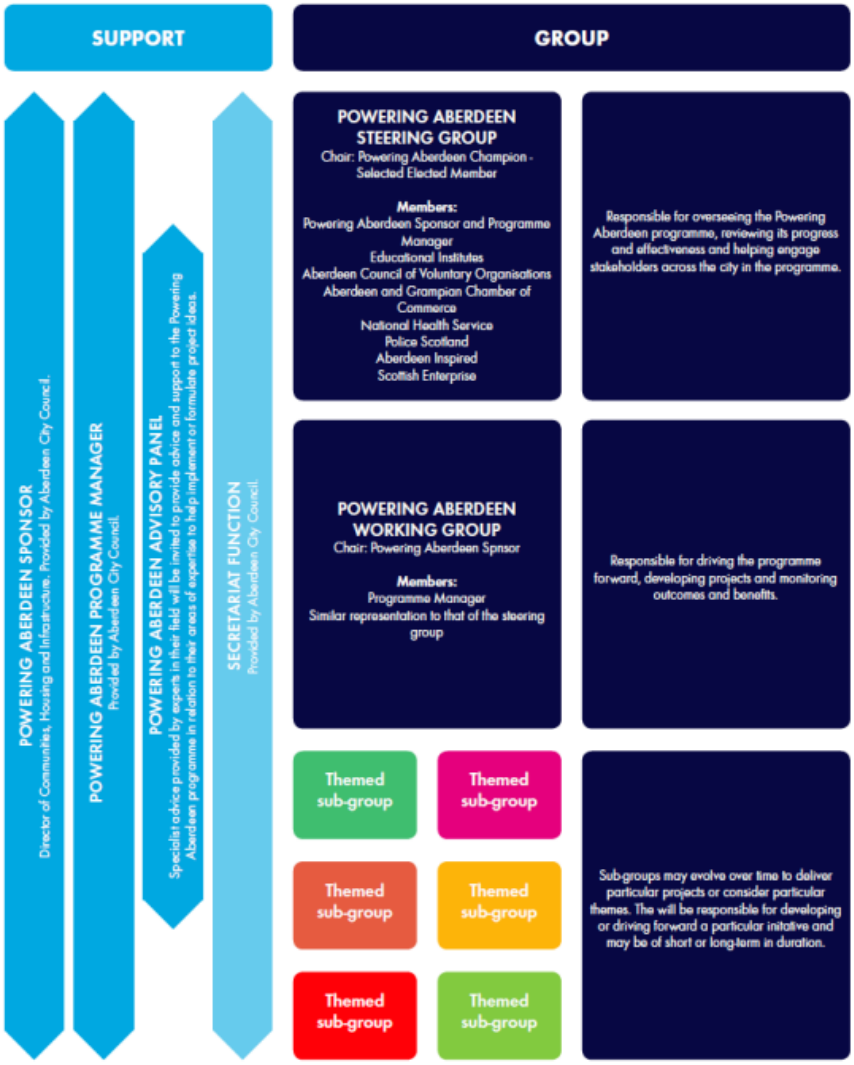
While the vision will necessarily need to incorporate the ambition for climate neutrality, it is recommended that it also include other more tangible benefits to the citizens of the city. For example, objectives around improved affordability of energy, reduced air pollution, enhanced green spaces or general improvements to the quality of life will improve the political sustainability of the vision, while also making it resonate more broadly with civil society.

The organisational structure to deliver climate neutrality should formalise the assignment of roles and responsibilities, comprising of the various departments of the municipality (and associated public and private partnerships where beneficial) to create an agreed-upon structure/process (for example using/augmenting organisational structures already developed for the Covenant of Mayors or other relevant initiatives where possible). Sufficient financial and human resources will need to be identified.

A **core team** is also recommended with overall responsibility for advancing climate action overall, in line with the agreed-upon timescales for delivery. To ensure diverse perspectives, it will be important that such core team includes personnel from different departments (i.e., environmental, finance, transport, planning, procurement, waste, etc.) and complementary competencies. The establishment of a dedicated **steering committee** (comprising elected officials and potentially other specific private/public sector representation) can offer value by providing strategic direction and to ensure continued political support for the process.

Cities have an important role in orchestrating the entire urban system to support climate neutrality with an inclusive approach from citizens to utilities, seeking opportunities for combining strategies whenever possible. Bringing stakeholders together and enabling cross-sector coordination across the various actors of the urban system will widen the scope for tackling the urban energy system and improve the chances of success. Mobilising city planners, building designers, public transport utilities, local energy utilities, water utilities, citizens, prosumers and many more with an inclusive approach is an essential component of a sustained, durable and far-reaching effort for climate neutrality. Co-designing strategies to operationalise implementation can also increase benefits for urban inhabitants, including employment opportunities and cleaner air, further accelerating the race for climate neutrality at the local and European levels. Cities that will champion climate neutrality under the Cities Mission will implement combined and reinforcing strategies in an integrated approach to advance the urban system to this ambitious target while pursuing multiple benefits for their citizens.

Figure 2. An example of a 'best practice' governance structure to deliver effective climate action



Source: Aberdeen City Council, 2016.

2.3 Climate Neutrality planning process

Once a governance structure and roles/responsibilities have been defined, the foundations are in place to develop a process and plan to achieve climate neutrality. This process should consider defining a baseline (i.e., a starting point), developing the various actions and policies to deliver the vision and then embarking upon a process of implementation while monitoring progress at regular intervals. A brief overview of a basic climate action planning/implementation process is provided in **Table 3**.

Table 3. A basic framework for effective climate action planning

1. Setting the vision

(a) Establish strong political engagement/consensus which informs the vision

(b) Consider how the vision can be communicated to citizens, including climate neutrality, but also improvements to quality of life, reduced energy costs etc.

(c) Incorporate non-climate related benefits (jobs, quality of life, air pollution, etc.)

2. Establish governance structure

(a) Create a governance structure which includes all relevant municipal departments, elected officials, private and public sector representation (see Section 2.2 above)

(b) Allocate specific roles and responsibilities and accountabilities to persons/departments/organisations

3. Baseline assessment & Climate neutrality target

(a) Select baseline year against which to measure progress

(b) Baseline GHG inventory – a baseline year and estimate of GHG emissions will be needed to establish the point of departure for this effort (if not already available)

(c) At least one additional GHG inventory for a recent year can be useful in assessing subsequent progress in reducing emissions (since the baseline year)

(d) Assess 'business-as-usual' scenario (i.e., GHG emissions in 2030 if no further action is taken) can be useful to determine the scale of emissions reductions required to achieve climate neutrality while accounting for population growth, increasing GDP etc. (see Section 2.5)

(e) An assessment of the targeted residual GHG emissions in 2030 (i.e., those emission sources which will not be eliminated) will be necessary to demonstrate the scale of Renewable Energy Certificates, carbon credits etc. which will be needed to demonstrate climate neutrality

4. Identify actions

(a) Consider actions for all sectors in consultation with all departments and stakeholders

(b) Consider actions which leverage existing national/regional/local policies/actions

(c) Evaluate the impact of the actions (e.g., energy savings, renewable energy produced, GHG emission savings, cost savings, job creation, etc.)

(d) Estimate the resources required to implement the actions identified and identify appropriate funding/financing

(e) Define the responsible organisation/department/person for implementing each action, as well as indicators to monitor progress

(f) Establish an indicative timetable for implementation of the actions, prioritising the most cost-effective

(g) Allocate the implementation of each action to an accountable person/organisation/department

5. Implementation

(a) Procure studies to implement actions where necessary (i.e., feasibility studies, technical studies and economic studies) to create 'bankable' projects

(b) Finalise financing / funding for implementation of actions

(c) Promote success stories regarding implemented actions

6. Monitoring / reassessing

(a) Track the indicators identified for each action (e.g., electric vehicle charging points installed)

(b) Update the GHG inventory every 2-4 years to monitor overall progress

(c) Interpret monitoring information to determine any necessary re-prioritisation of climate actions or renewing the climate action plan overall

(d) Report regularly to elected officials/steering committee on the progress and successes

Source: Own work.

2.4 GHG emissions accounting and target setting

It is anticipated that many cities expressing their interest to participate in the Mission will already have undertaken some level of due diligence/climate action planning (for example through the Covenant of Mayors) and thus will not be newcomers to the GHG inventory process. As such, the Mission encourages the use of existing GHG emission inventories for the purpose of baselining and will accommodate common existing practices for GHG emissions accounting in the course of Mission implementation, i.e., **cities will not need to adapt their practices, as long as all sectors and sources are accounted for.**

There are various GHG inventory methodologies available to guide a city's accounting of GHG emissions and demonstrate climate neutrality. For the purposes of the Mission, the methodology will be purposefully flexible to allow for use of inventories which cities may have already developed. For example, the EU CoM/SECAP approach, the GCoM Common Reporting Framework, or Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) would be acceptable methodologies, however other approaches will also be considered as long as the principal sources of GHG emission sources (stationary energy, transport, waste, IPPU and AFOLU) and sinks, if applicable, are included. Emissions from any EU Emissions Trading Scheme (EU ETS) should be excluded on the basis that municipalities have very limited influence over their operation and there is a dedicated EU process to reduce emissions from these sources.

The following GHGs should all be included in terms of carbon dioxide equivalent (CO_2e):

- Carbon Dioxide (CO_2)
- Methane (CH_4)
- Nitrous Oxide (N_2O)
- F-gases (hydrofluorocarbons and perfluorocarbons)
- Sulphur hexafluoride (SF_6) and
- Nitrogen trifluoride (NF_3).

Developing an accurate GHG inventory is a valuable process, however even with a diligent and robust process and data sources, exact calculations of real-world GHG emissions are notoriously difficult and subject to significant margins of error. As such, cities should try to achieve a reasonable level of due diligence, based on real world activity data, aligned on the same timeline (i.e., a calendar year) where possible. Where 'real world' data is difficult to collect/compile, proxy data or assumptions may be necessary. However, this proxy data (e.g., national or regional emissions) should only be used as a last resort as it can result in the loss of city-specific details. With the relatively short-–term nature of the Mission and the associated need for immediate and urgent climate action, cities should not delay their action planning processes on account of overly-detailed GHG inventory processes. An analysis of the key emission sectors is useful (i.e., stationary energy/buildings, on-road transport and waste generation/treatment); however, investing significant time and resources into understanding less prevalent sources of GHG emissions (i.e., off-road transport, waterborne navigation, etc.) may not be a beneficial use of time and will not be a requirement of the Mission. Cities should consider the sectors in which they intend to take action and ensure that estimates of GHG emissions for those sectors/sources are included so that progress can be tracked. Further detailed methodological guidance on this issue will be forthcoming and will ensure a balanced approach which will not require cities to invest significant time and resources into understanding less prevalent sources in detail. The basic parameters of a sufficiently detailed GHG inventory are provided in **Table 4**.

Table 4. The sources and sectors of GHG emissions which should be included in a city's GHG inventory for the purposes of the Mission.

	Direct emissions (Scope 1)	Indirect emissions (Scope 2)	Out-of-boundary emissions (Scope 3)
Buildings	Emissions from all buildings, facilities and permanent infrastructure / equipment (collectively referred to as 'stationary energy' and including public, private, residential and industrial sectors) within the city boundary (excluding EU ETS registered facilities)[3].	Emissions from outside the city boundary due to the use of grid-supplied energy (electricity or district heating/cooling) within the city boundary	Not applicable
Transport	Emissions from on-road and rail (as a minimum) transport within the city boundary[1], disaggregated by municipal fleet, public transport, private and commercial transport.	Emissions from outside the city boundary due to the use of grid-supplied electricity used to charge electric vehicles	Recommended by 2030
Waste	Emissions from waste generated and managed/sent to landfill within the city boundary.	Not applicable	Emissions from waste generated within the city boundary but managed/sent to landfill outside the city boundary.
IPPU	Emissions from GHGs used in, or as a by-product of industrial processes and products (if present / significant)[2]	Not applicable	Not applicable
AFOLU	Changes in GHG emissions from any changes in land use giving rise to (sources) or sequestering (sinks) emissions (if significant)[2]	Not applicable	Not applicable

[1] Emissions from other transport sub-sectors such as off-road transport, waterborne navigation, etc. should be included if significant. It should be noted however, that emissions associated with these sub-sectors will have to be abated by 2030.

[2] An emission source can be considered insignificant if the size of emissions is smaller than any other sub-sector that shall be reported. In addition, the combined emissions from all sources that are considered insignificant should not exceed 5% of total emissions that shall be reported. For example, if all the emissions sources that shall be reported amount to one million tonnes of CO_2e, the total emissions of all insignificant sources cannot exceed 5% of that, i.e., 50 000 tonnes of CO_2e. (see GCoM 2019)

[3] Considering that the shift from fossil fuels to biomass is often one of the first measures proposed by local authorities to achieve climate neutrality, it is important that biomass energy is associated with zero emissions only if the net gains are equal or superior to the net losses, meaning that the CO2 emissions to the atmosphere due to the end-user consumption are entirely compensated by the CO2 removal on the productive land, and that this has been certified.[8]

Source: Own work.

A climate neutrality target would typically be described as a fixed-level target, i.e., reduce, or control the increase of emissions to an absolute emissions level in a target year (e.g., net zero GHG emissions in 2030) (GPC, 2016).

[8] Article 29 of the Directive (EU) 2018/2001 (also known as Renewable Energy Directive or RED) lays down sustainability and greenhouse gas emissions saving criteria for biofuels, bioliquids and biomass fuels.

A climate neutrality target can, however, also be based on a base year emissions target (e.g., 90% GHG emissions reductions by 2030 compared to 2005 levels), as such explicitly acknowledging the level of residual emissions in the target year that will have to be offset (see Section 3.2). In this case, it is important to establish the base year emissions in a comparable manner. Another option is a target expressed as a certain level of per capita emissions per year, accounting for population change (i.e., a so-called base year intensity target).[9]

Box 3: Accounting for Scope 3 emissions – a possibility to go one step further

In addition to the GHG emissions that arise directly from within a city and those associated with energy used within the city, there are also a variety of emissions that occur outside a city's boundary, yet related to its activity and consumption. Some of the followings are examples of these other GHG emission sources:

— Transport occurring outside the city, but because of city activities (e.g., commuting to and from the city);

— Extraction/production of materials and products used/consumed in the city;

— Production, processing and transport of food and drinks consumed by citizens within the city;

— Fugitive emissions and transmission losses from energy being delivered to the city;

— Waste generated within the city, but managed outside the boundary.

These emission types are collectively referred to as 'Scope 3'. Under the framework of the Mission, **only Scope 3 emissions associated with waste disposal/management will be included** under the definition of climate neutrality (see **Table 2**). Other Scope 3 emissions (such as those listed above) are exempt. However, if cities working towards climate neutrality wish to account for and include other Scope 3 emissions at their own discretion, they are welcome to do so.

The Mission will re-evaluate the possibility of including other Scope 3 emission sources in the post-2030 era, when leading cities have achieved climate neutrality as currently defined.

2.5 Accounting for residual emissions

If cities have GHG emissions which cannot be fully mitigated by 2030 due to technological or financial constraints, those so-called residual emissions will have to be compensated.

There are two main ways for a city to deal with its residual emissions in order to reach net-zero GHG emissions in 2030:

— **Carbon sinks,** defined as any reservoir (natural or technological) which collects and stores CO_2 directly from the atmosphere, resulting in "negative emissions". Carbon sinks, i.e., removals through natural and technological solutions, within the city boundary can be used to account for any residual GHG emissions. There are two potential options for carbon sinks:

  - "Natural sinks" refer to the planting of trees or other conversion of land use. Carbon sinks should be accounted for as part of the 'AFOLU' sector of the GHG inventory. See Section 3.5 for more information on accounting for carbon sinks related to tree planting and other land use changes.
  - "Technological sinks", known as Biomass for Energy with Carbon Capture and Storage (BECCS) and Direct Air Carbon Dioxide Capture and Storage (DACCS) technologies, can be used to sequester CO_2 permanently (locked away in geological formations). See **Box 4** below for more information on Carbon Dioxide Removal (CDR) technologies.

— **Carbon Credits**, defined as a tradable certificate representing 1 tonne of CO_2 or CO_2e which can be traded where GHG emission surpluses and deficits exist. The use of Carbon Credits from outside the city's boundary to account for any residual emissions within the city boundary will be subject to certain rules and restrictions to be able to credibly demonstrate a city's climate neutrality (i.e., using formal credits/certificates verified and/or validated under rigorous standards by certified third-party auditors). These restrictions will aim to eliminate the possibility of 'double-counting' and ensure transparency and accountability. Carbon Credits should be focused on nearby projects where possible, within the

[9] Another possible target type would be a Baseline scenario target. Further information on target types can be found in GPC (2016) or GCoM (2019).

country or at least within the European Union and provide concrete additionality and co-benefits (see **Box 5** below).

Carbon Dioxide Removal (CDR) technologies such as BECCS and DACCS are not available at large scale to date, and they largely remain to be tested and proven as viable at a commercial scale. The extent to which Mission Cities can rely on this approach for dealing with residual emissions will therefore likely be very limited (likely to pilot projects at most). It is also necessary to follow precautionary principles related to the potential ecological and ethical impacts and risks of these technologies until further research and testing proves them to be effective and safe. C40 and the New York City Mayor's Office of Sustainability (2019) provide a useful definition and summary of principles that can be outlined to guide these considerations (see C40 & NYC Mayor's Office of Sustainability, 2019, pp. 43-45).

Box 4. Carbon Capture and Storage (CCS) Technologies leading to Carbon dioxide removal (CDR)

Bioenergy with carbon dioxide capture and storage (BECCS) refers to CCS applied to a bioenergy facility. BECCS involves the utilisation of biomass as an energy source, in combination with the capture and permanent storage of the CO_2 produced during the conversion of biomass to energy. Depending on the total emissions of the BECCS supply chain, with this technology CO2 can be removed from the atmosphere.

Direct Air Capture (DAC) is a technology which extracts CO_2 directly from the ambient air which is then either converted into a new product or stored within geological structures to be permanently sequestered. It is envisaged that DAC will play some role in stabilizing and reducing CO_2 levels in the medium to long-term, especially to offset GHG emissions from sources which are currently very difficult to eliminate (e.g., aviation, certain industrial processes), however the price per tonnes of CO_2 sequestered is currently prohibitively high for most applications. Nevertheless, cities will be permitted to utilise this technology within the scope of the Mission, as a carbon sink to account for any 'residual emissions'.

Only applications which result in permanent sequestration of the CO_2 (i.e., injected into geological structures) will be allowable.

It is important that for any offsetting activities undertaken by Mission Cities strict principles are applied. Useful guidance is already available, including from C40 (2019) and the University of Oxford (2020). C40's guidance on defining carbon neutrality for cities & managing residual emissions addresses all important aspects around using carbon credits, including environmental integrity principles. A brief summary is presented in **Box 5** below. The Oxford Principles for Net Zero Aligned Carbon Offsetting (the "Oxford Offsetting Principles"), targeted at companies, organisations, cities, regions and financial institutions, present an outline on how offsetting needs to be approached to ensure that it helps achieve a net zero society.

Box 5. Environmental integrity principles for carbon credit projects (short CCP)

Real	absolute net reductions of citywide GHG emissions because of actual project activity
Additional	CCPs would not have been realised without the city's investment (or investment by another entity on behalf of the city) (note: the city can purchase carbon credits)
Permanent	CCPs should be irreversible and continuously monitored
Measurable	CCPs must have the ability to be verified in a scientifically credible way and accurately quantified
Independently audited	CCPs must be verified by an independent, qualified, third-party verifier subject to an established accreditation system
Unambiguously owned	CCPs must have clear documentation of ownership rights, maintained on a secure registry, with no more than one credit associated with a unit of GHG emission avoidance or sequestration
Transparent	CCPs and their associated ID number must be publicly and transparently registered
Address leakage	CCPs must account for and avoid potential leakages over the life of a project

Source: C40 (2019), p. 34 ff.

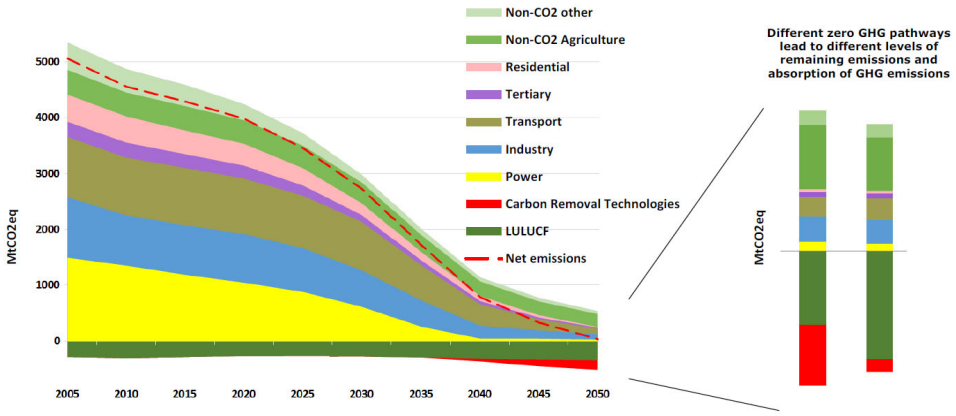
The separate reporting of gross and net emissions will ensure transparency regarding residual emissions cancelled out through offsetting mechanisms. Gross emissions will include all relevant emissions in all covered sectors without taking into account GHG emission reductions from carbon sinks and credits. The net emissions are calculated by deducting from the gross emissions, GHG emissions reductions from carbon sinks and carbon credits from projects outside the city's GHG inventory boundary, and adding GHG emissions from carbon credits sold from within the city's GHG inventory boundary.

The reporting of net emissions will allow to track the progress of participating cities towards achieving their climate neutrality goal. As described above, once all carbon sinks and if applicable carbon credits are accounted for, they should at least match the residual emissions from those GHG sources which are not viable to eliminate by 2030.

2.6 GHG emissions roadmaps

An optional 'extension' of the GHG inventory is to develop a GHG emissions 'roadmap'. This is a useful tool for cities to understand historic, current and projected GHG emissions in their territory and can help communicate the overall nature of a climate action plan. This type of analysis and graphic (see **Figure 3**) demonstrates the scale of GHG emission reduction required in each sector while also acting as a common vision for the municipal staff, elected officials and citizenry. This type of analysis can also assist in developing a 'Carbon Budget' type approach, whereby cities set declining limits on the level of permissible emissions from each sector. These types of approach help link the efforts of the various stakeholders/departments (e.g., energy, transport, planning) and can help allocate responsibility for implementation of the policies and actions required to achieve climate neutrality.

Figure 3. GHG emissions trajectory in a 1.5°C scenario.
Bars represent emissions in the two scenarios reaching net zero emissions in 2050.



Source: European Commission, 2108b.

3 Key sectors and strategies for reducing emissions (demand side)

3.1 Stationary energy (buildings, equipment, facilities)

3.1.1 The scope of the buildings sector

The 'buildings sector' includes all permanent and temporary structures, facilities or equipment and public lighting within the city's boundary. This will include the residential, commercial, industrial and municipal/public buildings and facilities. The type of impact a municipality has on the energy consumption/GHG emissions of these building types obviously varies, with direct control over municipally -owned buildings/facilities and influence of other building types (i.e., through behavioural campaigns, regulatory measures, financial incentives, etc.).

3.1.2 Definition of 'climate neutral' for the buildings sector

In the context of buildings, climate neutral would mean having no combustion of any fossil fuels associated with heating/cooling buildings, while there are also zero emissions arising as a result of the consumption of grid-supplied electricity and/or district heating/cooling (i.e., emission factors for electricity and district heating/cooling of 0 tCO_2e/MWh).

As described in Section 3.2 above, for any residual emission sources in buildings (i.e., for which achieving zero emissions is not feasible) the net emissions must be offset. Embodied energy/emissions associated with the construction, materials, etc. of buildings is not included as an emissions source in the context of the Mission.

3.1.3 Achieving Climate Neutrality in the stationary energy sector

EU-wide, buildings account for 40% of energy consumption and 36% of GHG emissions (European Commission, 14 October 2021) and thus will be a highly significant portion of any city's action in eliminating GHG emissions. Reaching net-zero emissions in this sector will require a combination of:

- deep renovations of the existing building stock;
- construction of high energy performance / net zero energy for all new buildings;
- eliminating point of use fossil fuel heating/cooling through fuel switching (to electricity) or district heating/cooling; and,
- supplying buildings with zero-carbon sources of electricity and district heating/cooling (covered in Section 4.4).

Only through a robust combination of efforts and investment in these aspects can net-zero buildings be achieved. Fortunately, the EU has a suite of regulatory, financing, and enabling measures which can support these transitions. The Energy Performance of Buildings Directive (EPBD), the Energy Efficiency Directive (EED) and the Renewable Energy Directive (RED) established a package of measures which create the conditions for significant improvements in the energy performance of buildings across Europe. With the advent of the EU Green Deal and the 'Renovation Wave' initiative, and the Fit for 55 – Delivering the European Green Deal package, these conditions are further enhanced to accelerate the action and investment needed.

Currently, primary energy consumption in the EU building stock is reducing at a rate of about 1% per year (Ipsos Belgium, 2019), meaning most cities wishing to reach carbon neutrality by 2030 will require a significant increase in 'deep energy renovation' rates to be able to manage building energy demand. Any residual energy consumption will need to be met by renewable energy sources (electricity and district heating/cooling). Energy scenarios currently indicate that the share of renewable electricity for the EU28 Member States ranges from 48% to 70% by 2050, compared to 31% currently (Tsiropoulous et al., 2020), so – much like energy renovation rates, cities will need to upscale local renewable energy generation and/or increase the purchase of certified green electricity to meet the objectives of the Mission.

With rising annual mean and summer peak temperatures occurring across many European cities, we can also anticipate an increase in annual energy consumption and peak summer demand associated with cooling. Managing this additional load through the deployment/enforcement of minimum energy performance requirements of cooling technologies and installing renewable energy sources (e.g., photovoltaics) to provide the additional electricity anticipated will be key to ensuring no additional GHG emissions arise on account of additional cooling requirements.

3.1.4 Deep Renovations of the Existing Building Stock

35% of the current EU building stock is more than 50 years old (Zangheri et al., 2021) and relatively energy inefficient which offers huge potential for improvement. However, on average only 1% of residential buildings currently undergo energy -efficient renovation every year and the annual amount rate of deep renovations is only around 0.2% (Ipsos Belgium, 2019). While the EU 'Renovation Wave' aims to double the rate of renovations in the next 10 years, more ambitious agendas will need to be conceived by cities aiming to reach climate neutrality by 2030.

Of those renovations that have been undertaken across the EU, most are '-step-by-step' (i.e., minor incremental renovations, not entire-building overhauls) with little primary energy savings (Ipsos Belgium, 2019). 'Light' and 'medium' renovations with favourable cost/benefit ratios are more prevalent than 'deep' renovations meaning that typically, only marginal energy savings are achieved. Average primary energy savings per residential

renovation between 2012 and 2016 were about 9%, while savings for non-residential renovations were 17% (Ipsos Belgium, 2019).

Thus, cities will need to find ways to encourage/enforce/implement 'deep' energy renovations to make a significant difference in energy consumption and resulting emissions from buildings in the long-term. This type of renovation typically faces economic barriers which need to be addressed by cities. For buildings/facilities owned and managed by the cities, this can be relatively straightforward and either delivered directly or in partnership with the private sector (e.g., ESCOs and EPCs). For other buildings/facilities in the residential and commercial sector, the city will need to use its influence through financial incentives, bylaws, technical assistance, one-stop-shops for building renovations and other innovative financing mechanisms to drive the level of renovation needed.

For a city to fund a significant upscale in energy renovations, it is likely that it will have to implement a range of traditional and non-traditional/innovative sources of financing ([10]). Some of the options are as follows (Bertoldi et al., 2021):

— *Traditional and well-established:*
  - Grants and subsidies
  - Tax incentives
  - Loans

— *Tested and growing:*
  - Energy Efficiency Obligations
  - Energy Services Companies (ESCO) and Energy Performance Contracting (EPC)
  - Energy Services Agreement (ESA)

— *New and innovative:*
  - On-bill finance (OBF)
  - Property Assessed Clean Energy (PACE) financing
  - Energy Efficient Mortgages
  - Energy Efficiency Feed-in Tariffs
  - Incremental property taxation
  - One-stop Shops
  - Crowdfunding

A list of the types of action/intervention to deliver energy efficiency renovations/improvements to a city's existing building stock/facilities is provided in **Table 5**.

Box 6: Bottlenecks until proven otherwise: the case of historical buildings and energy renovation

Historic buildings are the trademark of numerous European cities. However, the level of energy inefficiency is contributing to a significant percentage of GHG emissions (www.3encult.eu). Improving the energy performance of historic districts and their buildings is a balancing exercise between retaining their heritage significance and allowing the installation of retrofit measures, which requires juggling typically competing requirements (i.e., indoor comfort and materials conservation, energy savings and architectonic character of the building). Critical aspects are compatibility, reversibility and invasiveness.

Because of the additional challenges and the significant opportunities for reducing primary energy consumption, historical buildings have ushered in dedicated R&I lines, including a number of EU projects. Representative examples are:

— EFFESUS (cordis.europa.eu/project/id/314678) the project examined three retrofit measures (Eriksson et al., 2014):

[10] A detailed description of the financing options available for cities trying to implement energy efficiency policies is available in Section 9.

1. improvements in the thermal performance of the building fabric and technical building services;

2. improvements in the energy management of buildings;

3. decarbonisation of the energy supply through energy generation from renewable sources, be they retrofitted to individual or groups of buildings, or installed as neighbourhood or district systems (Interreg Europe, 2020).

— 3ENCULT (www.3encult.eu): the project demonstrates the feasibility of "Factor 4" to "Factor 10" reduction in energy demand, depending on the case and the heritage value of the building by following a multidisciplinary approach (Troi, 2016). Targets include air quality, visual and thermal comfort; building types include schools, museums and residential buildings; strategies include airtight and isolating windows, repaired thermal bridges, low-temperature heating systems, and daylight optimization.

— VIOLET (www.interregeurope.eu/violet): the project identifies good renovation practices from across Europe for enhancing energy efficiency in heritage buildings, developing action plans, and improving regional policies and European Regional Development Fund policy instruments. Enabling outcomes include calculation models for mapping the sustainability of a building in combination with its historical value, and guidelines for using local resources to improve energy performance and comfort (Interreg Europe, 2020).

— RIBuild (https://cordis.europa.eu/project/id/637268): the project focuses on internal thermal insulation, perhaps the most difficult retrofitting measure of historic buildings. Enabling outcomes include:

1. knowledge on how and under what conditions internal thermal insulation can be implemented in historic buildings, without compromising their architectural and cultural value, without risk of mould growth, and with an acceptable safety level against deterioration and collapse of heavy external wall structures;

2. web-based tools applicable to historic buildings all over Europe (Cordis, 2020) and inclusive of stochastic life cycle assessment and costing capabilities (Baldoni et al., 2021).

Additional challenges arise in case of privately owned and multi-property historical buildings, for which specific considerations should be contemplated (Sharing Cities, 2020). In this variegated mix of challenges, conservation of historic buildings and climate protection are not antagonists: historic buildings will only survive if maintained as living spaces, hence cities are encouraged to step up for a fully-fledged renovation of the building stock to ultimately protect the living symbols of Europe's rich cultural heritage and strong national identity.

3.1.5 New Construction

Owing to the existence of the EU Nearly Zero Energy Buildings (NZEB) initiative ([11]), the energy performance of new buildings is now mandated across Europe. All new buildings must be NZEB from 2021, while new public buildings have needed to be NZEB since 2018. While there are various conditions applied to the NZEB by Member States – using nearly zero-energy buildings national plans (European Commission, 2018a), the energy performance of new buildings across the EU is now reliably high. Use of renewable energy to supply any remaining demand (not met by energy efficiency) is now a common theme for NZEBs implementation. In addition, the prominence of 'Positive Energy Buildings' (PEBs[12]), Zero Carbon Buildings (ZCBs[13]), and Zero Energy Districts (ZEDs[14]) is increasing.

Based on the above, little action is required from cities other than enforcing these requirements as needed. Master planning and strategic decisions on the replacement of old, energy inefficient building stock with new buildings (i.e., brownfield redevelopment) can maximise the net energy/emissions impact of building turnover.

3.1.6 Building Electrification

Eliminating 'point-of-use' fossil fuel heating from all buildings will need to be a key pillar of any city's strategy to achieving eliminating GHG emissions. Currently, 75% of heating in the EU is provided by point-of-use fossil

[11] Nearly Zero Energy Buildings is the minimum energy performance level in Europe for all new buildings from 2021. An NZEB is defined as a building with high energy performance, where the minimal energy demand should be covered by renewable energy sources, produced on-site or nearby.

[12] Positive Energy Buildings are those buildings producing electricity, covering their heating and cooling needs and contributing to the grid stability or putting it differently, those with a negative net energy consumption over a typical year.

[13] Zero Carbon Building are buildings with net zero carbon emissions over the course of one year.

[14] A Zero Energy District is constituted by a group of buildings with a goal of achieving zero or positive energy, where residual energy demand is met through the use of renewable energy.

fuel combustion (Kavvadias et al., 2019). Conversion from boilers, furnaces, etc. to new technologies (i.e., heat pumps) offers a dual benefit, both improving the efficiency of heat generation and eliminating direct GHG emissions from the point of use (thus also improving local air quality). Generally speaking (depending on the current emission factor for grid electricity), this will already relate to a reduction in GHG emissions in most Member States, and as electrical grids continue to decarbonise, even more significant reductions will be realised. Current heat electrification rates across Member states range from 3% to 32% (Kavvadias et al., 2019).

It is estimated that cities with a large proportion of decentralized fossil-fuelled heating could reduce GHG emissions by 10–15% through heat pump deployment alone, with an additional 8% if heat pump demand is met by carbon-neutral electricity (Thomassen, 2021). In some cases – especially where the carbon intensity of electricity remains high, heat pump deployment can be costly in the range of between 200 and 300 EUR/tCO_2. Decarbonising electrical grids improves the cost/benefit of heat pump as a mitigation measure.

Table 5. Municipal actions for the buildings sector

Action Family	Example actions	Description	Links to case studies
Bylaws	Renovation permits	Bylaws on energy performance can be used by cities to leverage codes set by higher levels of government	Helsinki, FI
	Planning requirements for new construction	Bylaws enhancing requirements for energy efficiency/renewable energy for new buildings	Boffalora Sopra Ticino, IT
	Building electrification	Bylaws for electrification of appliances during renovation/construction	
	Energy audits	Mandated energy audits for certain commercial/industrial building types/sizes	Bolbaite, ES
Reducing energy consumption / emissions from public buildings / facilities	Energy audits and renovations	Conducting energy audits and retrofits of publicly-owned buildings	Murcia, ES
	Energy Performance Contracting	Appoint ESCO to undertake energy efficiency/renewable energy projects	Vantaa, FI
	LED street lighting	Conversion of public street and other outdoor lighting from traditional sodium to LED technologies	Ostrava, CZ
Influencing behaviour change	Fund energy audits / retro-commissioning	Incentivising / funding energy audits (and retro-commissioning of building management systems) for commercial / residential buildings as a service	Gijón, ES Rubí, ES Vedelago, IT

Action Family	Example actions	Description	Links to case studies
	Information campaigns / incentives	Encouraging building energy retrofits / renovations and behaviours to minimise energy consumption / boost renewable energy generation	City of Slagelse (DK) Case Study (pg. 32-33)
Fiscal mechanisms	Loans	Interest free loans, on-bill financing, etc.	Bree, BE
	Incentives	Incentives -to improve the energy rating of residential and tertiary buildings	A Guarda, ES
	Grants	Providing grants to homeowners / private sector to implement energy efficiency / renewable energy actions	Neerpelt, BE Grand Lyon, FR Warsaw, PL Energy renovation grants Brussels

Source: Own work.

3.2 Transport

3.2.1 The scope of the transport sector

The transport sector includes all mobility-related activity within the city. The vast majority of emissions from this sector are typically from on-road transport, but other sources include waterborne navigation, rail, air transport and off-road transport. For rail, air and waterborne navigation, journeys fully confined within the city boundary (origin and destination) need to be considered. Reporting and addressing the in-boundary components of regional or international journeys, such as the landing and taking-off (LTO) components of regional or international flights should also be accounted for. This sector covers all transport typologies from private transportation (including commercial) to public services. The city is responsible for all traffic regulation and transport infrastructure within the city boundary, exerting a critical influence in transport management.

3.2.2 Definition of climate neutrality for the transport sector

Cars, trucks, buses, vans and mopeds, mobile equipment and machinery produce GHG emissions directly by combusting fuel or indirectly by consuming electricity delivered via the grid (to charge electric vehicles). Hence within the transport sector, climate neutrality is achieved by reducing to zero all emissions from the combustion of traditional fossil fuels in transport activities as well as indirect emissions from primary energy sources (e.g., electricity generation) or emissions from the production process of alternative clean fuels (e.g., hydrogen).

From an emissions accounting perspective, emissions associated with vehicles manufacturing (unless taking place within the territory of the city) would fall under so called Scope 3 or out-of-boundary emissions and are currently not included in the context of the present Mission until 2030.

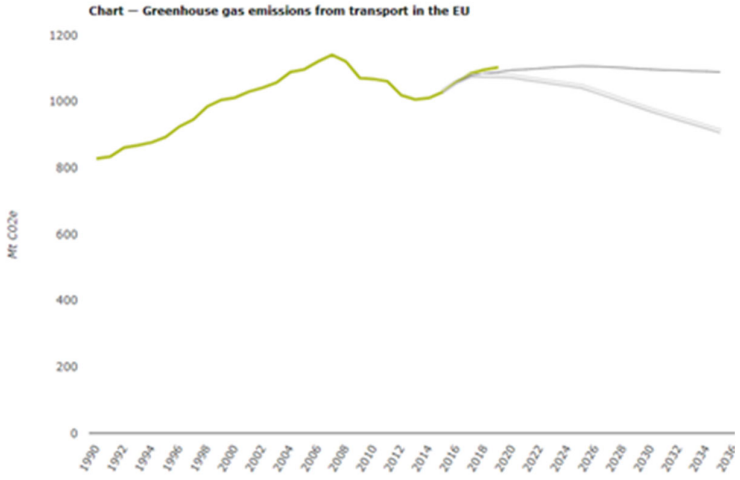
3.2.3 GHG emissions from the transport sector – Current situation

Reducing GHG emissions from the transport sector has a central role in the European Commission's strategy against climate change. As part of the long-term strategy in the transport sector, the White Paper on transport (European Commission, 2011) already established in 2011 an ambitious 60% emission reduction target for the transport sector (for year 2050 compared to 1990). The European Green Deal significantly raised the ambition by setting a 90% reduction GHG emissions reduction target for transport by 2050. In this context, the Communication on Sustainable and Smart Mobility Strategy (European Commission, COM(2020)789) identified the main actions needed in order to achieve this target. Coherent action is needed at all levels with cities playing

an important role in reversing the trend observable in recent years. The strategy aims to develop a transport sector is fit for a clean, digital and modern economy. The objectives include increasing the uptake of zero-emission vehicles, making sustainable alternative solutions available to the public & businesses, supporting digitalisation & automation, and improving connectivity & access.

According to the European Environment Agency (European Environment Agency, 13 April 2021) the domestic transport sector was in 2019 the second largest contributor to European GHG emissions in 2019 (22.98%) with on-road transport contributing to the vast majority of the emissions (95%). In contrast to the general decreasing emissions trend in the EU, transport-related GHG emissions increased in 2018 and 2019. National projections compiled by the EEA suggest that transport emissions in 2030 will remain above 1990 levels, even with measures currently planned in Member States. Further and more ambitious action is needed particularly for on-road transport.

Figure 4. GHG emissions from transport in the EU (EU-27).

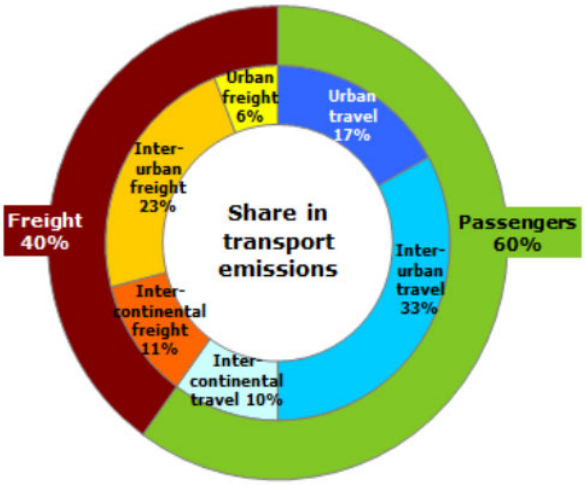


Source: European Environment Agency, 18 December 2020.

The European Commission, in its call to action on urban logistics (European Commission, 2013), identified that about 23% of transport emissions in the EU are attributable to transport in urban areas. Urban mobility represents 17% of the total volume of passenger transport and urban freight is the equivalent of 6% of the total freight activity.

These figures and the projected trends suggest that the transport sector is unlikely to reach the emission reductions needed to achieve the updated EU targets for 2030 (or climate neutrality by 2050) without a step change in urban mobility policy. To that effect, the Commission will come forward with a revised Urban Mobility framework in December 2021.

Figure 5. CO_2 emissions from transport in the EU.



Source: European Commission, 2013.

The ex-post evaluation of the impact of the 2013 Urban Mobility Package in the promotion of cleaner and more sustainable urban transport suggests that significant opportunities remain untapped in pursuit of more sustainable modes of urban transport and that further action is necessary (European Commission, Evaluation of the 2013 Urban Mobility Package SWD/2021/0047 final). Building on and upscaling proven solutions, the Mission Cities will showcase how this transition can be achieved.

3.2.4 Achieving climate neutrality in the urban transport sector

Cities can refer to the main European policy frameworks to set the vision for their climate neutrality transport actions. The European strategy towards more sustainable urban transport and decarbonisation is primarily laid out in the European Green Deal (European Commission, Transport and the Green Deal), mainly through the Sustainable and Smart Mobility Strategy (European Commission, 2020a). In this strategy, cities are identified as key players to reduce transport-related GHG emissions.

The Sustainable and Smart Mobility Strategy sets a number of goals and identifies key areas of action that have different implications for cities. Measures include boosting the uptake of zero-emission vehicles and renewable/low-carbon fuels and related infrastructure; making urban mobility healthy and sustainable (for instance by developing extra cycling infrastructure over the next 10 years); and greening freight transport.

On a similar theme, the Clean Vehicles Directive (Directive (EU) 2019/1161) is one of the main European legislative initiatives addressing urban transport, aiming to provide a framework to increase demand and encourage the deployment of clean vehicles.[15]

To ensure the progressive adoption of zero emission buses, the European Commission has established national targets on the minimum percentage of clean vehicles for the aggregate public procurement across a Member State. In the case of clean buses, at least half of the procurement target should be met in each period through the procurement of zero-emission buses. In the case of light duty vehicles (cars and vans), the targets for MS range from 17.6% to 38.5%. These targets should be met in two reference periods ending in 2025 and in 2030. The Member States are given the flexibility to distribute the efforts across their territory depending on the characteristics of the territories and according to their transport policy framework. Local authorities are encouraged to focus their efforts in areas specially affected by air and noise pollution and to ensure that the financial effort that is required to decarbonize the public fleet does not result in an increase in the prices or a reduction in the availability of public transport. In this regard, it is highlighted that promoting the use of clean

[15] The definition of clean vehicle depends on the nature and purpose of the vehicle. Light-duty vehicles (passenger cars or vans) are considered as clean when they emit no more than 50g/km CO_2 and up to 80% of applicable real driving emission (RDE) limits for NOx and PN (Particulate Number). In the case of heave-duty vehicles any truck or bus that uses hydrogen, battery electric (including plug-in hybrids), natural gas (both CNG and LNG, including biomethane), liquid biofuels, synthetic and paraffinic fuels, LPG, as energy carrier is considered as clean.

vehicles should always be accompanied by the improvement and development of public transport service, planning, availability and connectivity with other modes.

To maximise the impact of these investments, Member States are highly encouraged to promote and support the elaboration of Sustainable Urban Mobility Plan (SUMPs) for local authorities. These plans address major areas of urban mobility such as pollution, road deaths, or climate change in the context of the entire functional urban area, providing solutions for the main challenges and cooperation across the different institutions and stakeholders. In addition, SUMPs represent a useful reference for the assessment of city transport initiatives, from the evaluation of the best roadmap to follow in order to improve mobility within the city to the understanding of how the implementation of these actions is improving the city mobility landscape. Mission Cities can and should make their SUMPs an integral part of their Climate City Contracts (see Part I of this document, Section 1.2 above).

The deployment of clean vehicles goes hand in hand with the deployment of relevant infrastructure. In this respect it is worth mentioning the Alternative Fuel Infrastructure Directive, adopted in 2014, that requires Member States to put in place national policy frameworks for the development of markets for alternative fuels and the deployment of relevant infrastructure. The provision in the EPBD aimed to ensure that residential and non-residential buildings' car parks are progressively equipped with recharging points for electric vehicles is also relevant.

While the overall goal is to reduce the total CO2 emissions from urban transport, there are several partial objectives that can be combined in order to achieve an ambitious reduction target:

- From the technological side, shifting fuel consumption from conventional technologies to carbon-free or carbon neutral options would result in direct emission reductions. Examples include electric vehicles (but also tramways, trolleybuses and suburban trains), hydrogen and fuel cells or synthetic fuels, as long as the energy required for the production of electricity or alternative fuels is itself of low carbon content.
- For public transport, a transition to fully carbon-neutral busses and urban trains (while improving the quality of service) could provide an alternative to passenger cars, while contributing to the reduction of CO2 emissions.
- Legislative measures, such as the constitution of Zero Emission Zones, can drastically limit the access of internal combustion vehicles to urban areas.
- The promotion of public transport, cycling and walking can accelerate modal shift to cleaner modes, with additional benefits in terms of health, congestion, accidents, and noise. Ensuring appropriate cycling infrastructure and lowering speed limits will enable more people to travel and commute by bike.
- For urban freight, green last mile delivery options are available, including distribution by electric vans or cargo bikes.
- New technologies and business models such as telework, online shopping, e-health can decrease the total number of trips and bring significant savings in terms of emissions.
- In a similar fashion, emerging solutions in the fields of micromobility and Mobility as a Service (MaaS) can – under certain conditions – reduce the carbon footprint of mobility and stimulate innovation.
- New technologies or business models for urban mobility can also help shift demand to options with a lower carbon footprint. For example, applications allowing the shared use of bicycles, electric cars or electric mopeds can provide solutions for many mobility needs and help avoid the need for car ownership.

The integration and interaction of land use and transport planning can influence the use of private transport, hence GHG emissions, in existing and planned development. The urban form of a city has a direct effect on which measures would be more effective to achieve climate neutrality. A city's compactness and population distribution influence the potential for the development of a sustainable public transport network. Planning future urban development taking into account public transport needs (i.e., Transit Oriented Development, TOD[16]) can ensure that mass transit solutions have the critical mass required to provide an alternative to car use. Improving the walkability and providing safe and segregated cycle lanes in a city can encourage more active

[16] Transit Oriented Development (TOD) concept as originally explored by Calthorpe (1993): "mixed-use community within an average of 2,000 foot walking distance of a transit stop and core commercial area. TODs mix residential, retail, office, open space, and public uses in a walkable environment, making it convenient for residents and employees to travel by transit, bicycle, foot, or car."

transport. It is important to design decarbonisation policies that are coherent with the diverse city typologies. Local authorities should be aware of commuters coming every day from residential areas located outside of the administrative boundaries in order to coordinate the decarbonisation measures with the surrounding local administrations and propose alternative travel means while working with employers to incentivise new behaviours.

Table 6. Main action families in urban mobility

Example actions	Description	Case studies
Active mobility		
Promoting walking and cycling	Vehicles access restrictions within the city centre, on-street parking spaces removal, increase of pedestrian zones and bike lanes	Oslo, Norway.
Public Transport (PT)		
Increase frequency and reliability of PT	Introduction of high-frequency, low-emission bus lines reduce pollution and congestion	Funchal, Portugal.
Improve public perception of PT	Communication campaigns to improve the opinion of citizens on public transport reliability and safety	Gdansk, Poland.
Free passenger transport	Exploring the benefits and disadvantages of fare-free passenger transport	Luxemburg, Hasselt, Dunkirk, Tallin
Shared mobility		
Carpooling integration in the public transport authority	Integration of carpooling to increase private car occupancy to business areas	Tolouse, France. Craiova, Romania
Autonomous buses	Connections between urban and peri-urban districts by electric autonomous buses	Aalborg, Denmark.
Private Transport		
Zero Emission Vehicles (electric)	Electric recharging network for Electric Vehicles	Stockholm, Sweden
Zero emission vehicles (H2)	Development of hydrogen-based solutions (network of refuelling stations)	Germany
Collaboration/ Transport coordination		

Example actions	Description	Case studies
Transport plan	Plan to improve citizens' health and promote active modes	London, UK
Mobility management	Coordination with employers to optimize workplace related mobility	Amsterdam, The Netherlands.
Urban Planning		
Superblocks	Limitation of non-local traffic in residential areas combined with traffic calming methods within groups of residential blocks and adding new, green streets	Barcelona, Spain
Sustainable transport infrastructures required to emit new building licenses	New buildings and urban areas in the city should ensure that they are reachable by clean modes of transport	
Vehicle access regulation	Implementation of a congestion charging zone	Stockholm, Sweden.
Urban logistics		
Clean and efficient urban freight logistics	Consolidation centre with electric vehicles and local regulations for clean urban freight logistics	Madrid, Spain https://civitas.eu/mobility-solutions/consolidation-centre-with-electric-vehicles-and-local-regulations-for-clean
Micro depot	Micro-logistics approach to urban freight distribution	Frankfurt, Germany.
Use of cargo bikes	Promote and subsidize the purchase of cargo bikes by delivering companies to provide last-mile delivery within the city.	Berlin, Germany. Large-scale introduction of cargo-bikes in Europe
Urban lockers	Drop-off points facility helping to avoid failed deliveries and distribution in rush hours	Berlin, Germany.

Source: Own work.

3.3 Waste

Waste and wastewater management is a critical part of a fully-fledged climate neutrality strategy, required to deal with GHG emissions associated with the disposal and treatment of waste and wastewater generated within the city boundary. The actions in this sector will need to aim at preventing or minimising the generation of waste and the adverse impacts from the collection, recovery, disposal and treatment of waste and wastewater. GHG emissions in this sector particularly arise from

- on-site energy use within the waste and wastewater facilities (e.g., electricity used for pumping, natural gas for heating, etc.)[17];
- energy used for transporting waste to and from the facilities (e.g., diesel used in waste collection vehicles) as well as off-road vehicles operating within the facilities[18];
- the decay of solid waste and anaerobic degradation of wastewater in the facilities.

In terms of waste management, strategic planning to achieve climate neutrality by 2030 will require identifying the quantity of waste generated (categorised by different types of generation) as well as efficient treatment pathways (how and where it is treated). This affects the composition of waste, the type and quantity of GHGs emitted and the amount of air pollutants released to the atmosphere associated with any waste-related activity. For instance, disposal of solid waste is a major source of methane, whose contribution to the annual global anthropogenic GHG emissions amounts to 3 to 4 % (Pipatti et al., 2006) and lasts for several decades after disposal. Additional emissions include biogenic CO_2 and smaller amounts of nitrous oxide as well as other non-methane volatile organic compounds, nitrogen oxides and carbon monoxide (GCoM, 2019). The climate-altering potential also depends on whether solid waste is disposed of at managed sites (e.g., sanitary landfill and managed dumps) or unmanaged sites (e.g., open dumps, including aboveground piles, holes in the ground and dumping into natural features such as ravines). Beyond solid waste disposal, other waste sub-sectors are expected to participate in the climate neutral transformative process:

- biological treatment of waste, including composting and anaerobic digestion of organic waste;
- waste burning in controlled, industrial process (incineration) as well as open burning;
- wastewater discharge into an open body of water or its treatment (either aerobic or anaerobic).

Municipal solid waste generation in Europe ranges between 280 and 844 kg per capita (Eurostat, 2021) with numerous cities engaging in ways of preventing, minimising, recycling and managing waste while making progress towards zero waste targets when applicable. Avoidance measures and recovery of waste (i.e., as secondary materials or energy) are powerful means of achieving net-zero GHG emissions from the treatment of waste generated within the city boundary (C40 and NYC Mayor's Office of Sustainability, 2019; Stavrakaki & Papadopoulou, 2021). Waste (including by-products of waste disposal and treatment, such as landfill gas, biogas, and sludge) can be used to generate energy, to be grid-connected or consumed on-site. Waste heat can be used for district heating and other recovery systems. Waste can be avoided through behavioural changes that privilege the "reusable" instead of the "one-way" (e.g., reusable crockery, edible materials to serve food and drinks, paper bags), through smart management systems (for example based on bins' volume, to optimize collection routes), or through circular economy investments that curtail emissions both from end use waste and upstream emissions from transport.

The **new Circular Economy Action Plan** emphasises the importance of circularity as a prerequisite for decoupling economic growth from resource use and accelerating the transition towards climate neutrality (DG COMM, 2020). There are important opportunities for sustainable products and value chains, supporting the use of secondary raw materials, significantly reducing the amount of total waste generated and halving the amount of residual (non-recycled) municipal waste by 2030, which takes place as one of the objectives. Urban areas that are pursuing climate neutrality can synergize these opportunities for increasing circular economy in Europe that requires local contributions for bringing resource consumption under the limits of planetary boundaries within a safe operating space (Rockström et al., 2021). For example, increasing recycling options for energy technologies, including batteries of electro-mobility options, represents one of the ways of synergizing the energy transition with a circular economy. Anaerobic digestion or co-digestion of organic waste (Sakcharoen, 2021) and waste heat recovery from wastewater sludge are other options in the opportunity space while benefiting both the energy transition and circular economy. While not a core requirement in the Mission, urban areas that jointly pursue strategies that can consider both the energy transition and circular economy can

[17] From a GHG emissions accounting perspective, these emissions pertain to the stationary energy sector.
[18] From a GHG emissions accounting perspective, these emissions pertain to the transport sector.

discover that combined strategies can bring them closer to achieving co-benefits, including employment opportunities.

As a rule of thumb, successful waste management strategies combine environmentally conscious waste-to-energy options (Directive (EC) 2008/98) with conservation strategies (e.g., leakages minimization, valorisation of supply reservoirs in proximity to the city).

Best practices arise from the experience grown in recent years across a variety of initiatives. These include energy self-sufficient wastewater treatment plants (WWTPs) which succeeded in harnessing the full potential of local energy generation to the point of exceeding the on-site energy needs (Kollmann et al., 2018). In Neumarkt in der Oberpfalz, Germany, a sewage plant uses methane/sewage gas to run a cogeneration heat and power plant. The electric power produced supports the sewage processes, while the heat is supplied to the buildings on site, to the sludge digester and to dry the sludge, with a surplus used in the greenhouses of the civic nursery (Covenant of Mayors Europe, 11 December 2008). The BIOMASTER Project (supported by Intelligent Energy Europe) aimed at promoting biomethane production, its grid injection and use for transport by mobilizing all stakeholders along the chain and attracting investors to sustain long-term bioenergy ambitions and has created some good case studies. For instance, the project has helped the Polish company Biogasworks Małopolskie, fulfil its dedication to the ecological disposal of agricultural and food waste by achieving carbon-free electricity and heat production. Manure and agricultural waste are turned into bioelectricity, sold to the local power network and bioheat, used for the heating needs of farms.

Other best practices deal with separate waste collection to increase the recycling of municipal solid waste, the use of organic waste for biogas production, and the use of green waste for the production of compost and pellets. For instance, in Helsingborg, Sweden, the municipal waste treatment company produces biogas (80 GWh capacity) as well as biofuel through biogas upgrading. The digestion residue is then used as biofertiliser and is transported by pipelines to the farmers (Andreanidou et al., 2018).

Turning waste management into a carbon neutral activity is indeed possible, yet precondition is that all waste management streams work at optimal conditions. This requires that different waste fractions are addressed in a sustainable manner along with almost full recovery of biowaste and proper valorisation of the refuse in the form of refuse-derived fuel. Practical examples in Europe demonstrate that the optimisation is technically viable even in complicated contexts and should thereby pursued through a coordinated action (Fernández-Braña et al., 2020).

3.4 Industrial Processes and Product use

In the Industrial Processes and Product Use (IPPU) sector emissions are produced from a wide variety of industrial activities and processes that chemically or physically transform materials, including mineral industry, chemical industry, and metal industry. Additionally, GHGs are often used or contained in products such as refrigerators, foams or aerosol cans (see for example GCoM, 2019 for further guidance).

GHG emissions from IPPU are usually less significant than other sectors, specifically as large installations are covered by the EU Emission Trading Scheme and as such are outside of the scope of the Mission. However, those emissions can be notable for some cities, in which case these emissions should be quantified and eliminated (to the extent possible).

Urban areas are hubs of economic activity with various connections across supply chains, using both energy and materials. Partnerships that are established among actors can bring small and medium-sized enterprises (SMEs), entrepreneurs and industrial ecosystems to be part of the solution for urban climate neutrality, with many companies also engaging in net-zero targets. Based on partnerships, local actors, including any industry, can be engaged in mutual efforts for climate neutrality that would support both the mission and the **New Industrial Strategy for Europe** that emphasises twin green and digital transitions (European Commission, 2020d; European Commission, 2021h). Urban infrastructure, such as district heating and cooling networks, can provide opportunities for the industry to contribute its waste heat and the exchange of materials for waste valorisation can support circular economy approaches. Any initiatives in cities for supporting system flexibility can be diffused to the industry that could support the decarbonisation of the electricity grid with EU projections reaching to less than 100 gCO_2e per kWh in 2030 (European Environment Agency, 04 June 2021). Moreover, the industry can be a contributor in urban experimentation projects and pilot implementations, increasing the potential for upscaling solutions while providing new employment opportunities among co-benefits. Regardless of inclusion or exclusion in local emission inventories, local actors, including businesses, can find ways of supporting urban and European level climate neutrality through collaborative interaction.

3.5 Agriculture, Forestry and Other Land Use

Agriculture and forestry are likely not significant sources of emission within most cities. However, depending on choices for urban land use and spatial planning, cities can exert pressures on land use change to various extents. Land use efficiency is monitored as an indicator under SDG 11 and globally, there is a need to improve land use efficiencies that has been decreasing in more than half of the urban areas over the last decades (Carneiro Freire et al., 2018; European Commission, 2020f). The ambition for climate neutrality represents an opportunity to make progress in protecting and enhancing carbon sinks also by limiting land use change due to urbanisation while increasing urban green and blue infrastructure within cities. It is estimated that greening 35% of the urban surface in Europe can avoid up to 55.8 Mt CO_2e of emissions per year while providing multiple benefits for inhabitants (Quaranta et al., 2021). Locally, urban forestry will contribute to sequestering and storing carbon based on the types of trees and their maturity. In addition, green walls, green roofs and green areas large and small can provide co-benefits to communities (Wong et al., 2021), including through reducing the urban heat island effect that increases total warming when combined with global warming. For example, urban geometry and the materials that make up cities can amplify warming in urban areas while vegetation and water, including parks, forests, lakes and rivers, can contribute to natural cooling influences locally (IPCC; 2021c).

Simultaneously, while traditionally not considered a priority in the framework of urban GHG inventories, Mission Cities can account for negative emissions achieved through the enlargement or enhancement of natural sinks, as one way to address residual emissions within their territory. These types of measures, like planting trees in urban areas, are likely to generate positive co-benefits for the local climate and air quality. From a methodological point of view however, it is challenging to accurately determine carbon sinks and storage that can be accounted for; therefore Mission Cities will receive further methodological guidance and technical support. Nature-based solutions (i.e., trees and 'green infrastructure') absorb carbon over time, and cities will be permitted to use the natural sink of forests, soils, agricultural lands and wetlands within their city boundaries to account for any unavoidable residual emissions.

Box 7. Example: The role of sinks in the Carbon-Neutral Helsinki 2035 Action Plan

'In the next few years, the City needs to examine the potential presented by emission compensation in more detail. Even if the carbon storage in the tree stand, vegetation and soil in the City area and the changes therein are not taken into account in the emission calculations for Helsinki, the urban nature plays its part in binding carbon dioxide from the atmosphere. Growing the carbon storage and carbon sinks from their current state may also present the City with an opportunity for emission compensation. This requires us to examine the carbon sink potential of the entire Helsinki Group and to constantly monitor the carbon storage and carbon sinks in Helsinki.'

Source: City of Helsinki, 2018, p. 13.

If a Mission City is considering accounting for negative emissions through natural sinks within the territory, it is imperative that all changes in the carbon stock are taken into consideration and only the net gain is considered to cancel out remaining emissions from other sources. If, for example, the urban land area is expanding, this has an impact on the surrounding carbon sinks, which has to be taken into consideration. The monitoring of the development of urban sinks could in the future be supported by satellite imagery (like the GHSL - Global Human Settlement Layer), including development of a new metric in itself (covering the change in urban built areas and additional or enhanced carbon sinks).

Simultaneous with ambitious mitigation for climate neutrality, the **new EU Strategy on Adaptation to Climate Change** further upholds the need for more systemic adaptation beyond sectors with specific referral to the EU Covenant of Mayors as well as nature-based solutions (European Commission, EU Adaptation Strategy, 2021).

3.6 The role of circular economy

A cleaner and more competitive Europe thinks of materials and energy within cities as circular, self-contained flows that reduce the pressure of human settlements and activities on natural resources and promote sustainable growth. Circular economy harnesses the potential of research, innovation and digitalisation. It generates new sustainable services, innovative jobs and upgraded knowledge and skills, as well as high quality, functional and safe products, which are efficient and affordable, last longer and are designed for reuse, repair, and high-quality recycling (DG COMM, 2020). As such, circularity is a prerequisite to climate neutrality as also highlighted in the previous two sections.

As a key enabler for decarbonisation and biodiversity protection, circular economy constitutes one of the main building blocks of the European Green Deal and a priority area of the Green City Accord. To accelerate the process, the EU's new circular action plan (CEAP), adopted in March 2020 (DG COMM, 2020), promotes a set of initiatives to encourage sustainability along the entire life cycle of products. Production methods and consumption paradigms are inter-connected to ensure that waste is minimised, and the resources used are kept in the EU economy for as long as possible (DG COMM, 2020). Measures focus on the sectors that use most resources and where the potential for circularity is highest: electronics and ICT, batteries and vehicles, packaging, plastics, textiles, construction and buildings, food, water and nutrients. Furniture and high impact intermediary products such as steel, cement and chemicals will be also prioritized. Multiple goals are envisioned, including improving product durability, reusability, upgradability and reparability; increasing recycled content in products, while ensuring their performance and safety; restricting single-use and countering premature obsolescence; discouraging the destruction of unsold durable goods, and mobilising the potential of digitalisation of product information. The plan aims at boosting the transformational change by capitalizing on circular economy actions implemented since 2015 (DG COMM, 2020) to make circularity work for people, regions, and cities.

The European Urban Initiative (European Commission, 2021f), the Intelligent Cities Challenge Initiative, the Circular Cities Declaration, and the Circular Cities and Regions Initiative will provide key assistance to cities to part from a take-make-waste economic model and target climate-neutral circular and bioeconomy transitions, covering safe integrated circular solutions at territorial and sectoral levels. But many other resources can be helpful (see Circular City Funding Guide, Circular City Initiatives and Resources).

Some of them focus on methodological frameworks. An example is the Circle Economy – Circle Cities Programme (Circle Economy, n.d.), a global platform that helps regions, cities and local businesses transition towards a more circular economy, through the Circle City Scan, a tried-and-tested method comprising five phases (city baseline analysis, material flow analysis, strategic development, action planning, and local business acceleration). Another example is REBus (REBus, n.d.), a step-by-step guide to the circular procurement resource efficient business model. Further, the H2020 project REPAiR brought together models and methods from environmental, geographic and economic sciences to provide local and regional authorities with an innovative transdisciplinary open source geodesign decision support environment aimed at establishing a strong circular economy. From the collective experience of six peri-urban living labs (PULLs) across different metropolitan areas, place-based, eco-innovative solutions for strategic management of waste flows are conceptualized to activate processes of urban regeneration in a collaborative decision support environment. A dissemination kit and a handbook are available to stimulate further uptake of the project's insights.

Case studies, best practises and policy instruments are showcased across different online platforms for cities such as the Circle Lab, the Circular Europe Network, the Circular Economy Practitioner Guide, and the Circular Economy Toolkit which draws from 100 circular business and environmental concepts, and 50 surveys to gain industry insight. Further, reports, frameworks, and other publications are available through the Ellen MacArthur Foundation – Circular Economy in Cities website, while the European Circular Economy Stakeholder Platform offers opportunities to strengthen cooperation among stakeholder networks and facilitate the exchange of expertise, good practices, knowledge and lessons learnt in the circular economy.

Additionally, the use of common indicators for circularity performance, in tandem with digitization and smart software solutions, is essential to accelerate the transition to the circular economy. A number of initiatives has focused on establishing shareable metrics to measure circular flowing, including:

- the Urban Agenda Partnership for Circular Economy (Ecorys, 2019) which offers a categorization into process indicators (linked to city activities to support the circular transition e.g., communication campaigns), outcome indicators (linked to transformative effects e.g., as increased rate of recycling), and context indicators (linked to trends, e.g., annual amount of solid waste);
- the WBCSD – Circular indicators (WBCSD, n.d.) a universal and transparent framework to measure circularity and provide a common language across industries and value chains;
- the OECD – Circular cities and regions (OECD, n.d.) that supports cities and regions in their circular transition by developing indicator frameworks, stimulating dialogue and shared experiences.

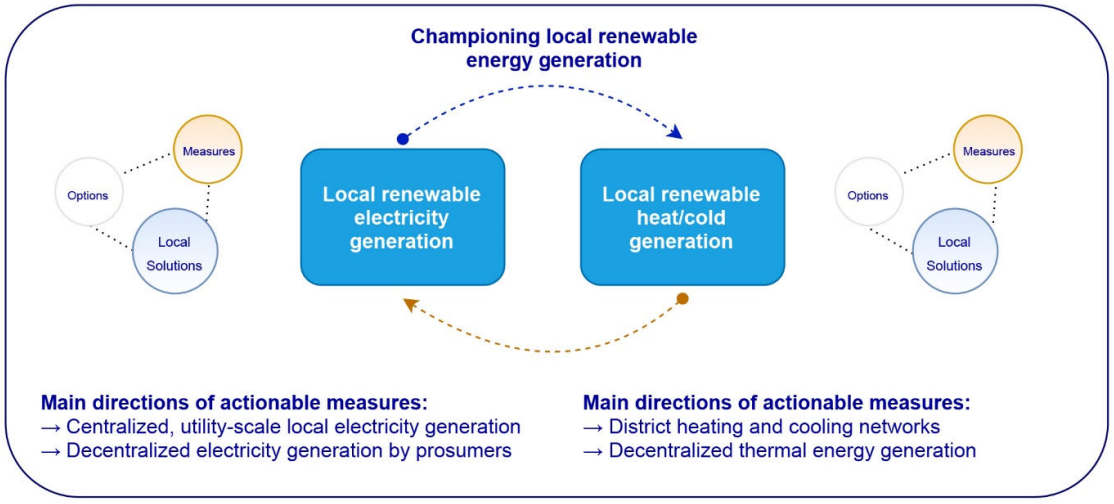
4 The role of local energy production and Renewable Energy Sources (supply side)

4.1 Local renewable energy generation

Utilising renewable energy in cities is a key strategy for reaching climate neutrality. In the limited time to reach this target, upscaling access to renewable energy to meet urban energy demands through local energy generation and supporting system flexibility for allowing much higher shares of renewable energy in the broader energy system becomes a top priority. This requires dual strategies for integrating urban energy demands in the broader renewable energy context (Thellufsen et al., 2020). Actionable measures to increase access to renewable energy will provide quicker results than the time that it can take to change urban form in cities, which can take effect over longer timeframes.

Renewable energy has a key role for delivering the European Green Deal, including the target of reaching a share of 40% in gross final energy consumption by 2030 (European Commission, 2021c). Cities have key roles in mainstreaming renewable energy as well as facilitating system integration of renewable electricity in the urban energy system. On the supply side, local renewable energy generation can involve centralised and decentralised solutions for local electricity generation – as well as local heat and/or cold generation (Andreanidou et al., 2018, Part 3). The identification of sites for utility-scale local renewable energy generation will itself require urban land use and spatial planning, especially if linked with district heating and/or cooling networks, while brownfield sites can provide alternatives in certain contexts, including for large-scale solar and wind farms. It is important to recognise that higher densities, based on heat or population densities, will increase the options for centralised distribution systems through district heating and/or cooling networks (Persson et al., 2019). In a given context, cities can champion local renewable energy generation that involves local electricity generation as well as local heat and/or cold generation for climate neutrality. **Figure 6** summarises the main directions of actionable measures in this domain for local solution possibilities.

Figure 6. Main directions of actionable measures for championing renewables.



Source: Own work.

A number of possible local energy production options and technologies are discussed in the following sections. To increase public acceptance and accelerate the uptake of RES, it is advisable that cities promote the participation of citizens in project development (see Section 8.1 for further information). **Table 7** provides an overview of the types of interventions cities can take along with some examples of actions other cities have taken.

Table 7. Municipal actions for renewable energy generation/district heating & cooling.

Action Family	Example actions	Description	Links to more information / case studies
Information / facilitation	Data publication	Providing data to support the uptake of renewable energy systems	Berlin Solar Atlas Paris Solar Registry
	Real-time data	Monitoring/publishing real-time renewable energy generation	Real time electricity generation data on PV systems of the City Council (Málaga, ES) and visual consoles on CO2 reductions
	Promotional campaigns	Information campaigns / targets to encourage citizens to invest in renewable energy (community-owned or private)	Alessandria, IT
	Joint procurement	Coordinating group purchasing for citizens / private sector (e.g., PV panels) to reduce costs	
Municipally-owned	District heating / cooling systems	District heating / cooling systems	Madrid (ES) Mini hydroelectric power station Municipal Wind Turbines: Eskilstuna, Sweden HELSINKI'S Katri Vala heat pump captures MALMÖ'S pioneering building-level solar thermal system
	Building-mounted renewable energy	Small-scale PV, wind and solar thermal systems	Comune di Solarino, IT Funchal, PT
	Renewable electricity generation	Large (>500kW) PV, wind and micro-hydro installations	Construction of a PV park on ground of municipal property at a former landfill site in Torrile, IT
	Municipally-owned utility	Municipally-owned electrical/district energy infrastructure/systems	Wolfhagen, DE
Shared ownership	PPPs/ESCOs	Investing with private sector partners (incl. ESCOs) to install renewable energy technologies	Coruche, PL

Action Family	Example actions	Description	Links to more information / case studies
	Community-owned	Facilitating community ownership of renewable energy technologies	Nijmegen, NL
Municipal financing	Incentives / subsidies / grants	Financial incentives to encourage uptake of renewable energy	Subsidy per square meter of solar thermal collector area in Bonn, DE

Source: Own work

4.2 Electricity

Cities and their regions have access to ample renewable energy resources for local electricity generation, particularly solar and wind energy. There are two main directions of actionable measures in which local renewable electricity generation is being pursued:

— centralised, utility-scale local renewable electricity generation

— decentralised electricity generation by privately-owned buildings.

Photovoltaic (PV) panels can be arranged in large-scale solar farms or integrated into urban infrastructure, including the roofs of large facilities, public, residential and commercial buildings and even utilities and waterworks. Similarly, wind turbines can be placed in wind farms at suitable locations with favourable wind conditions in the region and supported by such policy measures as public procurement of municipal wind turbines. In both cases, business models can have a crucial role in supporting local electricity generation opportunities, including community cooperatives that involve local ownership of local energy projects, engaging citizens and local authorities. Wastewater, biological waste and residues for bioenergy production can be untapped sources in urban areas. Anaerobic digestion of biowaste that is collected from the urban area or anaerobic digestion of wastewater sludge can provide promising alternatives to using rural biomass resources for local electricity generation, which may be managed at more limited levels considering their sustainable use and protection of carbon sinks. Among other renewable energy sources, medium to high enthalpy geothermal energy sources can provide additional support for local electricity generation when this may be physically available. Similarly, local electricity generation options based on micro hydropower, wave and tidal energy will depend on context.

For cities wishing to achieve climate neutrality by 2030, it is likely that a significant amount of local low/zero carbon renewable energy technologies will be required within the city boundary. While national electricity grid emission factors continue to decline with the introduction of more industrial scale renewable energy generation across the EU, it is unlikely that emission factors will reach zero before 2030 in any of the Member States. Thus, for a city to realise net zero carbon electricity supply, local renewable electricity generation will be pivotal. Solar PV, geothermal, bioenergy, and wind should all be considered/exploited to produce the energy to meet the demand of a city's buildings' needs.

Renewable energy applications within the city boundary can take the form of building or industrial scale generation. The Energy Performance of Buildings Directive already requires that newly constructed buildings are nearly zero-energy buildings (NZEB), i.e., will have very high energy performance and will meet their own residual energy demand mostly by on-site or nearby renewable energy sources. Retrofitting renewable electricity generation (mostly solar PV) to the existing building stock continues to show improved cost/benefit and paybacks (IRENA, 2021).

The EU Renewable Energy Directive has recently been updated to raise the overall renewables target to 40% by 2030 (European Commission, 16 July 2014). Current energy projection scenarios show that in 2030, the share of renewable electricity in the EU could range from 48% to 70%, compared to 31% currently – 2020 (Tsiropoulous et al., 2020). While this projection is hopeful, cities wishing to achieve net zero emissions by 2030 will need to generate a significant proportion of renewable energy within their boundaries to minimise the carbon intensity of the electricity used within the city boundary.

Renewable Energy Credits (RECs) is a market-based instrument that certifies electricity generated from renewable energy. RECs can be sold on the open market once the power provider has supplied the energy to

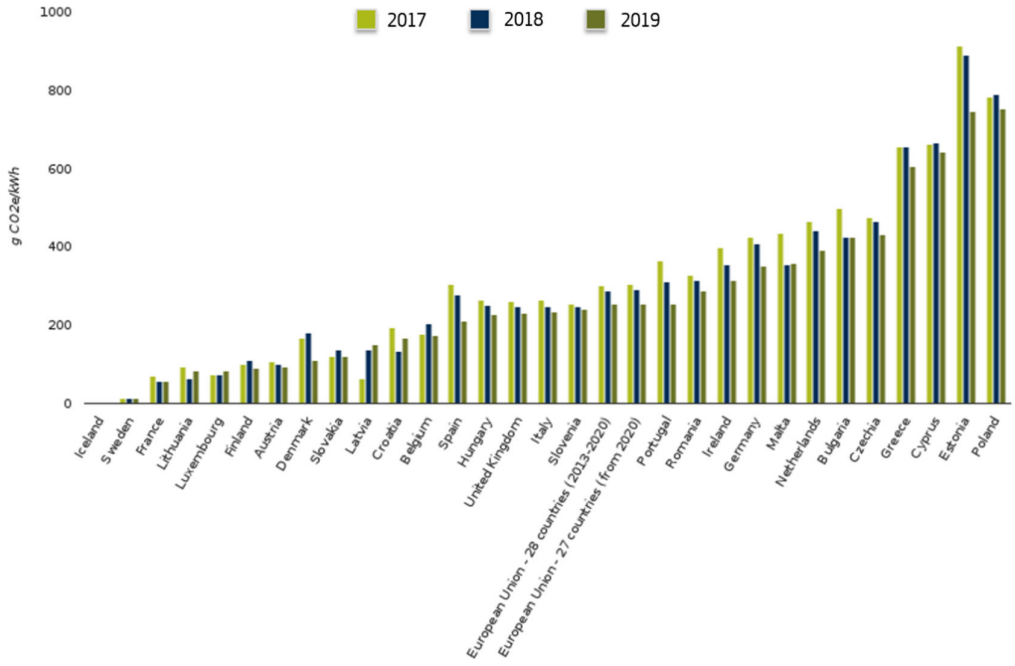
the grid. RECs can be sold to entities to reduce their net GHG emissions. The 'Guarantee of Origin' is the EU mechanism for proof of source. For cities using renewable energy from outside their boundary to lower the implicit emission factor (EF) for electricity consumed locally, RECs will need to be used to demonstrate the credibility of the source and amount defined. It should be noted that RECs are only permitted to address Scope 2 emissions from electricity consumption (i.e., where a city cannot achieve an emission factor of zero for electricity) as described in the GPC (Fong et al., 2014). It is accounted for in the calculation of the local emission factor for electricity consumption (i.e., it lowers the indirect emissions associated with final electricity consumption) and cannot be used to compensate for emissions associated with other energy carriers.[19]

Cities should also consider (where possible) municipal ownership of the local electricity grid (and/or district heating/cooling) infrastructure and systems. Many cities have realised significant benefits in terms of revenue generation, reduced energy costs for citizens, retaining currency within the local economy and creating local jobs, all while being able to invest in renewable energy technologies to decarbonize local grids (see, e.g., 100% Renewable Energy Atlas, 2019).

4.2.1 How to account for locally produced electricity in the Mission Cities' GHG inventories?

Emissions from electricity consumption within the city boundary are calculated using so-called emission factors (see **Box 8** below). An emission factor is the rate of emission per unit of activity, output or input, for example a particular fossil fuel power plant can have a CO2 emission factor of 0.765 kg/kWh generated (IPCC, 2007).

Figure 7. Country level – GHG emission intensity of electricity generation[20] for the years 2017, 2018, 2019



Note: Data sources: National emissions reported to the UNFCCC and to the EU Greenhouse Gas Monitoring Mechanism provided by European Environment Agency (EEA); Supply, transformation, consumption - all products - annual data provided by Statistical Office of the European Union (Eurostat); COM 562 final and SWD 176 final provided by European Commission

Source: European Environment Agency, 2021.

[19] A main difference between renewable energy certificates and carbon credits is that owners use RECs to claim possession of a certain amount of low-emissions or emissions-free electricity supplied to the grid, whereas owners use offset credits to claim possession of a certain amount of CO_2 emissions avoided and/or sequestered. I.e., the first is measured in MWh, the second metric tonnes of CO_2 avoided and/or sequestered (C40, 2019).

[20] Note: Greenhouse gas emission intensity (g CO_2e/kWh) is calculated as the ratio of CO_2e emissions from public electricity production (as a share of CO_2 equivalent emissions from public electricity and heat production related to electricity production), and gross electricity production (European Environment Agency, 2021).

Mission Cities will want to account for the effect of an overall decarbonised grid contributing towards meeting their target. While this effect usually comes with limited active contribution from the city, the major decarbonisation effort of the grid at European level has a significant impact on emissions attributable to consumption within cities. This is done by changing the emission factor over time, i.e., grid emission factors should be time-specific to the inventory year, and geographically-specific to the inventory boundary.

In the Covenant of Mayors Europe, the currently applied practice is to keep national/regional emission factors constant, to clearly demonstrate the effect of increased local renewable energy production over time. At the same time Covenant cities calculate a local emission factor for electricity, by correcting the European/national/regional emission factor for the baseline year based on local electricity production and certified green electricity purchases/sales by actors within the city's territory, using a specific formula[21]. It is important to note that **no negative emission factors can be applied** in the calculation of energy-related emissions, even in the case where cities are generating more zero-emissions electricity than they consume.

Box 8. Scope 2 emissions and the role of emission factors

Scope 2 emissions refer to indirect emissions associated with grid-supplied energy (electricity and/or heat and cold) consumed within the geographic boundary, irrespective of where the energy generation facility is located.

With the growing electrification of energy demand (e.g., use of electricity heat pumps for buildings' heating, large-scale heat pumps in district heating and/or cooling networks and increasing penetration of battery electric vehicles) and progressive phasing out of fossil fuels, Scope 2 emissions are expected to become predominant in GHG inventories. A GHG accounting approach based solely on direct (i.e., Scope 1) emissions might fail to capture an important part of emissions that could be influenced by cities.

Scope 2 emissions are calculated by multiplying activity data (e.g., MWh of final energy) by relevant emission factors for electricity and/or heat and cold, expressed as GHG emissions per unit of consumed energy (generally tonne of CO_2 equivalents per MWh). While heat and cold are delivered within relatively short distances and can easily be traced back to the production plant, this is generally not the case for electricity.

Different options exist for the choice of the emission factor for electricity and whether it should be time-specific to the inventory year or not. The two most common ones are the following:

— Use a European/national/regional/local emission factor reflecting the European/national/regional/local grid electricity mix and change it over the years to track the actual evolution at European/national/regional/local level (consistent with GPC), and applying it to all grid-supplied electricity consumed in the city. This approach is more realistic and accounts for the continuing decarbonisation of the grid helping cities' emission reduction efforts with or without intervention from the local authority itself.

— Calculate a local (weighted) emission factor for electricity, by correcting the European/national/regional emission factor for the baseline year based on local electricity production and certified green electricity purchases/sales by actors within the city's territory (as in the EU Covenant of Mayors, see Kona et al., 2019). In this case, the European/national/regional emission factor is assumed constant through the years, while the local emission factors change over the years. This way, emission savings reflect more accurately the efforts made by the local authority and not the changes in the national electricity mix.

Both approaches on their own have advantages and drawbacks, why in the case that it is possible to differentiate the local renewable energy generation that is utilized directly within the urban area and the amount that is provided to the grid, the two approaches may be further harmonised while avoiding a double-counting of the efforts of the local authority for decarbonisation. This third approach is recommended for Mission Cities wherever feasible, to both encourage and account for local renewable energy production and at the same time allow cities to reap the significant effect of an overall decarbonizing national and European grid[22].

[21] See Andreanidou et al., 2018.

[22] The GHG emission intensity of electricity generation is decreasing for most EU member states, especially in recent years. The EEA projection (European Environmental Agency, CO_2-emission intensity from electricity generation - trajectory) is for reducing the EU emission intensity to less than 100 gCO_2e/kWh by 2030 (75,5 – 96,8 gCO_2e/kWh).

It should be noted that the inclusion of Scope 2 emissions in GHG accounts at city level implies attributing to the city (part of) the emissions associated with power plants or district heat installations and supplying grid energy, irrespective of where they are located. For this reason, it is recommended not to account for emissions from installations for energy generation under the stationary energy sector, as this would result in a double-counting. The approach based on Scope 2 emissions puts the emphasis on the sectors consuming final energy in the form of electricity or heat and, consequently, on mitigation measures aiming to improve end-use efficiency. To the opposite, if Scope 2 emissions are excluded while energy-producing installations are included in GHG accounting, the main focus is on energy generation.

The Mission clearly encourages a deep decarbonisation effort in Mission Cities, i.e., that all avoidable emissions are reduced to zero by 2030. However, in the context of having residual emissions in 2030, the question may arise on the extent that a surplus in any given sector can be used to offset emissions in a non--decarbonised sector. Concretely, if a Mission City produces more green electricity than it consumes, can it use this green electricity to offset residual emissions in other not fully decarbonised sectors (for example, if fossil fuels are still used in the transport sector)? The answer is that ideally in such a situation all effort should be undertaken to make further progress towards climate neutrality by using the renewable electricity generation surplus to further decarbonise the non-decarbonised sectors (for example by using the renewable electricity for light rail transport). Using the surplus to offset the residual emissions in a sector that is not yet decarbonised would only give a favourable balance (on paper) while opportunities for system integration would remain. Transparency in reporting by providing the gross and net emissions is important in this context. The Mission hence follows the principle of making sufficient progress to decarbonise every sector and using integration in the urban system whenever possible to advance progress towards climate neutrality and then to first focus on enhancing local carbon sinks to cover any residual emissions for net zero.

4.3 Renewable Technology Options

4.3.1 Photovoltaics

Photovoltaic (PV) systems are now a cost-effective means of generating electricity in urban areas and can make a significant contribution to Europe's energy transition. The costs of electricity at PV module level have dropped to less than 0.02 EUR/kWh, making it amongst the lowest cost technologies for electricity generation (Jaeger-Waldau, 2018). However, realising PV's potential is challenging not only at policy level, but also in terms of electricity system planning. So far, the potential to generate electricity with PV systems is still largely untapped.

The main small-scale PV categories are:

1) PV systems on rooftops: Residential and commercial rooftops can be used to generate electricity using PV systems (Bódis, 2019);
2) Building façades with PV: PV façades on buildings can reduce the heat load in the building and reduce the power needed for cooling (Defaix et al., 2012; El Gammal et al., 2016);
3) Building Integrated Photovoltaic Systems: PV materials that are used in place of traditional building components or materials such as facades or roof tiles.
4) Parking lots: Covering parking lots with PV canopies enables sustainable electricity generation to charge electric vehicles and provides shading for the automobiles (Neumann et al., 2012; Krishnan et al., 2017).

Generating electricity with PV systems on residential and commercial buildings can increase the overall efficiency of the energy system. Due to the proximity of PV generated electricity to the point of consumption, transmission losses can be avoided. In addition, the generation of electricity using PV systems reduces the transformation losses from primary energy to electricity.

Cities can facilitate/incentivise the acceleration of PV installation in a number of ways:

1) Providing citizens with localised data on solar radiance, generation estimates and cost/payback information;
2) Organise/facilitate group purchasing initiatives to further lower the cost of PV installation;
3) Offer (low interest) financing or property assessed financing (using municipal taxes) to allow building owners to eliminate up-front costs;

4) Bylaws for new construction or major renovation mandating PV capacity;

5) The EU PV Performance Tool provides a macro-level map of potential energy generation from PV globally. The Google Environmental Insights Explorer can also provide estimates of rooftop solar potential.

4.3.2 Solar thermal

Solar thermal technologies convert sunlight directly into heat (typically hot water) using either flat plate or evacuated tube collectors. The primary application is for domestic hot water heating (DHW) for residential homes and commercial/public sector buildings with significant heat demand. In addition, solar thermal heat can be used to drive cooling. Solar thermal collectors currently represent about a 2% share of the EU renewable energy generation (Carlsson, 2019). Recently, the solar thermal market has faced difficulties as the cost competitiveness of heat pumps and solar PV combination systems has increased.

Cities should consider building-scale solar thermal panels for buildings/districts where there is high demand for hot water (i.e., hospitals and swimming pools).

In addition to building-scale solar thermal, solar supported district heating and cooling (DHC) systems are becoming more common (see Section 4.4, below).

The EU Solar Radiation Tool (https://re.jrc.ec.europa.eu/pvg_tools/en/#MR) provides a macro-level map of solar radiation which cities can use to estimate the potential heat generation from solar heating at their location.

4.3.3 Wind

Wind power contributed a 34% share of all EU renewable electricity production (European Court of Auditors, 2019) in 2017, more than any other renewable source. Most of this supply is 'industrial scale' and not necessarily relevant to most cities which would not have the capacity or space to install large wind farms. Distributed wind systems (less than 100KW) are emerging as a solution for cities which experience the necessary wind speeds (see European Wind Atlas at https://map.neweuropeanwindatlas.eu/ and below). These smaller turbines can be used in a greater range of locations/applications. Building-scale (or small-scale) wind turbines (less than 20kW) are also an emerging technology, especially with improvements to the vertical axis wind turbine (VAWT) design/efficiencies.

Typically, the built environment inhibits the availability of wind power as the various structures tend to convert high-speed, laminar flow (where present) into a low speed, turbulent flow. This is especially poorly suited to conventional horizontal axis wind turbines (HAWT), however advances in vertical axis wind turbines have created a real chance for wind power in cities. Despite this, small-scale wind turbines are more expensive than large-scale (per kW installed) so cost/benefits can be difficult to justify.

Cities which benefit from sufficient wind speeds should consider the opportunities for small-scale (building mounted) VAWT turbines and/or 'distributed wind systems'. Small-scale wind turbines suitable for the urban environment are still far more expensive than large scale versions as they are still in a research and development phase.

Large-scale wind farms will only be viable for coastal cities (offshore) or cities with significant rural space within their territory (onshore).

The New European Wind Atlas (https://map.neweuropeanwindatlas.eu) provides average wind speeds across the EU and can be a useful tool to help assess the viability of wind power dependent on cities' locations.

4.3.4 Mini-Hydroelectric

Hydropower is derived from flowing of water which powers a turbine, and represents 36% of the EU renewable electricity consumption (European Commission, 21 April 2020). As for wind power, cities are unlikely to have opportunities/finances to construct large scale hydroelectric, however small-scale 'run-of-the-river' plants have proven to be viable and successful in the urban context.

Cities should analyse any watercourses within their territories with the potential to generate power in an environmentally responsible and safe way.

4.3.5 Biomass heating (point of use)

Small-scale biomass combustion for residential and commercial heating or for industrial heat production can offer opportunities for reduced GHG emissions when compared with fossil fuel alternatives, especially where the biomass fuel is sustainably sourced. The technology is mature and competitive with fossil fuels. Typically, heat is delivered in one of three ways:

- Traditional burners (i.e., open fireplace, closed fireplace, firewood space heater etc.) with low efficiencies of 10 - 30% (Scarlat, 2020);
- Modern burners (i.e., wood log, wood chips, or pellet burning) with efficiencies up to 90% (Scarlat, 2020);
- Small-scale automated heating boilers (i.e., wood chip or wood pellet boilers) are used for central heating and are equipped with a water heat exchanger and connected to a heating water circuit and can achieve efficiencies of 80-90% (Scarlat, 2020);

While the deployment of point of use biomass heating will have its applications, they also have their drawbacks. Biomass systems typically give rise to higher levels of some other pollutants (i.e., particulate matter and NOx) while also raising questions about the scale of available, sustainable fuel supply.

4.4 District heating and cooling (DHC)

The potential of using renewable energy sources in cities towards decarbonised urban areas extends into matching urban thermal energy demands with renewable energy opportunities. In this scope, the two main directions of actionable measures involve (1) district heating and cooling networks and (2) decentralized thermal energy generation. Regulatory measures that can be taken by cities, such as zoning and compulsory connections to renewable energy-based district heating and cooling networks in related zones, and can improve the impact that can be reached through this measure. District heating and cooling networks also provide the advantage of integrating multiple renewable energy sources and sources of waste heat for being distributed across the urban area. In addition to large-scale solar thermal plants that can support solar district heating networks, residual heat from biogas cogeneration plants and heat pumps that utilize other renewable energy sources, including seawater heat pumps, geothermal heat pumps, and heat pumps that utilize waste heat from wastewater, data centres or the industry, are available to support cities in related strategies. Community partnerships and co-financing schemes can have a special role in enabling these solutions. In contrast, especially in areas where there may be more limited heating and/or cooling densities, decentralised thermal energy generation can be viable and can be supported with solar thermal ordinances and other policy tools.

The application of 'conventional' (fossil fuelled) district heating and cooling systems can save up to 50% primary energy usage[23] and GHG emissions compared to typical point-of-use boilers/furnaces, especially in high-density urban environments or where there is significant heat demand (e.g., hospitals and swimming pools). Currently, many of these systems are still powered by fossil fuel combustion, however the prevalence of biomass is increasing. Renewable energy sources to power district heating and cooling (i.e., geothermal, solar thermal and excess/free heating/cooling) can also be integrated/retrofitted to further reduce GHG emissions. Combined Heat and Power (CHP) using electric boilers, heat pumps and thermal storage also offers significant potential for the effective use of energy. New, fourth generation district heating systems can be feasible even when the heat density is between 30 and 100 TJ per km^2 and can allow the possibility of sharing waste heat across users in the network (Möller et al., 2016).

Approximately 12% of the EU heat/hot water demand is currently met by district heating (Paardekooper et al., 2018) and it is estimated that through system expansion in urban areas it could supply around 50% of EU heat demands by 2050, 30% end-use savings could be achieved, while heating costs could be reduced by 15% (Connolly et al., 2014).

The Renewable Energy Directive that is amended with a new 2030 climate target also emphasises the importance of ensuring that district heating and cooling is an enabler of renewable energy supply in buildings through modern, renewable-based smart district heating and cooling systems. This emphasis that directly pertains to cities underlines the opportunity of harnessing a wider range of renewable heat and cold sources in the local context in an efficient and flexible way as a means of increasing renewable energy deployment and deepening the process of energy system integration. Among the local opportunities, cities can steer the development of district heating and cooling networks towards modern, renewable-based efficient district

[23] District energy in cities: unlocking the potential of energy efficiency and renewable energy | UNEP - UN Environment Programme.

heating and cooling systems while also utilising cost-effective local waste heat and cold potentials. Similarly, cross-sectoral measures to increase energy efficiency in alignment with climate targets are covering the progressive integration of renewable energy and waste heat or cold in district heating and cooling networks.

Cities should develop (if they have not already) heat maps to establish how/where to develop district heating/cooling systems and networks. The Pan-European Thermal Atlas[24] provides an excellent resource for heat demand at the macro level (for some Member States). Municipal ownership or private-public partnerships should also be explored to maximise the opportunity for revenue generation by the municipality and to enhance the local economy.

A variety of potential heating/cooling supply technology options (listed below) should be considered in the context of energy efficiency and GHG emissions for a city considering installing/expanding/updating a district heating or cooling system. **Figure 8** depicts relative improvements in energy efficiency as more renewable/efficient technologies are included.

4.4.1 District Heating and Cooling Technology Options

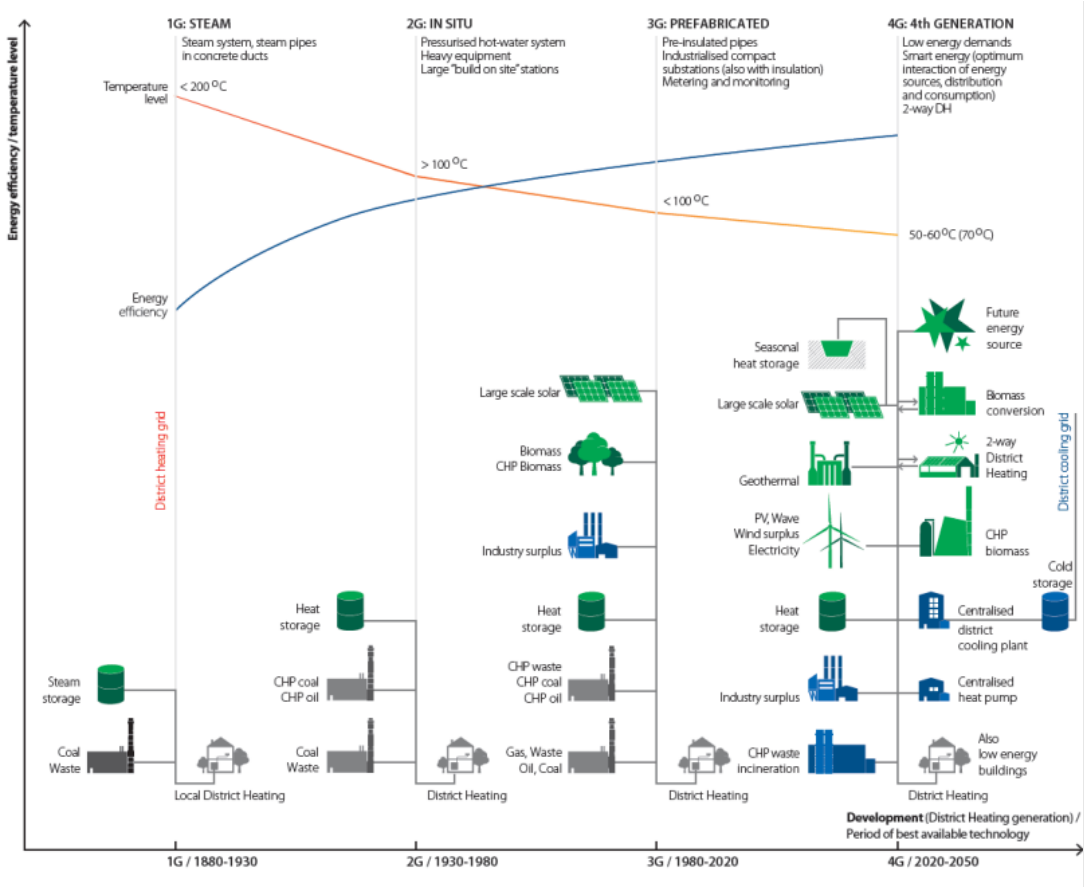
The following is a non-exhaustive list of the prominent technologies and applications cities should consider when developing their district heating/cooling strategies:

- **District heating boilers** – conventional fossil fuel, biofuel or electric boilers used explicitly to generate heat. With a goal of climate neutrality, it is likely that cities would need to utilize biofuel sources (or electricity where the electricity supply is low/zero carbon).
- **District chillers** – electric or absorption chillers used explicitly to generate cooling. District level cooling will not be relevant/cost-effective for a large proportion of EU cities where average summer temperatures don't justify the demand. A map of cooling demand densities is available from Peta4 – Heat Roadmap Europe.
- **Large-scale solar thermal** – collect heat for use in combination with other heat generation sources in a DHC system and can also be integrated into existing district heating systems. Such installations can be well-suited for ESCO schemes with favourable cost/benefit. Cities considering solar thermal systems should assess annual radiance levels and land availability (in proximity to the district heating system/network for existing systems). A map of areas well-suited to solar district heating is available from Peta4 – Heat Roadmap Europe.
- **Geothermal energy** – (not to be confused with ground source heat pumps) utilises hot water/steam generated deep beneath the earth's crust. A map of geothermal energy potential is available from Peta4 – Heat Roadmap Europe.
- **Thermal Energy Storage (TES)** – can assist with integration of renewable energy sources (as renewable supply does not always coincide with demand for heating/cooling). A variety of technologies can be used to store renewable energy for periods of high demand.
- **Combined heat and power (CHP)** – simultaneously generates thermal energy and electrical and/or mechanical energy from a single input of fuel generation and represents about 11% of the gross electricity generation in the EU. CHP leads to a reduction of fuel consumption of at least 10% when compared to conventional fossil-fuel derived electricity and separate heat production and can be sourced by gas turbines, reciprocating engines, Stirling engines or fuel cells (Andreanidou et al., 2018). Cities should consider CHP for sites/districts that have steady thermal and electric loads (i.e., industrial, hospitals, swimming/leisure facilities, universities, multi-family buildings, etc.).
- **Waste heat** – recycling waste energy increases the energy efficiency of a city (as part of a circular economy). For many cities, district heating is the only technology that enables the utilization of low-exergy (energy content) waste heat in a city. A map of excess heat is available from Peta4 – Heat Roadmap Europe.
- **Large-scale heat pumps** – use of heat pumps in conjunction with air, water, ground or waste heat. Heat pumps work well in conjunction with waste heat sources or with CHP/renewables as sources for the electricity to power the cycle.

[24] Peta4 – Heat Roadmap Europe.

— **Waste-to-energy** – utilises the energy content in non-recyclable, combustible waste. Where a city generates sufficient waste levels (perhaps in partnership with neighbouring authorities), waste-to-energy can become viable. Systems are typically developed in a PPP or ESCO arrangement.

Figure 8. District heating generations by supply, efficiency, and temperature level.

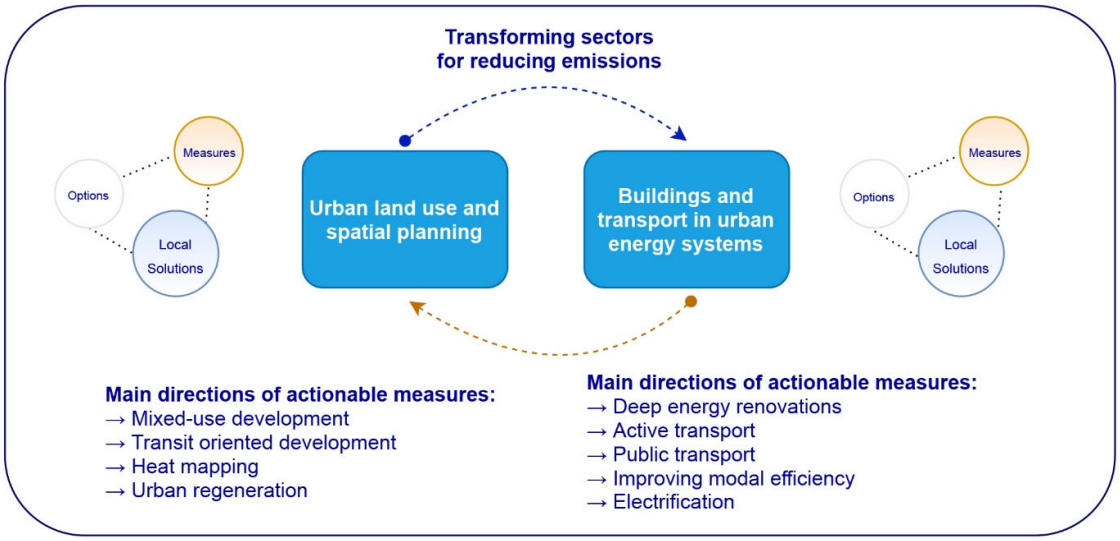


Source: Lund et al., 2014.

5 Transforming sectors for reducing emissions

Cities are places where emission reduction strategies that will transform multiple sectors, including buildings and transport, co-exist and intersect in close proximity. This uniqueness provides numerous opportunities for capturing synergies between decarbonisation strategies, not in isolation, but in connection, also considering their interlinkages with urban land use and spatial planning. Cities will find that a holistic view that focuses on these connections can provide a multiplier effect for reducing emissions on the demand side. **Figure 9** provides an overview of related directions of actionable measures for cities in urban land use and spatial planning as well as those for buildings and transport in the urban energy system. Local solutions will also find connections with measures for championing renewables and system integration.

Figure 9. Main directions of actionable measures for transforming sectors



Source: Own product.

5.1 Land use and spatial planning

The way that urban areas continue to be designed and built can define the opportunities for urban energy systems. There are multiple interactions across land use, buildings, transport and local energy generation in the urban system which demand a systemic approach to achieving climate neutrality in cities. Land use and spatial planning have a coordination role to play, allowing to integrate the numerous issues and opportunities at stake and ensuring their effective implementation (i.e., identification of areas for RES installation, updated planning instruments and entry into force of regulations and codes, decisions on new developments and regeneration). While these strategic planning issues are long-term in nature, and realistically will have minimal impact between the launch of the Mission and 2030, they are still pivotal for advancing the sustainability of cities and reducing GHG emissions.

Some relevant approaches aiming at improving accessibility, connectivity, containing growth, reducing energy use and providing clean and efficient urban infrastructure, are reported below:

1) An important strategy for containing growth in urban extent is ***mixed-used development***, especially in areas of higher urban density. Mixed-use development supports walkable and compact urban form, improves accessibility and reduces energy demand for transport through co-located accommodation, employment and services. Spatial planning for more compact urban form can also improve opportunities for public transport and district heating / cooling networks while supporting the protection of carbon sinks surrounding the city (Andreanidou et al., 2018). For urban land use and spatial planning to be most effective in supporting climate neutrality in cities, it is important that these opportunities are linked with broader strategies for the urban energy system.

2) ***Transit oriented development*** strategies develop compact mixed-use developments around public transit stations, thereby creating high-accessible neighbourhoods with attention to cyclist and pedestrians. Integrating land-use and transport planning can induce to a reduction of the use of private car and single motorised journeys towards public and green sustainable modes of transport. When the public transport options are linked to electrified solutions with renewable energy, this will support rapid progress for reducing transport related emissions. Limiting vehicle infrastructure and lowering private vehicle ridership, even if electrified and sourced from renewable energy, can also reduce demand on the urban energy system. Urban green and blue infrastructure can be used to support both pedestrian and cycle routes. Overall, decisions for urban land use and spatial planning will largely shape lifestyle and behavioural changes by providing opportunities that can promote active modes of transport and preferences for public transport.

3) In the scope of urban energy planning, ***heat mapping*** of urban areas helps identify the locations of heat densities and determining strategies for district heating / cooling networks. This can also help

identify renewable energy opportunities and options for utilizing sources of waste heat, including waste heat from wastewater, data centres or industry. The PanEuropean Thermal Atlas maps heat densities for 50 000 districts in Europe (Möller et al., 2019; version 5.1, 2021) and other related heat mapping studies exist which can be used for guiding the integration of spatial and energy planning to support climate neutrality.

Through ***urban regeneration*** abandoned, underdeveloped areas can be renovated and repurposed bringing them to long-lasting life. Urban regeneration can produce new liveable environments, able to include and integrate many energy-related and climate measures aligning the development to updated goals and striving to keep the pressure for new settlement construction as low as possible: e.g., eco-districts adopting transit-oriented development strategies, including pedestrian and cyclist friendly areas, mixed use, low energy buildings and renewable energy production. Therefore, urban regeneration brings additional benefits linked to other EU strategies: reduced pressure on existing greenfield sites around cities, thereby contributing to counteraction of soil sealing, reduced disaster risk. When brownfields are regenerated land decontamination is an additional benefit.

An enabler for all of these aspects is to bring together multiple expertise, departments and services in participatory and integrated governance structures. In this way, cities can facilitate the interactions of urban planning in supporting climate neutrality and be empowered to coordinate their pathway to climate neutrality.

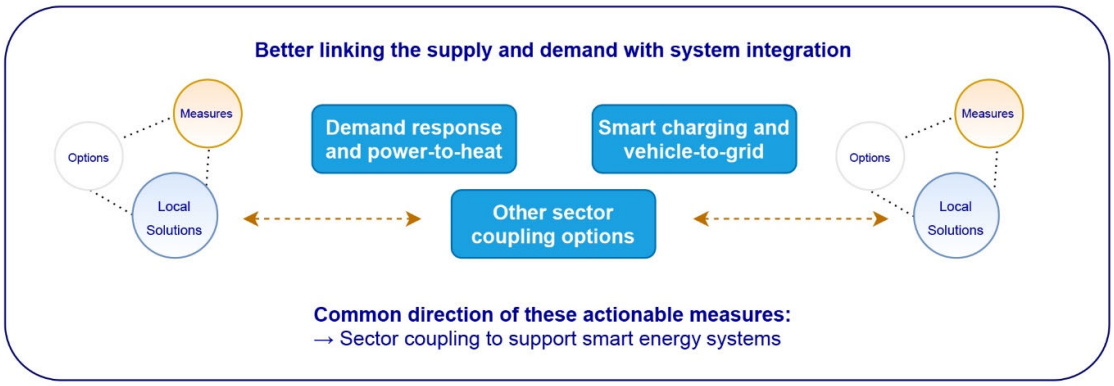
5.2 Buildings and transport in urban energy systems

One of the main directions of actionable measures that effectively cross-cuts both buildings and transport is *electrification* within the urban energy system, also considering its interactions with public transport as well as district heating and cooling networks, such as through light rail systems and large-scale heat pumps. With rapidly reducing prices for technologies that utilise variable renewable energy sources, particularly solar energy (IRENA, 2021), the power sector has a significant advantage for decarbonisation and will be the fastest in reaching net-zero in related scenarios. Electrifying energy demands in both buildings (see Section 3.1.6 above) and transport (see Section 3.2.4 above) can benefit from this rapid progress while a smart energy systems approach that integrates the power, heating, cooling and transport sectors is essential for enabling a renewable energy future (Lund et al., 2017). Cities that take upon the challenge of being pioneers for climate neutrality can demonstrate ways of increasing the interactions of buildings and transport in *smart energy systems* that involves smart power grids, smart thermal grids as well as smart gas grids (Mathiesen et al., 2015). Increasing the interactions of buildings and transport in smart energy systems will extend beyond a view of either sector and allow cities to consider options to increase sector coupling for climate neutrality.

6 Better linking the supply and demand with system integration

One of the areas with the greatest potential for innovation is solutions that will allow a better linking of the energy supply and demand so that urban energy demands can be made to follow the energy supply more closely as it continues to involve increasing shares of variable renewable energy sources. These solutions are also applicable to grid-supplied electricity where system flexibility options will allow for reaching much higher shares of renewable energy in the broader European energy system. The **EU Strategy for Energy System Integration** places emphasis on energy system integration through a process that involves the "coordinated planning and operation of the energy system as a whole, across multiple energy carriers, infrastructures, and consumption sectors" (European Commission, 2020c). Urban areas are where the energy demand is largely co-located across sectors and infrastructure, opening a highly promising venue for supporting energy system integration.

Figure 10. Main directions of actionable measures for system integration



Source: Own product.

There are **three main measures** that cities can implement to support energy system integration:

1) **Demand response** involves options for shifting energy demand in time for reducing peak demand, improving load balancing and most recently, reducing the curtailment of variable renewable energy generation in the energy system. The impacts that are realized for each of these aims depend on the scale and the number of participants that are aggregated in related programmes. Power-to-heat is one of the demand response options and couples the power and heat sectors when necessary to enable higher shares of renewable energy penetration as a means to this end. Smaller capacities can provide limited ability for shifting the time of use while large-scale demand response opportunities that utilize urban infrastructure can be especially relevant for cities (Gjorgievski et al., 2021). This includes utilizing district heating and/or cooling networks in smart energy systems as well as shifting the time of use of certain electrical equipment in wastewater treatment plants. In particular, using district heating and cooling networks as thermal energy storage through large-scale heat pumps can support time shifting based on demand response with power-to-heat for better matching the supply and demand. The amended Renewable Energy Directive emphasizes the role of thermal energy storage that is integrated to district heating and cooling networks as an important source of flexibility for renewable electricity and cost-effective operation (European Commission, 2021c). The potential of district heating and cooling for providing flexibility services in electricity markets through sector coupling is one direction of actionable measures that can be considered in cities.

2) As a demand side option, **smart charging** seeks to address the uncontrolled charging of electric vehicles and electric public transport that can necessitate larger investments for expanding the capacities of the power grid in the energy system (Heilmann & Wozabal, 2021). Beyond cost savings, both smart charging and vehicle-to-grid also have an important role in supporting a renewable energy system with which the transport sector will interact (Gonzalez Venegas et al., 2021). A bidirectional power flow that is made possible through smart charging and vehicle-to-grid allows electric vehicles and electric public transport to act as energy storage for renewable energy systems. According to one estimate, smart charging infrastructure can reduce the impacts of electric vehicles on peak demand by about 60% (IEA, 2021). Both smart and slow charging of electric mobility will be important within energy system strategies. On the side of vehicle-to-grid, electric vehicles are expected to provide up to 20% of the flexibility that is required on a daily basis in renewable energy systems (European Commission, 2020c), with an important concentration of electric mobility assets taking place in urban areas. Overall, with an expected 30 million electric vehicles in the EU by 2030, allowing these distributed storage assets to absorb renewable electricity at times of abundance and feeding it back into the grid at times of scarcity offers considerable opportunities (European Commission, 2021c). Increasing publicly accessible bidirectional charging infrastructure can be an enabler of realizing the role of electromobility for providing this flexibility.

3) There are other **sector coupling** options beyond demand response with power-to-heat, smart charging and vehicle-to-grid opportunities. Among power-to-X, one of these options is the production of clean hydrogen with renewable electricity that can be used again to generate renewable electricity in specific

moments of energy demand or injected in smart gas grids. As a vector for renewable energy storage, renewable hydrogen, mainly using wind and solar energy through electrolysers, has a strong potential while new lead markets and sustained research and innovation are important. The Hydrogen Strategy for a Climate-Neutral Europe involves the objectives of at least 6 GW by 2024 and 40 GW by 2030 of renewable hydrogen electrolysers with possibilities for local hydrogen clusters in islands, regional ecosystems or sectors where electrification may be more difficult (European Commission, 2020b). As another option, beyond its use for local electricity generation, biogas can be upgraded as biomethane to support smart gas grids when this may represent a local need or opportunity. Cities can combine the needs and opportunities in versatile ways to support transitioning to climate neutrality.

The common direction of these measures is sector coupling in support of smart energy systems as depicted in **Figure 10.** Main directions of actionable measures for system integration. These actionable measures are cross-cutting enablers of the urban transition to climate neutrality. Sector coupling provides cost-effectiveness in energy systems with high penetration of variable renewable sources (Pfeifer et al., 2021) and is one of the ways of capturing synergies in accelerating climate mitigation in urban areas as cities work across the multiple opportunities that are available, including urban land use and spatial planning (Kılkış, 2021). As further indicated in the EU Strategy for Energy System Integration, a Network Code on Demand Side Flexibility will support unlocking the potential of electric vehicles and heat pumps to contribute to system flexibility. Through system integration, cities will be supporting smart energy systems for climate neutrality.

7 The role of smart and digital solutions

7.1 Introduction

Digital solutions can be used to address environmental and climate issues (e.g., pollution, traffic congestion) and reduce GHG emissions. With the introduction of cheap sensors, the Internet of Things (IoT), Artificial Intelligence (AI), High-Resolution Global Positioning System (GPS), and Big Data, key functional elements of cities are expected to change and impact all aspects of our lives (Vandecasteele et al., 2019).

Smart city solutions and data-sharing can be used, for example, in monitoring emission reduction in mobility, providing smart energy grids, improving energy efficiency in buildings, monitoring air pollution, water and waste management. Particular added value can by gleaned by decision-makers when data from across sectors are combined, to understand and model interdependencies in a complex city environment, for example the impact of traffic management on air and noise pollution in a particular street or district. Integration of data, via interoperable local data platforms, is a powerful driver of the systemic transformation of a city (Pellegrin et al., 2021, p. 30).

The process of digitalisation in smart cities is triple layered (Woetzel et al., 15 June 2018), consisting of:

- the infrastructure (networks and sensors);
- smart apps and data analysis;
- data-informed activities (decision-making and behaviour changes).

To achieve impact and ensure long-term sustainability, smart cities innovations need to be scalable and ideally cross-sectoral (State of Green, 2020). In addition, public-private partnerships (PPPs) and networking with other cities can be key to increasing the chances of success. The Living-in.EU community was established to respond to this demand, for cities and communities to join forces to accelerate the digital transformation, in particular by driving market demand for interoperable solutions.

7.2 The benefits of digitalisation for low-carbon cities

Useful knowledge about the state of the environment and how the economy, society, and the environment interact, can be provided by data, algorithms, and insights. If used effectively, digital technologies can help reduce overall emissions by up to 15% (Ekholm & Rockström, 2019). It is also believed that artificial intelligence and local digital twins can be powerful tools for cities and communities to make well-informed decisions (European Commission, 2021d), support sustainable integrated urban planning and facilitate citizen engagement (European Commission, Integrated Planning, Policy and Regulations). Digital Twins can in particular

help address complex challenges in a holistic manner, due to their ability to combine data from multiple domains, visualise their correlation as well as provide simulations and what-if scenarios. The added value of artificial intelligence and local digital twins are for example illustrated by the "DigiTranScope" project and various local digital twins which have been created in Europe, such as the Amsterdam City Dashboard, the Helsinki Energy and Climate Atlas, the Rotterdam Digital Twin and the Flanders DUET Digital Twin (European Commission, 2021d). Data platforms and the use of open standards and technical specifications to share data across sectors, will also be of importance for the (scaling-up of) digital transformation.

Other benefits of digitalisation are mentioned in the 2021 report by the International Energy Agency (IEA, 2021), some examples include:

- Improving the operation and efficiency of energy systems and addressing equity and reliability issues, through the synthesis of new information flows;
- Creating economies of scale and minimising the need for new infrastructure and creating new opportunities (especially in cities with high population density);
- Creating new business opportunities and revenue streams, enabling innovative financing mechanisms, and improving risk perception.

Although creating new business opportunities is advantageous, systemic transformation will be key (requiring sustainable, integrated innovation). In devising and implementing a strategy/plan for smart and low-carbon cities, it is crucial that local authorities take into account the potential **co-benefits** ensuing from the digitalisation process for all local stakeholders belonging to the quadruple helix spectrum, including local administrations, research institutes, industry, citizens, businesses and other local actors (Borsboom et al., 2019). Conveying the wide variety of expected positive spill-overs, while highlighting the linkages with stakeholders' needs and expectations, increases the chances of support of green digitalisation measures, and take-up of new technologies and services.

7.2.1 Improving evidence-based decision making

In the context of the twin transitions, ICT-based solutions enable the collection and production of large amounts of data that can be used by local governments in the planning, implementation and evaluation of municipal activities, making decision-making at the local level more informed, less time-consuming and more efficient and effective.

Indeed, the delivery of most urban services (e.g., transport) is more efficient when local governments have a better understanding of citizens' preferences, as a tailored public service delivery increases the chances of widespread citizens' use, which in turn leads to economies of scale.

For example, the use of real-time data and digital technologies helps city governments to develop more accurate land use plans (e.g., based on climate- or natural hazards-related risks) or to optimally match the energy distribution network infrastructure to the local renewable energy potential (e.g., through GIS mapping), allowing for a more efficient management of city services overall (IEA, 2021).

More generally, digitalisation can also improve organisational and administrative capacity, enhance operational performance, and help overcome challenges such as excessive bureaucratisation and silo approaches to policy development, which are detrimental to the adoption of integrated and cross-sectoral solutions critical to achieving climate neutrality.

7.2.2 Advancing R&I and the digital economy

The large-scale deployment of ICT/IoT infrastructures and the use of ICT-enabled devices and smart applications in urban contexts can be an opportunity for incumbents that already have a relevant track record in digital products and services to increase their transaction volumes (often businesses). Similarly, it is an opportunity for local individual entrepreneurs, SMEs and start-ups to enter and consolidate their presence in a new market (Kummitha, 2019). However, in order to support the development of an open and fair market where smaller businesses can grow and thrive, (local) municipalities need to take complementary measures to ensure interoperability, and thus steer clear of the technology and vendor lock-in mechanisms that exclusively benefit multinational corporations (European Commission, 2021e).

While cities aim to digitalise for carbon neutrality, they can leverage green innovation opportunities in critical sectors (e.g., electrification, hydrogen, bioenergy) by encouraging investment in R&D for the development of new (and potentially disruptive) products and technologies. Cities can thus contribute not only to the creation

of new business opportunities, but also to the development of a stronger knowledge base in the region (universities, research organisations) and to the consolidation of academic-industrial ties in the local ecosystem, especially if they adopt an integrated and open approach to innovation.

Once the innovative technologies are deployed in smart cities, the data generated could be made available in the form of open datasets, representing an additional entrepreneurial opportunity that can be exploited *inter alia* by enterprises and researchers for the development of new products and services. The European Commission will support data-sharing within and across cities, including through the creation of data spaces under the **Digital Europe Programme**, as part of the European Data Strategy. The smart communities data space will be a cross-sectoral data space to facilitate re-use of data within and across cities, with an emphasis on use-cases addressing the European Green Deal objectives.

Box 9. Good practice: open data

Since 2011, the Helsinki metropolitan area has provided free access to the vast amounts of data collected in its cities (Helsinki, Espoo, Vantaa and Kauniainen) via **Helsinki Region Infoshare**. More than 600 datasets are now available on the Helsinki Region Infoshare platform for the perusal of citizens, businesses, universities, academia, research facilities and municipal administrations, and have been used to develop around 280 applications.

Helsinki Region Infoshare has also published a guide that provides insight into the release of public data and explains the Finnish public administration's path to open knowledge.

7.2.3 Data for citizen engagement

Citizen awareness of sustainability and energy saving is not always present, and in any case such goals cannot yet be considered a priority. Nevertheless, the (co-)benefits of ICT-enabled low-carbon transition remain relevant for individuals and households.

In the area of energy efficiency – particularly in relation to homes and vehicles – a tangible reduction in costs, together with other non-monetary tangible improvements in living standards (e.g., thermal, visual and acoustic comfort, aesthetics, health and safety), can be an important incentive for citizens to adopt new smart solutions (Borsboom et al., 2019).

Similarly, efficient mobility and traffic management enabled by real-time data can reduce traffic congestion, facilitate and shorten commuting, and, together with the deployment of accessible smart multimodal solutions (e.g., mobility as a service), significantly improve citizens' daily lives.

Again, the reduction of GHG emissions contributes to the improvement of overall air quality in urban areas, an indicator that can be concretely perceived by residents and thus positively linked to smart green initiatives and practices, especially if access to and interaction with such data is promoted (e.g., see the *Snifferbike* pilot initiative in **Box 10**).

More generally, new ICT and IoT-enabled services are more likely to be tailored to the needs of citizens and to be able to adapt flexibly to changes in trends thanks to the monitoring of data in real time.

Moreover, the use of urban, interconnected infrastructures and digital technologies is known to generate direct and indirect network effects for the benefit of citizens, provided that a sufficient critical mass of users is reached.

Finally, civil society as a whole can benefit from open data policies, as citizens gain better access to information on issues that concern or interest them, the public sector becomes more transparent and accountable, and civic organisations and advocacy groups can use open data to better inform their work and optimise their outreach efforts (Partanen et al., 2013).

Digital tools such as Local Digital Twins are a powerful tool for citizen engagement, by presenting data and evidence in a compelling way, and for simulations and visualisations, which can help engage citizens in shaping their city. For example, FinEst Digital Twin, a smart cities collaboration between Finland and Estonia is developing a simulation tool that will allow citizens to shape development of green urban spaces using gaming technology. (Finest Twins, Tallinn-Helsinki dynamic green information model).

Box 10. Good practice: air quality monitoring

The Province of Utrecht (FIWARE, 01 October 2020), in collaboration with other stakeholders, has launched the pilot initiative "**Snifferbike**", in which a number of volunteer citizens equip their bicycles with sensors to monitor air quality. The *Snifferbike* sensor not only measures three types of particulate matter and other air quality indicators, but also anonymously tracks cyclists to determine their habits and where cycling infrastructure could be improved based on traffic patterns.

Based on the data collected, a mobile application for citizens allows cyclists to track air quality and choose healthier routes. A management dashboard also provides data on the current state of the environment that can be used by policy makers dealing with environmental and mobility issues, as well as by local research agencies.

The pilot was eventually scaled up and by August 2020 all *Snifferbik*e sensors had collected nearly 35 million data points and participants had cycled nearly 500 000 kilometres and spent 35 000 hours on their bikes.

7.3 Measures to enable and foster digitalisation for the green transition

Measures to enable and foster digitalisation span three dimensions: technological, policy-driven and funding/finance. This section discusses each of these dimensions in more detail.

7.3.1 Enabling smart (data) infrastructure and integrated solutions

Digital twins of a city are considered the next phase in smart city management, as they enable policy-makers to visualise and simulate the impact of their decisions in a test environment, while facilitating the participation of citizens in decisions around urban planning that impact their lives. Many cities do have data about their built environment through their cadastre or geo-spatial information systems, while information about real-world objects in cities (e.g., buildings, roads, bridges, etc.) and, in particular, real-time data (collected through IoT and sensors) is usually distributed, stored, and managed by different organisations and actors. Due to the distributed and heterogeneous nature of the information, creating a **digital twin** of a city is both technically and organisationally challenging, yet could be a powerful means to break administrative silos and address complex urban challenges (European Commission, 2021d). To link and leverage such distributed and heterogeneous data, the Commission will support the creation of a data space for smart communities; a secure environment, where smart cities and relevant stakeholders can share data under a set of jointly agreed set of conditions (European Commission, 2021d, p.19) The first set of pilots to validate the data space will focus on topics including climate adaptation and extreme weather events. In addition, spatial data infrastructures for smart cities can play an important role in establishing interoperability between systems and platforms (Kolbe & Donaubauer, 2021). Smart data infrastructures (SDIs) for smart and sustainable cities have been introduced to enable integration in this context (Moshrefzade & Kolbe, 2016).

An example of a digital twin is the Helsinki Climate Energy Atlas, a 3D model of the City, reflecting buildings and energy uses, on the basis of which four models were built to forecast energy consumption and future demand and the renewable energy potential (Solar, Geothermal) and to plan renovation of the city's building stock to improve energy efficiency (Dumitrascu, 2021). Another good example is RUDI, the Rennes urban data interface (Urban Innovative Actions, RUDI - Rennes Urban Data Interface, no date).

Another data infrastructure initiative is Gaia-X[25], a project to create a federated and secure data infrastructure. The architecture of Gaia-X is based on the principle of decentralisation. The organisational structure of Gaia-X is based on three pillars: the Gaia-X Association, the national Gaia-X Hubs, and the Gaia-X Community. The members of the Gaia-X Hub Germany, for example, are organised in working groups, including a Smart City/Smart Region working group. The Smart City/Smart Region working group aims to "*improve the infrastructure by providing data platforms for cities, municipalities, and districts in order to ensure secure, legally compliant, rule-controlled data exchange and comprehensive data processing as well as the shared use of data from various sources*".

Urban Data Platform

A key enabling infrastructure is a local data platform (also known as urban data platform or urban digital platform), **the beating heart of the urban digital transformation.**

[25] See the Gaia-X website for more information: https://www.data-infrastructure.eu.

Urban data platforms are at the core of the digital transformation of cities and communities. It is the centrepiece for new and innovative services; from a simple route-planner to a complex digital twin solution. Urban Data Platforms are the beating hearts of the urban digital transformation as they connect, analyse and visualise all data from the urban fabric. From here, data can be further shared to city services or third-party providers offering seamless mobile experiences for citizens.

Cities and communities are benefitting most from Urban Data Platforms when those are *open*. Following the German Institut for Standardisation (in German "Deutsches Institut für Normung" or "DIN") "DIN definition", an open urban platform is an *"urban platform that uses open standards and interfaces to guarantee compatibility and interoperability with other systems and other urban platforms."* (Beuth, 2017). Open urban data platforms enable cities and communities to: (i) customise the platform according to their needs, (ii) avoid vendor lock-in & technology-debt, (iii) share data with third parties, (iv) connect services and data more easily, and (v) provide better digital services to their citizens at lesser costs (Living-in.EU, Urban Data Platform & Sheombar, 2020).

Box 11. Other good practices: Interoperability initiatives

An example of integration of cross-domain city data is the European Commission-endorsed[26] **FIWARE**, a framework of open-source platform components that supports the development of context information-based smart solutions. Thanks to its vendor-neutrality and interoperability, it enables, among other things, cross-sector interchange/utilisation of data and helps avoiding vendor lock-in, all the while contributing to building a holistic, beyond-silos city governance (Kobashi et al., 2020). Many cities worldwide already use FIWARE in the realisation of their smart city projects. For example, Cartagena, thanks to its FIWARE-powered city platform, is currently implementing a Smart Irrigation Management System, through the deployment of compatible third-party IoT devices. The project, by allowing the smart monitoring of water consumption and the management of irrigation programs based on sensor data (e.g., soil humidity, temperature sensors, meteorological station) is already contributing to climate neutrality, having reduced water consumption by up to 30% and CO2 emissions from soil by 40% (FIWARE, 20 April 2021).

Minimum Interoperability Mechanisms (MIMs), developed by the Open and Agile Smart Cities (OASC), are a set of practical capabilities based on open technical specifications that allow cities and communities to replicate and scale solutions globally. By sharing and re-using digital, data-driven solutions, MIMs contribute to reducing the cost of innovation, increasing the return on investment, and – through the use of open standards and Application Programming Interfaces – help avoiding vendor lock-in. Currently, OASC features three types of MIMs, namely Context Information Management, Common Data Models, Marketplace Enablers (Ecosystem Transaction Management), and it is working on Personal Data Management and Fair Artificial Intelligence (Open & Agile Smart Cities vzw, Minimal Interoperability Mechanisms – MIMs, no date). The MIMs Plus, are developed and maintained by the Living-in.EU movement, and combine the MIMs and additional fundamental building blocks (Living-in.EU, 2021).

7.3.2 Policy driven measures

As cities may have different needs, a technology governance framework is required that they can consult and adapt to local circumstances. The G20 Global Smart Cities Alliance was established to create a policy roadmap to help cities identify and adopt basic strategies for smart city technologies (World Economic Forum, 2021). The first of five model policies were announced in 2020 and focused on the following: (1) ICT accessibility (in public procurement), (2) open data, (3) privacy impact assessment, (4) Dig Once (for digital infrastructure), and (5) accountability model for cybersecurity.

7.4 Funding and financing for Smart City solutions

When considering financing and funding options for testing, deploying and scaling-up smart city solutions and projects, cities should (1) understand the value of the project, (2) link it to funding and financing options, and (3) determine the appropriate delivery method (Deloitte, 2018).

Several financing and funding options are listed in Section 9, and there are many urban initiatives that have led to successful innovative digital solutions, such as:

— the European Innovation Partnership on Smart Cities and Communities (EIP SCC),

[26] As of 2018, FIRWARE Context Broker is one of EU CEF's building blocks. see also for background info https://wayback.archive-it.org/12090/20210727234802/https://ec.europa.eu/digital-single-market/en/future-internet-public-private-partnership.

- the Digital Transition Partnership of the Urban Agenda for the EU (DTP UA),
- the Smart Cities Information System (SCIS),
- Horizon 2020 projects such as the Lighthouse projects and the large-scale IoT pilots,
- Urban Innovative Actions,
- the URBACT programme,
- the European Institute of Innovation and Technology (EIT) and its communities,
- the 100 Intelligent Cities Challenge and the Declaration of Cooperation on Digital Transformation and Smart Cities Growth signed by the mayors of all participating cities,
- the eGovernment action plan 2016-2020, and
- the Tallinn eGovernment ministerial declaration (2017) (Living-in.EU, Declaration).

The **Digital Europe Programme** will support the creation and validation of a governance scheme and reference architecture for a **data space for smart communities**, for the secure exchange of public and privately held data at EU level. The identification of common priority datasets linked to the environment and climate-related challenges will increase the potential for sharing data solutions between communities across borders and sectors and help them meet the objectives of the European Green Deal. The action will contribute to the definition of the technical infrastructure for data sharing across relevant domains (in particular, traffic, electricity, pollution, extreme weather events, water, sewage, waste management, urban infrastructure, etc.), in order to create cross-domain innovation and move towards the Green transition in each local context. The data space will be tested through dedicated pilots, and also through the AI Testing and Experimentation Facilities for smart communities. In addition, the Commission will procure and make available to interested cities and communities interoperable, technical building blocks, to help create their (local) digital twins.

Box 12. Example of leveraging financing for smart city projects:

Sharing Cities is a major international smart cities project that addresses some of the most pressing urban challenges facing cities today, such as energy consumption, low-carbon transport and buildings, and the harnessing and use of data for the good of the city. The programme brings together 34 partners from government, industry and academia to collaborate on solutions together – thus ensuring a greater chance of success, sustainability, and scalability. Its user-centric, city-focused approach is helping to shape the smart city market. The H2020 project is funded by the EU with EUR 24 million. It aims to trigger EUR 500 million of investment and to engage over 100 municipalities across Europe.

7.5 Using data and financing Smart City solutions

Data can illustrate the sometimes initially intangible value that cities have generated and can be used to attract private investment and finance smart city solutions. Data is also a fundamental opportunity that smart cities can exploit in the future. For example, data-driven innovations can improve the circular economy, by more accurately managing consumption and production processes.

However, data can also be a weakness in cities that are less able to leverage data, and a threat given the privacy concerns arising from the wealth of data generated by smart cities (OECD, 2020). Moreover, as highlighted by the University of Birmingham *"the overall evidence suggests that we do not lack technologies, nor the data captured by technologies, but that the bigger challenge lies in governance, financing, and complex ownership structures that make it difficult to put the data to good use"* (Birmingham Policy Commission on Future Urban Living, 2014).

In 2020, the European Commission put forward the Data Governance Act, also known as DGA (European Commission, 2020e), as part of the European Strategy for data. The DGA addresses, amongst others, the situation of allowing data use based on altruistic grounds. The Data Act follows up on this proposal and aims to propose measures to ensure fairness in the allocation of data value among the actors of the data economy.

Box 13. Sidewalk Toronto project

Quayside is a waterfront district in Toronto, Canada, where former port facilities and industrial uses are to be redeveloped. The government agency Waterfront Toronto is planning a 4.9-hectare site for a new residential development to be built between the East Bayfront and Port Lands neighbourhoods**.** Alphabet's Sidewalk Labs in cooperation with the City of Toronto, proposed a smart-city project "**Sidewalk Toronto"** for the Quayside neighbourhood**.** The project would be composed of climate-positive buildings, the use of an automated pneumatic waste-disposal system, affordable housing, and extensive public spaces and use nature-based storm-water management (Vandecasteele et al., 2019). However, the project was criticised from the beginning by citizens who were concerned about how Alphabet would collect, protect, own and use their data. Block Sidewalk, a citizens' group, was particularly critical of the lack of transparency in the implementation of these smart city ideas and the fact that citizens were not adequately informed about how their data was being handled (Appleton, 2020). In May 2020 it was announced that Sidewalk Labs would not be pursuing the Quayside project in Toronto (IoT M2M Council, Sidewalk Labs pulls out of Toronto Quayside project).

Careful and transparent consideration is needed when addressing issues of public control and ownership of data collected through (new) technologies, particularly in cases where services are outsourced to third parties. Technologies in themselves are neutral – it is how they are managed that will determine the real impact on city life (Vandecasteele et al., 2019).

7.6 Delivery example – (ICT) innovation procurement

By developing a forward-looking innovation procurement strategy that uses Pre-Commercial Procurement (PCP) and Public Procurement of Innovative Solutions (PPI) in a complementary way, public sector procurers can drive innovation from the demand side. This enables the public sector to modernise public services faster, while creating opportunities for companies in Europe to become leaders in new markets. However, PCP and PPI are still underused in Europe compared to other parts of the world.[27] The European Commission has also published a practical guide to public procurement in the field of innovation (European Commission, 2021f). The guide contains technical advice and examples, particularly in relation to the management of intellectual property rights (IPR).

Horizon Europe strengthens co-financing for public procurers across Europe addressing common challenges by jointly implementing PCPs or PPIs. Specifically, Horizon Europe provides funding opportunities for PCPs and PPIs in several areas: health, security, energy, climate change, ICT, AI, satellite and research infrastructures etc. This includes an open PCP call to support public buyers in all areas of public sector activity to develop new green digital solutions. The following funding opportunities are offered to consortia of procurers: (i) to prepare and undertake together PCP or PPI procurements, and (ii) to cooperate on identifying opportunities and preparing for future PCPs / PPIs. The funding rates are 100% and 50% for the PCP respectively PPI actions, respectively. For PCP actions, groups of procurers implement together one joint PCP procurement. In PPI actions, procurers can choose between implementing one joint PPI procurement or several separate but coordinated PPI procurements.[28]

The Digital Europe Programme also supports the procurement of cutting-edge digital solutions. Synergies with the Structural Funds (ESIF) can also be used to co-finance innovation procurement. The Digital Europe Programme provides strategic funding supporting projects in five key capacity areas: supercomputing, artificial intelligence, cybersecurity, advanced digital skills, and ensuring a wide use of digital technologies across the economy and society, including through **Digital Innovation Hubs**.[29]

[27] For more information consult: https://digital-strategy.ec.europa.eu/en/policies/innovation-procurement

[28] For more information consult the dedicated website: Horizon Europe funding for PCP and PPI | Shaping Europe's digital future (europa.eu).

[29] For more information consult the dedicated website: Digital Programme | Shaping Europe's digital future (europa.eu).

Box 14. Good practices: example of a Pre-Commercial Procurement process "AI4Cities"

AI4Cities applies a Pre-Commercial Procurement process, consisting of a solution design phase, a prototyping phase and a prototype testing phase, where start-ups, SMEs, and larger companies are encouraged to deliver innovative AI-based solutions to key climate-neutrality challenges (A4Cities. What is the Pre-Commercial Procurement (PCP) tool?, n.d.). AI4cities - Accelerating Carbon Neutrality is a three-year project, funded under the Horizon 2020 programme that brings together leading European cities looking for artificial intelligence (AI) solutions to accelerate carbon neutrality. The participating cities are Amsterdam, Helsinki, Copenhagen, Paris Region, Stavanger, and Tallinn. The project will focus on the specific priorities of each city.

For more examples, a list of EU-funded projects implementing Pre-Commercial Procurements (PCP) or Public Procurement of Innovative Solutions (PPIs) is provided online.

7.7 Challenges for cities to consider

Collaboration between cities and communities will be key, even if they have data and digital technologies at their disposal, to increase impact and have more control over the smart city solutions they ultimately choose. In order to remain flexible in their choice of technology providers and to create added value from their data for the common good, recent studies (Brandt et al., 2020) suggest that cities should implement interoperable, urban data platforms using a common set of open standards (European Commission, 2021d). Understanding the broader impacts of specific technologies, including the interaction, interdependencies and feedbacks between different technologies, will be critical. The full integration of different technologies that are essential for the functioning of a city (e.g. water, food, energy distribution, logistics, mobility, sanitation and waste management), will be indispensable for efficient city systems. Therefore, the components and solutions used should be able to work together through a set of interoperable standards (Vandecasteele et al., 2019).

Some cities are working on how (best) to process and use the increasingly available Big Data, often in public-private partnerships with large IT companies. While technology integration is key, it must be done in a way that benefits as many people as possible, regardless of their affinity and capabilities in terms of technology and socio-economic status (i.e., age, gender, education and income), with data use being transparent to citizens (Vandecasteele et al., 2019).

Other challenges for cities to consider:

- Data protection policies and protected ICT-platforms concerning data use, sharing, management, and exploitation by public and private sectors. Including data ownership, appropriate and consistent legislation, data sharing and standards, and cybersecurity (Vandecasteele et al., 2019). (See also **Box 15** for a good practice illustration).
- Stakeholder engagement and alignment of interests and activities. Open innovation approaches can help address this challenge (see Section 7.8).
- Limited operational and financial capacity. Collaboration with other cities (e.g., joint investment, development and maintenance of data infrastructure) can help address this challenge.
- Limited staff and skills to implement smart city projects.
- Future proofing in terms of technological, economic and legislative changes (Romualdo-Suzuki & Finkelstein, 2020).

The pollution risks associated with digitalisation should not be neglected, even if the environmental benefits of digital solutions can mostly offset their negative environmental impacts. Unfortunately, the environmental burdens and impacts associated with digitalisation are still under-researched and more investigation is needed. Be that as it may, this should not deter efforts to reduce energy consumption, GHG emissions and resource use through better circularity, as these measures will implicitly also reduce the environmental footprint of digitalisation (European Commission, 2021d).

To measure and monitor progress toward climate neutrality, it is important to assess the impact of the use of ICT and digital technologies in cities. For example, the United for Smart Sustainable Cities (U4SSC) initiative has developed a methodology to collect data or information from key performance indicators (KPIs) for smart sustainable cities (Smiciklas, 2017).

Box 15. Good practices: data protection

CITIXL, a private/public initiative co-funded by the city of Amsterdam, has developed a six-step **Responsible crowd-sensing toolkit (RST)** to help other municipal innovators in the implementation of ethical, open, and effective crowd monitoring solutions. From the design of the project to its evaluation, the RST provides guidance and insight on how to address the main challenges in the deployment of sensing technology, such as: balancing trade-offs between invasiveness and public utility of the technology while abiding by the data protection legal provisions; responsibly collecting, processing and visualising data; engaging citizens both in the planning of the project and in the measurement of its ethical impact (CITIXL, Responsible Sensing Toolkit, no date).

7.8 Living Labs in Smart Cities

To reap the benefits of digitalisation and address the challenges it brings, cities are increasingly experimenting with a variety of **open innovation approaches** (Chesbourgh, 2003) to implement smart city solutions. Open innovation frameworks enable the development and testing of smart city technologies and solutions, while taking into account the local context, such as the physical and digital infrastructure, resource availability, and innovation readiness of the public administration, local stakeholders and city inhabitants. In this way, cities can constitute open innovation ecosystems where R&I, technology and data can be shared and co-created by and for all stakeholders to make urban areas greener and smarter, and to support the transition toward climate neutrality. Open innovation approaches are well-suited to implement smart city projects for climate-neutrality because they allow for (1) multidisciplinary and experimental approaches and integrated solutions that are needed to address complex and interconnected urban challenges, and (2) citizen-engagement and multi-stakeholder approaches that are needed to ensure impact and uptake of new smart and green technologies.

Living labs (ENoLL, What are Living Labs, no date) are one specific open innovation approach that is particularly practical and versatile for urban transitions. Living labs enable smart cities to "foster user-innovation and tailor innovations to the needs of their citizen by stimulating collaborative development of innovations with multiple stakeholders" (Baccarne et al., 2014). The following outlines how living labs can support and promote multidisciplinary approaches and integrated solutions, and ensure citizen engagement and multi-stakeholder approach, with a particular focus on the impact on climate neutrality.

7.8.1 Testing integrated smart city solutions in real-life settings

Key to the living labs approach is the idea of testing innovations in real-life settings. Before new technologies and applications are put into operation, they need to be tested under (close to) real-life conditions in agile environments and interoperating with a multitude of devices, systems and infrastructures. Cities can therefore implement living labs by providing the physical context for the development of new climate-neutral technologies and solutions. These can range from individual buildings to entire neighbourhoods to large-scale integrated public services (See examples in **Box 16**).

By implementing living labs, cities can therefore provide vital support to businesses in developing, evaluating and commercialising products and services as testing in real-life setting helps them identify and address legal, regulatory, technical and operational barriers. It can also enable city authorities to observe and address the multiple environmental, social, policy and regulatory implications of smart city projects.

Living labs further promote an iterative approach to innovation. Feedback gathered from use and evaluation of the products and services can accelerate development cycle and time to market. City authorities can test new concepts and identify solutions that can be scaled up, and in the process, attract support and attention from different stakeholders (Borsboom et al., 2019).

7.8.2 Multi-stakeholder approach and citizen-engagement

The complexity of smart city projects calls for the engagement of many different stakeholders and alignment of diverging interests (Borsboom et al., 2019). Living labs promote a **quadruple helix approach** (Arnkil et al., 2010) in order to involve and collaborate with a range of stakeholders, including citizens, companies, research, academia, industry, local businesses and other local actors. It applies co-design and co-creation methods to involve and align different parties that contribute to, and are affected by, new technologies and applications. While living lab approaches are not dependent on smart technologies, new ICT and infrastructure capabilities of smart cities enable and facilitate living lab activities by providing digital platforms, technology and data for multi-stakeholder participation and engagement.

In particular, these capabilities have given rise to an increased emphasis on citizen/user centricity which is at the core of living labs. Here the idea is that cities can involve users/citizens in the early conceptualisation and design of smart city technologies and solutions. On the one hand, solutions that are implemented in a real-life setting and validated by users are more likely to be adopted smoothly and swiftly. Citizen/user engagement serves to foster uptake, trust in, and acceptance of green and digital technologies, contributing to achieving climate-neutrality. On the other hand, solutions are created and adapted to citizens' diverse need, local contexts and specific circumstances, improving their effectiveness and ensuring that they work for people.

In this way, the new digital tools and methods can be used to benefit from **collective intelligence** by enabling new ways of understanding citizen needs, concerns and expectations, and of creating value through collaboration. Digital technologies can assist with citizen engagement, for example by visualising data in a way which clearly communicates the impact of actions, or for participative planning and decision-making (for a case study see Dembski, et al., 2020). However, consideration must also be given to ensuring that use of such digital tools for citizen engagement do not exclude older or vulnerable groups who tend to be less digitally literate.

Together, multi-stakeholder approach and citizen engagement enable cities to raise awareness and garner the support of different stakeholders for the digital and green transitions. Moreover, "Smart City pilots can foster change on a more latent level, by inspiring and stimulating debate on contemporary urban challenges and solutions" (Baccarne et al., 2014).

Box 16. Good practices: Living Labs in Smart Cities

Mobility HUB. Since 2018, Bergen is implementing mobility hubs that combine car-sharing stations on public street space linked to public transport, cycle routes, bicycle parking, real-time transport information and pedestrian facilities (Nordic Smart City Network, Smart mobility, n.d.). To exchange best practice in shared mobility solutions with other European cities, Bergen participates in the EU-funded Interreg North project "SHARE-North", which implements living labs for integrating modern technology with activities to support changes in mobility behaviour (SHARE-North, n.d.). As a result of these efforts, from 2016 to 2017, CO_2 emissions from road traffic in Bergen were reduced by almost 12 per cent (SHARE-North, 2019).

IoT Living Lab and City Innovation Exchange Lab (CITIXL). Initiated in 2015 in Amsterdam, the IoT Living Lab promotes IoT interactivity in public spaces to encourage citizens and cities in testing and prototyping innovations. The original project received support from the Open Data Incubator, a project funded by the Horizon 2020 research and innovation programme (Van der Veen, 2016). A follow up to this initiative is CITIXL, a public-private partnership that implements inclusive experimentation, testing with the public in Living Labs, and sharing their expertise and experience globally (CITIXL, About, n.d.).

LEAD project. The project (2020-2023) aims at developing Digital Twins of urban logistics networks to support experimentation and decision making with on-demand logistics operations in a public-private urban setting. Living Labs have been set up in six cities (Budapest, Lyon, Madrid, Oslo, Porto, The Hague) to improve low-emissions operation and efficiency of parcel delivery, reduce costs and externalities through forecasting and predictions, and support advanced decision making through the entire logistics lifecycle, while fostering stakeholder participation. The project has received funding from the European Union's Horizon 2020 research and innovation programme and is part of the CIVITAS initiative (Lead Project, About n.d.).

Antwerp Circular South. From 2018 to 2021, the city and its residents tested advanced technological solutions together, through online and offline activities, to collectively reduce resource-consumption, using 'behavioural nudging' (see also Section 8.3 below). The online activities included a personal dashboard that displays real-time dataflow from smart energy, water and waste bin meters, helping to increase awareness about consumption. The block-chain-based system used a special online rewarding and exchange system to encourage circular behaviour. A local Energy Cooperative enabled experiments with smart energy exchange in line with availability of renewable energy. This project was co-financed by the European Regional Development Fund through the Urban Innovative Actions Initiative (Urban Innovative Actions, Antwerp, n.d.).

8 Citizens as key drivers of the transition

Regardless of the transition stage at which they find themselves, cities and their citizens possess power to transform local, national and international agendas to support and enable sustainable transitions. Thus, in addition to investments in hard infrastructure, cities need to mobilise advanced policy making and governance capabilities so to adequately include local communities. Approaches inspired by social science highlight the importance of this. Citizens' inclusion in policy making and governance is key to enabling sustainable urban living and an accelerated transition. For example, the co-creation of strategies to reduce GHG emissions is vital for their success as citizens can often provide new perspectives and solutions.

The sections below outline main governance and policy structures and strategies that put citizens at the centre to achieve socially robust, sustainable and effective outcomes regarding climate neutrality. These include citizen engagement and co-creation, social innovation, and behaviourally informed planning practices that bind together bottom-linked, bottom-up, and top-down governance approaches.

8.1 Citizen engagement in transitions: Co-creating the City

8.1.1 Why citizen engagement in co-creating the city is a condition to succeed

This section provides information on why and how to engage citizens in the design and implementation of climate neutrality projects in cities. In many cities around the world and for some time, citizens have been invited to take part of planning the city. When transitions are imperative, it is hard to conceive of citizens as mere receptacles of top-down strategies and design. The COVID-19 pandemic is showing that dialogue is necessary and that citizens have resources (knowledge, ideas, networks, etc.) that will have to be activated if the goals set for the climate neutrality are to be seriously achieved. Novel technologies can significantly improve citizen participation, but there is a need to better understand and systematise current and emerging practices.

Meaningful engagement with citizens in the design and implementation of projects and policies to reach climate neutrality is important in terms of sustainability and success. The energy transition towards low-carbon energy resources requires both a technical and social shift. Energy systems are often characterized as *socio-technical* systems in that they involve not just technical infrastructures (grids, machines and devices), but also the people who design and make technologies, develop and manage routines, and use and consume energy (Miller et al., 2013). Research shows that the social dimension is equally important to that of technology, stressing the need for institutional responses that are directed towards participatory formats (Rogers et al., 2008; Goedkoop et al., 2016). A socio-technological transition can occur only with citizens' support and participation (Vainio et al., 2019).

From citizen-led projects at the grass-roots level to citizen engagement initiatives kick-started by public authorities, citizen participation regularly offers paths not considered or followed by other actors – thus citizen engagement offers a level of innovation and critical thinking that might otherwise not be incorporated into policy. For example, citizens can place pressure on approaches commonly used within cities to address complex issues, while also enlarging the available pool of knowledge and resources (Nascimento and Pólvora, 2016). They may also help to improve the democratic traits of specific solutions, with good opportunities for networking or amplification effects via the use or creation of new technologies[1]. These developments are enshrined in the goals of the New Urban Agenda which calls for more inclusive, accountable and participatory sustainable urbanisation and settlement planning.

Box 17: Citizen participation is happening in cities, whether orchestrated or bottom-up. The processes need to be harnessed and multiplied.

More inclusive styles of urban governance are already being adopted, but will require larger transformations in the management of cities in the future. Including a more diversified set of actors in urban deliberative processes is a key trend within bottom-up structures of governance now sprawling across the world to tackle diverse issues, from enhancing cultural diversity to off-grid production of food and energy. In this transformation process, citizens can increasingly influence the governance of local matters, from neighbourhood assemblies to the use of participatory online platforms. Decidim.org is an example of an open-source online infrastructure that has been adopted by more than 40 municipalities in Spain and France. Through Decidim, thousands of people have the opportunity to organise themselves democratically on several levels by making proposals, fostering decision-making discussions, and monitoring the implementation of decisions. For instance, in Barcelona, since its launch in 2016, more than 28 500 people have joined the platform, with around 12 500 proposals submitted, 9000 of which have been turned into public policy. Investing in the city – Participatory budgeting (PB) is a collaborative approach to distributed resource allocation and investment, via structures that are co-produced within the political, social and economic environment of each city. Since 1989, when it was first adopted in Porto Alegre (Brasil), PB has spread to over 7000 municipalities worldwide (Dias 2018). A wider implementation of PB programmes aimed at empowering citizens at more levels of governance can be seen as an opportunity to also provide historically excluded citizens with access to important decision-making venues (Wampler 2007). Organisations such as the UN199 and the World Bank200 flagged PB as a good practice in public spending, as well as in interactions between government and civil society.

Source: Alberti et al., 2019.

8.1.2 Citizen engagement: some basics

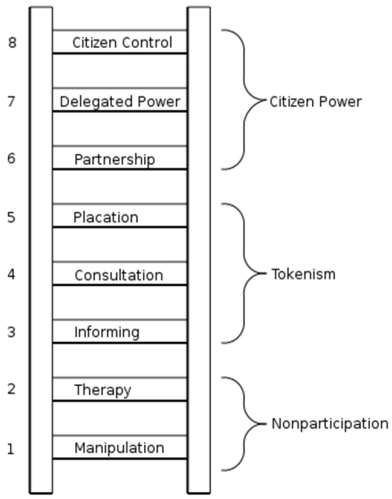
There are several definitions of citizen engagement (or citizen participation), but in the context of the Mission, citizen engagement should not just be about exploring opinions and interests, or eliciting knowledge and values, but about openly discussing matters of 'concern' and controversy (Chilvers and Kearns, 2015). Furthermore, this definition recognises that there is not a single public with coherent and static views that can be 'surveyed' but that such views can only emerge through co-creation and deliberation. In addition, engagement should aim at mobilising the knowledge, imagination, affections and values of citizens to improve the quality of policymaking.

In 1969 S. Arnstein published a ladder of citizen engagement – see **Figure 11** – that, as of today, is still a valid way to map citizen engagement from a citizens' empowerment perspective. Her work was focused on city planning processes and the ladder reflects different degrees of engagement and 'citizenliness' (M. Michael). For the purposes of the Mission, it is considered essential to focus on methodologies that are compatible with an understanding that we are essentially in the upper steps of the ladder, in other words, processes that seek to engage citizens in the co-creation of proposals and/or their prioritisation in order to address collective matters that concern them.

This guidance assumes that citizen engagement aims to genuinely influence the design of the process it is contributing to, and therefore the idea of deliberative process is equally key.

There are different flavours of organised citizen engagement, which correspond to different objectives and expectations, but the stage at which citizens are engaged in the policy process and the political follow-up of their framings, recommendations and proposals is specifically important. Deliberation and co-creation are used often to describe processes where citizens actively contribute to the shaping of processes they are engaged with – see **Figure 11**, roughly these are citizen engagement modalities that fall on the ladders 6 through to 8. A deliberative process is about "determining what a group of people can agree to, rather than what as individuals they might like or want. This process produces a set of well-informed recommendations that can form the basis of future policy decisions, rather than generating a list of top-of-mind opinions. (…) [So, it is about] weighing different factors, exercising good judgment, and proposing a solution." This implies a political commitment to take citizens "views seriously and to respond constructively" to their proposals and recommendations.

Figure 11. Ladder of public participation.



Source: Arnstein, 1969

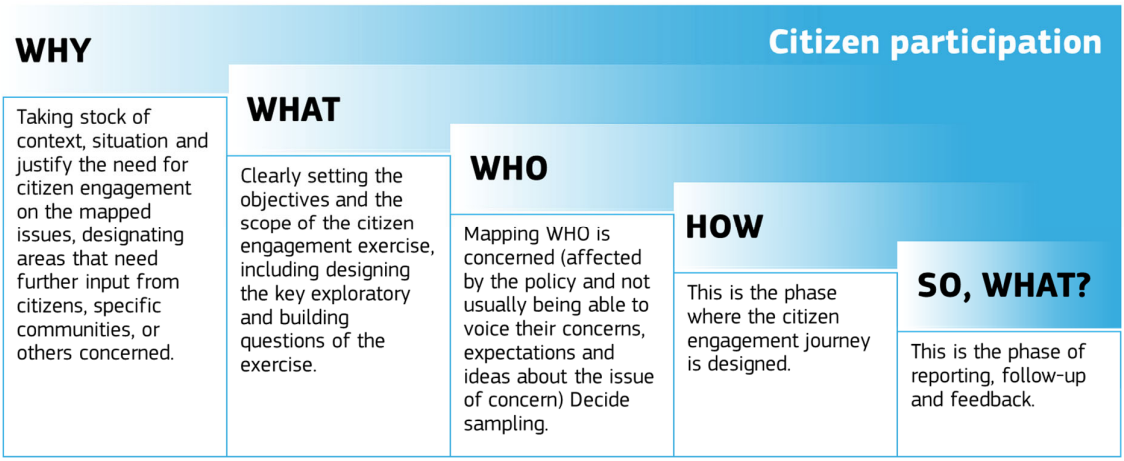
Co-creation is simultaneously 'mindset, method and tool'. Here we are interested in co-creation both as mindset, i.e., as the set of principles that ensure a respectful and equal relationship with participants, and as a method to the extent that it provides a collection of tools and techniques to be used mainly during the exploration phases of the policy design.

In any case, through such processes, citizens can be invited to co-frame the issues; situate those issues in the contexts known to them; and co-create possible solutions. In other words, citizens can be engaged in co-creating and deliberating their cities' transitions.

8.1.3 Planning citizen engagement

This picture summarises citizen engagement planning. It is a phased process which includes a large number of dependencies among the phases. The duration of these processes is variable, but it is advisable to allocate at least 12 weeks from start through to reporting. It all starts with understanding the context.

Figure 12. An interlaced cycle of citizen engagement planning.



Source: Own work.

8.1.3.1 Why?

This is a first phase of the process[30], which is preliminary work that needs to be done in order to take stock of the situation. The overall question is why citizen engagement is being done and how it will be used. It is focused on studying the context and the situation. In the case of energy transition, it is necessary to explore which areas are in need of intervention, also according to public opinion as expressed through the local media, local organisations, and so on. It is important to take stock of ongoing or recent past citizen engagement activities which can help with framing the issues in which citizens are required to engage with. Are there any bottom-up initiatives? How can they help extending the engagement process?

8.1.3.2 What?

The scope and objectives of the citizen engagement stem from the "Why?" phase, i.e., the preliminary study of the situation. After knowing why citizen engagement is necessary, it is necessary to decide what the focus of the engagement should be in order to inform the design phase. What will be the guiding question? What is it that citizens will be asked to engage with? Is it co-designing actions, establishing priorities, deciding on funding, etc.?

8.1.3.3 Who?

This is the phase where a decision needs to be taken on whether to identify and target specific communities, or a random sample representative of the population of the city is more appropriate, or both. There are at least 3 different types of sampling (Teddlie and Yu, 2007): representative sampling, 'opportunity sampling'[31] and 'purposive sampling'[32]. When choosing the sampling method, time is an important factor to allow for a proper randomisation and assuring representativeness. A professional recruiting agency can take 3 to 4 weeks to randomly recruit 50 citizens. 'Representative sampling' based on solely demographic criteria is irrelevant in qualitative studies and co-creation settings, where the relevant criterion is diversity. Opportunity sampling can also be described as a call for expression of interest addressed to particular communities (e.g., university students) to participate.

Both previous phases are crucial to inform a 'purposive sampling' strategy, as that type of work is the backbone for identification of communities concerned with the policy/action envisaged to advance the climate-neutrality agenda. The number of participants needs to be decided. It is recommended that not less than 50 citizens are involved in each country.

8.1.3.4 How?

This phase is about designing the engagement journey. In this step, the structure of the engagement events is prepared. The event responds to the objectives of the process and the questions posed. The practical organisation of the event is aimed at ideation and development of ownership about the issues of concern, but it should also allow to explore trade-offs and deliver group (collective) proposals and recommendations about those issues. Information should be provided beforehand to the participants in the form of information kits, following a logic of 'progressive disclosure of information' (different layers complexity that respond to diverse needs and education).

8.1.3.5 So, what?

Feedback and follow-up are key to ensure trust in the process. Participants need to know what happens with their proposals, recommendations, framings, etc. Therefore, the reporting needs to be tailored to the (planning/design/etc.) institutional process that invites citizens to engage with. With regards to feedback, a summary report should be sent to participants and be made publicly available to ensure that participants can check if the reporting corresponds to what was discussed, created, or deliberated during the event.

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[30] This work is not totally described by for example, what EPA describes as 'situation assessment', which aims at "purpose of understanding the needs and conditions of your project and stakeholder community in order to design an effective public participation process." Not least, because the term 'stakeholder' does not describe the meanings of 'citizen' that we are covering here.

[31] 'Opportunity sampling' is sampling based on easiness to recruit (e.g., students in university, their friends and family; networks, such as friends of the museum; communities of makers, etc.).

[32] 'Purposive sampling' is sampling based on a criterion that matters of the issue of concern (e.g., for 'cancer' include patient communities; for oceans, include coastal zones communities, etc.).

Box 18. Citizen engagement methodologies

Distributed dialogue consists of a range of conversations happening in different spaces. Dialogue events are organised by interested parties (rather than centrally planned), held across different geographical areas and through a range of different media including on-line forums. The commissioning body of the Distributed dialogue is responsible for selecting the policy question and providing groups with clear questions, background information and a planning and facilitation toolkit provided. These are most important elements on which the commissioning body can deliver for successful deliberation/co-creation. Distributed Dialogue envisages overcoming the isolation of different groups, create a clear channel between them, and collect the results of the different conversations in order to feed them back into the decision-making process.

Future workshops and futuring tours consist of planning and forming a vision of the future by helping identifying aims and problems. The purpose of a future workshop method is to formulate concrete solutions and action proposals with a group of participants based on their own experiences. They usually work best for a local/proximate issues or challenges or in connection with the planning of a local action concerning a particular development.

World Café is a method which makes use of an informal cafe setting. Participants explore an issue by discussing it in small table groups through different rounds and ideally have multiple conversations that build on each other in order to consider the issue in-depth. The discussion is held in multiple rounds of 20-30 minutes. Each round is initiated with a specific question related to the overall purpose of the event. Participants discuss the questions at their table, before moving on to a new table/group for each new round. Each table has one participant as the table host, who remains and summarises the previous conversation to the newly arrived participants. At the end of the process the main ideas are summarised in a plenary session and follow-up possibilities are discussed.

Fishbowls consists in having a room arranged so that the speakers asked to start the conversation are seated in the centre of the room 'in the fishbowl' along with a facilitator, with the other participants seated around them in a circle to listen to their conversation. Some chairs may be left empty. Experts can be included among these participants. The rest of the group begins the session seated on the remaining chairs arranged in concentric circles outside the fishbowl. The facilitator opens the discussion with a question to the people in the fishbowl. Once the conversation has started, any member of the audience can come and join the fishbowl, either by taking an empty chair or replacing somebody already seated in the circle. The discussion then continues with participants frequently entering and leaving the fishbowl. When time runs out, the fishbowl is closed and the facilitator summarises the discussion.

This methodological illustration does not include for example prototyping methods which can be quite relevant in some policy topics. For more methodologies, see for example Guimarães Pereira & Völker (2020).

8.2 Social Innovation enabling fair transitions[33]

Achieving the climate-neutral, socio-economic and cultural transition is a tremendous task for our societies. Along with the technical difficulties, the transition may (if not controlled) contribute to the growing disparity between the economy and society, generating negative impacts on both, and potentially jeopardising the transition itself. Thus, social innovation is considered increasingly important for addressing the **social dimensions** of the climate-neutral transition.

To reduce its effects and risks, both academic and institutional actors recognise the need for new types of socio-economic organisation within communities and initiatives at local level. Community dynamics and the locality possess qualities that assist the generation of innovative solutions to social problems that otherwise could not be conceived or designed top-down. Cities operate at the optimal scale to become a testing ground for real-life experimentation of technologies and social arrangements needed for a successful and inclusive transition. Social innovation, which generally can be accounted for every change of social practice towards the satisfaction of human needs, will play a key role to it.

Social Innovation is context-dependent and emerges in places where the market, institutions and policy cannot guarantee adequate conditions to satisfy human needs inclusively for all. Bottom-up forces utilise local dynamics, assets, networks and/or top-down support to create a new set of products, services and organisational models that meet those needs and collaboratively alter the social relations and material conditions.

[33] Caramizaru and Uihlein, 2020; Della Valle et al., 2021; Ostrom, 2015; Koukoufikis, 2021; Mikkonen, et al., 2020.

The value of various forms of Social Innovation is sought on the processes of sense making, empowerment and increased adaptive capacity over systemic changes. By being closer to the local context, bottom-up social innovation solutions can embrace unpredictability and come up with innovations, greater suitability as well as control on decision-making and increased acceptance of transition initiatives.

The notion of innovation has a dual meaning. On the one hand, innovation means change on the way things are being done, like a newly invented set of rules, practices, technologies and structures or new in relation the practices used so far and the local context. On the other hand, innovation signals the change in the social institutions and structures so as to possibly fix the structural origins of the problems.

8.2.1 The role of Social Innovation

In the context of climate neutrality Social Innovation must be perceived **both as a process and as a strategy** capable of fostering decarbonisation and society's development by matching technological innovation with innovation in social practices and relations. Similarly, civic engagement and citizens' participation is **a goal and a result** of social innovations for the climate neutral transition.

As recent research indicates, Social Innovation promotes behavioural change on individual and collective levels as initiatives increase the acceptance and adoption of new technologies and practices, while attempting to tackle the visible but not inevitable rise of poverty and exclusion.

Moreover, acceleration is also achieved thanks to the release of local creative forces that act and utilise assets (e.g., abandoned buildings) that would otherwise remain idle. This promotes bottom-up innovation, creates a new local relational landscape and acts as a catalyst for addressing issues of fairness.

Social Innovation requires various steps, where impact is being slowly generated, transformed and transmitted from the local to the system level. For example:

- Increasing social capital and cohesion, builds a stronger sense of 'locality' and 'society'
- Interactive educational and learning processes (seminars, workshops, word of mouth, etc.) generate coordinative and synergetic opportunities
- Engaged actors and networks emergence, create competence to reach desired impacts
- During citizens' interaction, new social relations are generated, leading to a more collective, democratic, and sustainable thinking citizenship model
- Local Social Innovations diffuse and proliferate carrying transition potential on to the systems level

Given the above, cities should (and already do) include planning for Social Innovation actions in their cross-sectoral policy toolkit for the climate transition. Dedicated teams can map relevant local activities and action domains, organize municipal services, allocate funding and create programs to nurture the local Social Innovation ecosystem.

8.2.2 Community involvement and ownership

Community-based projects often lack resources and capacity to fully address the persisting social problems of inequalities, poverty, exclusion and deprivation. Alternative business models like cooperatives and social enterprises have proven to be viable. However, entering markets and competing with large traditional players with abundant financing, and often de facto monopolies, is not easy. Cities have several options to assist local projects to achieve their goals:

- Create or sustain the frameworks within which community initiatives operate
- Provide economic, technical, and legal instruments calibrated to fit community needs and assist the projects maturity
- Create a diverse landscape of social policy and action
- Facilitate a permanent dialogue between local initiatives, administrative and government bodies and non-state actors at all levels
- Accept and facilitate a change of social relations and governance dynamics
- Develop advanced communication and collaboration capabilities in a multi-stakeholder setting

— Promote power sharing and allocation beyond traditional power-holding individuals and institutions.

The above indicates that the process of empowerment of local communities should become a central and indispensable element of Social Innovation. Empowerment not only in terms of access to services and goods but also in terms of capacity-building to self-manage and own the means to achieve wellbeing during the transition.

One example is the way empowerment takes place via Social Innovation projects in the energy domain. A city could easily set up and organise open access energy communities that can:

— Empower local communities and citizens via

- Active participation in the energy transition and other climate neutral modes
- Direct ownership of RES and management of other energy projects
- Reduced costs or even profits from local RES potential
- Leveraging participation in the energy market and protection from speculation
- Contributing to energy democracy

— Empower vulnerable social groups via

- Tackling energy poverty by direct (or indirect) participation in energy communities
- Participation in energy efficiency projects

8.3 Cooperating for the urban energy transition: insights from behavioural economics

As part of the urban sustainable transition challenge, policy makers have increasingly tried to identify the most effective ways to regulate behaviours harmful to the environment. Treating climate change mostly as a problem caused by market failures, policy makers have attempted to mitigate its negative impacts by using traditional economics interventions, which typically include:

— mandates or bans (changing the availability of options),

— fiscal measures (monetary incentives and disincentives),

— non-regulatory measures (such as mandatory disclosure of information).

However, these interventions have so far proved ineffective, partially because they do not consider how the individuals targeted by the policy actually behave in their daily life. Specifically, individuals have been assumed to always make rational and selfish decisions and would change their behaviour only if provided with more information, monetary incentives or less options, however, this model does not mirror the actual way real people make decisions.

Behavioural economics provides a framework to model the behaviour of real people, which is not only more realistic but also empirically accurate. Thus, policy makers now have a scientific framework that could better support the design and evaluation of measures to achieve their policy goals.

There are two main avenues for promoting cooperative behaviours with behaviourally informed interventions:

1) Nudges

   Urban stakeholders can act as '**choice architects'** and encourage sustainable actions by influencing the **decision structure** by:

   - **changing the effort required to select an option** or the consequences associated with an option. For example, establishing a more energy efficient default setting can effectively decrease emissions from buildings, as citizens might stick to the default temperature unless prompted to do otherwise. Default options are effective instruments that change behaviour in the desired policy direction, while leaving individuals free to opt out and change the status quo. This approach always needs to be preceded by a careful assessment of the right default to select, as defaults might not work well if the target group has too heterogeneous preferences.

- **reducing the effort associated with the choice**. For example, to reduce perceived financial effort that prevents individuals from adopting energy efficient measures, choice architects can change the factors that affect perceived financial costs by enabling individuals to pay for those using the generated energy savings.
- **connecting the choice of an option with social consequences**. For example, individuals are more likely to choose electric vehicles when this choice is connected with an increase in status, and self-presentation is made possible.
- **providing citizens with assistance in following their intentions.** For example, providing reminders by disseminating information about the visit date and time of the energy audit is likely to increase the final audit uptake. Providing individuals with a planning aid or prompting them to make a plan can be effective in helping individuals switch to more energy-efficient appliances/ renewable energy products. Finally, promoting 'dedicated accounts' offering concrete saving targets that require a mild commitment might be effective in retaining beneficial behaviours.

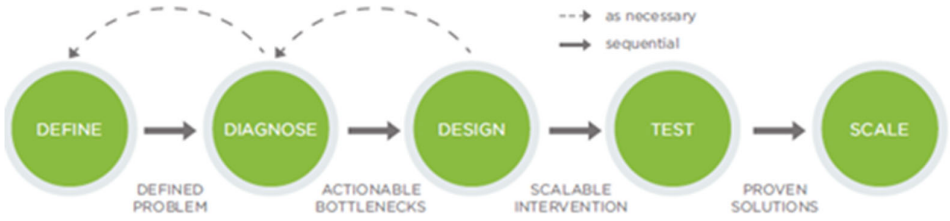
2) Boosts

Information programmes are a type of traditional intervention that enables to increase individuals' awareness of problems. In contrast to nudges, boosts are interventions that target competencies rather than behaviour, with the aim of empowering individuals to make complex decisions autonomously, such as the decision to invest in energy efficiency, to adopt an electric vehicle, etc.

Boosts target area-specific (e.g., understanding energy information) and general competencies (e.g., statistical literacy), as well as the related context (e.g., information representation). For example, energy efficiency training that provides some basic financial concepts can boost the skills needed to make calculations, thus easing the decision to invest in energy efficiency. Also, in order to be processed, information should be always presented in a simple way, for example with graphical representations.

A well-defined process to ensure that citizens' potential is unlocked helps cities address the climate neutrality challenge, monitor progress and evaluate benefits. A roadmap that relies on the best evidence/data can unlock this potential and indicate decide whether an intervention has to be improved or whether it can be scaled up or replicated in other places. To this aim, **Figure 13** below provides a roadmap to inspire cities address the nature of the problem, identify solutions and evaluate their effect.

Figure 13. The behavioural design process.



Source: Barrows et al., 2018, p. 28.

Define the problem: why does it occur? Can behavioural economics explain some behavioural drivers? (Problem: People do not use public transport. Are there enough buses? If yes, perhaps we can say that people are not motivated enough, so it is a behavioural problem, if not then the problem is structural).

Diagnose the drivers of the problem (behavioural or others?)

Design interventions that address those problem drivers (if behavioural, then we can design a behaviourally informed intervention - such as a nudge or a boost - otherwise think about other solutions).

Test the designed intervention to see whether it is effective at addressing the problem and use a Randomized control Trial.

Scale the intervention if it results to be effective, otherwise reiterate the process.

8.4 How can we ensure the transition benefits every citizen?

As cities develop and implement their climate neutral plans and policies, they need to ensure these benefits are equitably distributed across society and that potential adverse impacts are recognized and mitigated early on.

For example, more remote and less accessible, insular, or mountainous areas might be disadvantaged when developing low-emission mobility. Neighbourhoods disconnected from district heating might not benefit equally from energy efficiency upgrades of the network.

Additionally, existing inequalities (European Environment Agency, 2018) can be unintentionally exacerbated by climate policies. If not properly addressed, actions may disproportionally affect vulnerable households, micro-enterprises and transport users who spend a larger part of their incomes on energy and transport or who do not have access to alternative and affordable transitions generated by climate policies. In certain local contexts, energy efficiency polices have determined 'renovictions' (renovations causing evictions and displacement of low-income tenants), when renovation costs are passed onto tenants through rent increase, often leading to welfare losses and gentrification. They also face disproportionally high energy burdens, spending a higher proportion of their income on energy bills. Many marginalized communities are excluded from clean energy initiatives and are cut-off from efficient and affordable transit systems, while being underrepresented in the energy efficiency and renewable energy workforces. There is also evidence of gender-specific consumption patterns, emissions, and impact from climate neutral policies. In many communities, women are responsible for home care duties and are often more dependent on domestic energy, and have lower levels of car ownership, thus are more reliant on public transport. Additionally, they represent 85% of single parent families, which have a particularly high risk of child poverty. Due to their lower average income, women are at greater risk of energy poverty than men, and have fewer chances of investing in low carbon options such as energy efficiency and renewable energies. For this reason, there is increasing support for moving from gender-blind to gender-transformative policies within the European Green Deal (Heidegger et al., 2021).

At the EU and national level, to address the social and distributional impacts on those most vulnerable potentially arising from climate neutrality measures, a Social Climate Fund was created. Additionally, the Just Transition Fund was created as a key tool to support the territories most affected by the transition towards climate neutrality providing them with tailored support.

At the local level, cities must consider the potential harmful impact of national policies as well as the impact of their local policies. For instance, energy access and poverty, gender equality and equal opportunities for all, as well as questions of accessibility for persons with disabilities should be taken into account and promoted throughout the preparation and implementation of every climate action plan to ensure no one is left behind.

8.4.1 What can cities do to ensure a just transition?

Several aspects can be taken in consideration for local climate policies that benefit every citizen. Cities should know how to identify their vulnerable groups, locate them to address their needs, and involve them in the planning process. Additionally, cities should plan to monitor socially just climate actions to ensure that the actions and policies do not worsen or create new inequalities or unintended effects. On the contrary, cities should monitor urban climate policies and interventions and make sure they ultimately benefit all citizens and especially those most vulnerable groups.

- ***Mapping social vulnerability within cities.*** Finer-scale information about social vulnerability is to be used to support decision making in better targeting resources and actions, and addressing potential future increase in their vulnerability, also in relation to the implementation of climate policies. One of the main approaches is the mapping of various indicators for spatial units used in statistical reporting (i.e., percentage of households at risk of poverty with arrears on their utility bills). For example, in the context of climate change vulnerability, the Helsinki Metropolitan Region used a set of 23 indicators that are grounded in scientific research and discussed with the local stakeholders to validate their applicability in a given location (Breil et al., 2018).
- ***Links to existing tools, funding schemes, global initiatives***. Local governments could consider innovative funding mechanisms for socially just actions, such as local taxation schemes and crowd funding. Cities should benefit from synergies via participating in multiple initiatives addressing climate and social equity, such as sharing methodologies, data collection and best practices. For example, within the Covenant of Mayors for Climate and Energy, social equity, energy poverty, and vulnerable

people are addressed in defined categories[34]. There are recent attempts in localizing the Sustainable Developing Goals (SDG), offering examples of local indicators that cities can use in addressing inequality, such as goal 10, and 1/11/13 (Siragusa, 2020).

- ***Broaden participation of society in decision making processes.*** Inclusive planning processes, co-creation and engaging communities from the beginning can improve immediate climate equity outcomes and enhance long-term stability of programmes by conveying relevant and culturally accessible climate information for socially and environmentally vulnerable groups, respecting existing cultural knowledge and values (see also section 7).
- ***Ensure social protections and adapt education programmes.*** Long-term strategies should include local social protections (i.e., for job losses in sectors that rely on fossil fuels) and a change in skills training and local school curricula to ensure social equity for affected communities. Local authorities, employers, trade unions and research and training institutions need to cooperate to effectively integrate measures for a just transition into local sustainable economic development (see examples from the 'Pact for Skills' of the European Skills Agenda, anchored in the European Pillar of Social Rights (European Commission, Pact for Skills, n.d.)).
- ***Integrate equity in policy and programs assessment and monitoring.*** Including justice criteria in urban climate policies, programmes, infrastructure systems and urban design, will help the decision-making process to ensure they ultimately benefit all citizens. For instance, including procedures like the Strategic Environmental Assessment (European Commission, Strategic Environmental Assessment – SEA) for climate plans, often conducted at the local level, can highlight who will gain or lose as a result of these decisions and plans, and can help in assessing and monitoring the social impacts and positive effect of climate policies for every citizen.
- ***Integrate justice considerations into energy governance.*** A supportive choice architecture and boosting of core competencies (such as financial and energy literacy) are key channels for the fair inclusion of citizens exposed to higher risks related to energy access in the energy transition (Della Valle and Sareen, 2020). The local authorities are well placed to identify vulnerable consumers and advise, train and help them with possible solutions to overcome energy poverty and improve living conditions in building, for example by financing investments in energy efficiency. Local one-stop shops can help in the task of training and empowering vulnerable citizens to be part of the energy transition and to avoid leaving them behind and being heavily impacted. Revenues collected by carbon pricing schemes could be partly used for enabling local one-stop shops to take effective action on the ground to alleviate the impact of higher energy prices.

8.4.2 Anticipating co-benefits and trade-offs: air quality, urban heat and climate resilience

While it is important to identify and manage any potential adverse impacts of the envisaged policies, most of the measures aimed at mitigating climate change also bring important co-benefits in terms of pollution, in particular air pollution and its impact on the health of human beings and ecosystems.

According to the European Environmental Agency (EEA), a relevant share of the urban population of the EU is still exposed to levels of pollution above the air quality standards. For instance, in 2018 15% of the EU urban population lived in cities exceeding the Particulate Matter (PM) standards, while 35% suffered from excessive exposure to ozone. Unfortunately, such an exposure translates into direct impact on human health, with the EEA estimating a number of premature deaths related to PM2.5 exposure equal to 379 000 in 2018 in EU27+UK (European Environment Agency, 2020).

Cities have an important role in controlling the air quality in their territory: recent works from the EU Joint Research Centre have provided estimates on the share of pollutant concentrations attributable to sources located inside the city's area for a relevant number of European cities, for both NO2 (Degrauewe et al., 2019) and PM2.5 (Thunis et al., 2017). In both cases, the role of local emissions emerges very clearly. For NO2 the local contribution is the highest, up to 75% for the 30 cities considered in the NO2 Atlas. For PM2.5 the values are somewhat lower, with 30% of the 150 cities considered in the PM2.5 Atlas contributing to at least 40% of their air pollution, and about 50% contributing to more than 30%.

[34] Women and girls, Children, Youth, Elderly, Marginalized groups, Persons with disabilities, Persons with chronic diseases, Low-income households, Unemployed persons, Persons living in sub-standard housing, Migrants and displaced people (www.covenantofmayors.eu).

Thanks also to the experience of the cities participating the Covenant of Mayors initiative, there is now clear evidence that properly designed urban policies are an opportunity to streamline the cities' actions to jointly achieve climate and air quality objectives (Monforti et al., 2018; Peduzzi et al., 2020).

In particular, energy savings in all sectors, including transport, and fuel switching from fossil to most of renewable sources are providing benefits on both sides. At the same time, trade-offs should be minimized: for instance, fuel substitution from coal/oil to biomass/biogas in the building sector can in principle be a sound measure for pursuing cities' climate neutrality. However, such a change has to comply with the best technological practices to avoid an excessive increase of air pollutant emissions.

Further, there is evidence that hot spots for urban pollutants are also hot spots for urban heat (Ulpiani, 2021). A core benefit of achieving climate neutrality at city level is the co-reduction of urban heat islands (UHIs) and urban pollution islands (UPIs), namely localized areas where temperature and pollution levels are significantly higher compared to the surrounding rural areas, largely due to human activities and to the replacement of natural features with man-made materials. Urban heat and pollution are typically magnified under the same conditions of elevated temperature, low relative humidity, low wind speed and cloudlessness. As such, most UHI mitigation strategies have co-benefits in terms of air quality. However, potential trade-offs and secondary effects may arise and should be carefully evaluated (Ulpiani, 2021):

- Increased urban vegetation is a major ally in the pursuit of climate neutral cities. However, low-BVOC-emitting species (where BVOC stands for biogenic volatile organic compounds) should be selected to preserve air quality and avoid tropospheric ozone formation. Also, evidence suggests that high temperature can impact a wide variety of tree functions, especially when drought stress accompanies heat waves. This may result in impaired local cooling. However, some species exhibit remarkable tolerance to thermal stress (Teskey et al., 2015). Given the expected escalation of climatic extremes, advice from experts should be sought ahead of any implementation of greening measures. For instance, the VEG-GAP LIFE project works specifically on supporting the design of urban Air Quality Plans that ponder the role of urban vegetation ecosystems characteristics such as green area extension, plant type and state.
- Limiting the city size and sprawling dynamics is a key-step to achieve climate neutrality in most cases. However, adverse impacts may be observed in terms of air quality in highly centralized urban centres in valley and mountainous cities, where the increased air vertical mixing over the cityscape is beneficial for dispersion of pollutants. Coastal cities may also benefit from sprawling if the sea breeze is a major transport mode of secondary pollutants. Such transport mechanisms should be known before any major urban development is put in place.
- Highly reflective materials (cool roofs and pavements) reduce temperature-dependent emissions of ozone precursors and Particulate Matter and curtail GHG emissions by cutting buildings' cooling needs. They also alter UV reflectance, which, in some cases, may result in increased rate of ozone production at the local scale. The benefits of reflective materials are typically way higher than the potential UV-related drawbacks, however careful selection of materials and places of installation is key to deliver their full potential.

The formation of localized pockets of heat and pollution stems from a variety of site-specific phenomena. Knowledge of the local territory is key to conceive proper mitigation actions that get to the root of the problem and prepare the grounds for climate resilient, sustainable and prosperous cities.

Moving towards ambitious climate policies and investing on a healthier urban realm is also an economy-saver. There is evidence that monetised health benefits from improved air quality could offset mitigation costs in Europe (Schucht et al., 2015). Projections at the 2050 horizon in terms of morbidity and mortality impacts of PM2.5 and ozone pollution reveal that the monetised damage largely depends on how different climate policy pathways intertwine with geophysical impacts of climate change. However, the enforcement of ambitious climate policies would effectively reduce health impacts from both PM2.5 and ozone with significant co-benefits in terms of reduced health impacts (68% decrease in life years lost from the exposure to PM2.5 and 85% decrease in premature deaths from ozone in 2050 as compared to a no-climate-policy scenario) and air pollution cost savings (77%). Collectively, these effects would offset at least 85% of the additional cost of climate policy in Europe. The benefit would be even more evident during extreme events, such as heat waves, when relieving the strain on patients, hospitals and clinicians becomes a priority. For a healthcare system already tried by the COVID19 pandemic, moving to climate neutrality would go in tandem with faster stabilisation, strengthening, and recovery.

Because of their population density and developed infrastructure, cities are not only contributors to rising global temperatures, but also highly vulnerable to the impacts of climate change. The most pronounced impacts in European cities are likely to be linked to extreme weather events, such as heatwaves (exacerbated by the urban heat island effect described above), heavy precipitation, flooding and storm surge, and droughts, but also other risks including wildfires and vector-borne diseases (European Environment Agency, 2020b).

It is therefore necessary that climate resilience is pursued hand in hand with the transition to climate neutrality. Climate-smart cities are not only cities that are 'climate friendly', but also cities that are protected from climate change's negative effects (Golubchikov, 2012). Adapting European cities to reduce these impacts represents a serious challenge in itself, as tackled for example by the EU Mission on Adaptation to Climate Change.

Key aspects in mitigating present and future negative impacts of climate change are improved adaptation and resilience of urban areas. On the one hand, there are external changes, rapid or slow, which expose cities to new situations or disturbances. On the other hand, there are internal capabilities and capacities of urban systems to withstand these changes, to minimize negative impacts and to maximize benefits. Urban resilience with regard to climate can then be understood as a product of successful policies, whereby the adaptive capacities of cities (as human and technical systems) are able to withstand climate challenges with no or minimal losses to their functionality and well-being (Golubchikov, 2012).

When developing their climate change mitigation strategies, cities are therefore encouraged to assess urban specificities, and seek and identify complementarities between mitigation and adaptation strategies to foster synergies, avoid possible trade-offs and spill-over effects and to optimize the use of available resources (Andreanidou et al., 2018).

Priority should be given to "win-win" or "multiple-benefit" measures, i.e., those that deliver the desired result in terms of reducing GHG emissions but also have a significant contribution to minimising climate risks or enhancing resilience, such-as nature-based solutions or green roofs that help reduce emissions and cool buildings. A recent report by the European Environment Agency (2021b) on Urban adaptation in Europe highlights three case studies from Rotterdam, Zaragoza or Dresden, showcasing how the 'renovation wave' initiative, while encouraging renovation of existing buildings with the main aim of decarbonisation, can help to climate-proof buildings against future heatwaves and flooding. Focussing on options with multiple benefits can also facilitate the funding of the related actions by pooling resources and putting the emphasis on shared benefits that outweigh the investments (see Urban Adaptation Support Tool for further guidance).

All investments linked to the climate neutrality need to be climate proof, i.e., resistant to the changing climate, as outlined for example by the newly published technical guidance on climate-proofing of infrastructure projects for the period 2021-2027 (European Commission, 2021i). This guidance helps mainstream climate considerations in future investment and development of infrastructure projects from buildings, network infrastructure to a range of built systems and assets. That way, institutional and private European investors will be able to make informed decisions on projects deemed compatible with the Paris Agreement and the EU climate objectives.

Overall, the sooner cities will start deep reflections on how climate neutrality could be pursued via holistic approaches, the sooner possible strategic synergies and avoidable pitfalls will be identified and the sooner the benefits of properly tuned actions will be extended to the citizens.

Box 19: Critical thinking shapes the roadmap for climate neutral cities

Climate neutrality builds upon general principles that are the core of a truly climate resilient and holistic transition and stand as the backbone of any successful strategy. These can be summarized as follows:

— The climatic context matters: a solution that works for a given climate may be ineffective or even counterproductive for another. Knowledge of the macro-, meso- and micro-scale climatic dynamics is precondition for selecting the most appropriate measures.

— Passive VS active solutions: the most sustainable and climate-resilient strategy is the one that comes with no energy use. Accordingly, passive solutions should be given priority over substitute active solutions anytime they do not introduce significant trade-offs.

— Holistic thinking is all about combinations: combinations of sectors (e.g., green transport, urban planning, building energy retrofit), combinations of technologies (e.g., bioenergy and carbon capture and storage), combinations of heat mitigators (e.g., solar shadings, greenery, reflective materials, water features), combination of methods and enablers (e.g., digitalisation, circularity). Combinations are "mixed-breed" strategies: as such, they tend to be healthier, more climate resilient, and more effective under extreme events, while being multipronged and multipurpose.

— Prevention is better than cure: potential adverse impacts are even more important than benefits. This basic principle is key to enable long-lasting, economy-saving strategies. Adverse impacts stem from general considerations as well as local specificities. Comprehensive analytical methods (e.g., SWOT analysis) should be deployed to identify internal strengths and weaknesses, as well as external opportunities and threats of any planned action/measure beforehand.

— Establishing an overall organisational framework is pivotal and is the key initial investment. This requires i) identifying or setting up a dedicated policy unit to supervise and deliver policies and strategies at the city level, ii) facilitating and coordinating interdepartmental links, and iii) establishing the necessary cooperation with relevant authorities at the national and regional level. Failing this step means running for climate neutrality in low gear.

— It always comes back to health: accelerating climate neutrality is a powerful means of saving lives and protecting citizens from the detrimental impacts of a changing climate and a changing urban metabolism. Co-benefits in the health sector are sought-after feature of any strategy, while trade-offs are exclusion criteria.

9 And who will pay for all of this?

The climate neutrality objective requires the acceleration, enhancement and implementation of climate action plans, calling for a massive and expedited financial mobilisation, embedded into the institutional architecture of a city and looking across national and EU funding, finance, blending and private investment (large scale investors and crowdfunding).

The following table provides a list of financing instruments, together with application examples.

Table 8. Financial products and their use for climate action.

Financial product	Concept	Use
Grants, subsidies, and technical assistance	These instruments are considered financial products as they are commonly used in project preparation, feasibility studies, as well as fostering early investment in emerging market segments, such as feed-in tariffs for renewable energy. Without these instruments it is very unlikely that loans or more sophisticated financial products could get traction and scalability.	Subsidies to audits to identify energy efficiency in housing retrofits, grants for buying electric vehicles (including cars, scooters, and bicycles), and feed-in tariffs for renewable energy are some of the uses of grants, subsidies and technical assistance.
Loans	This is one of the most common financial instruments. It is widely known and accepted, and its simplicity generates a lot of traction.	Loans are widely available for financing energy efficiency retrofits in buildings, industry, and small and medium size enterprises. The combination with credit enhancement improves its penetration.

Financial product	Concept	Use
Credit enhancement tools	Guarantees and local currency loans are common credit enhancement tools, and are typically offered by a financial institution, reducing the risk of an investment in being paid back in full.	Commercial banks have received partial credit guarantees, enhancing the credit of a lender, such as a household, in getting a loan to retrofit a house. Financial guarantees improve access to financing as well as reducing the cost of capital in niches where risk perception is a determinant for financing and scaling up.[1] Also, providing financing in a local currency increases the demand for loans, reducing foreign exchange risk.
Private equity funds	These funds take an active role in having a partial or total ownership of a firm providing a service. PE funds are active in the entrepreneurial environment and are very reactive to policy and market changes.	PE Funds are becoming active in investing in Property Assessed Clean Energy (PACE) financing in the residential sector, but are also sensitive to investments in residential, commercial, and industrial buildings that comply with international green credentials.

[1] Saheb and Ossenbrink, 2015.

Source: Own work.

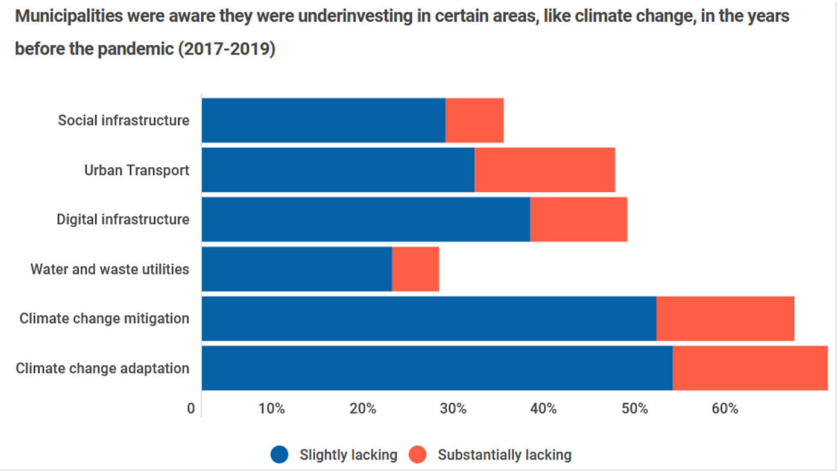
This financial mobilisation is key to reduce the existing investment gaps in financing urban infrastructure and services by engaging the private sector in this fundamental transformation. In this context, understanding investment planning is vital to ensure the right combination of investors, instruments, and financial mechanisms with the regulation and institutional capacities of a city. For this purpose, cities will have access to useful resources and guidance to accelerate this process through the Mission Platform (see Section 1.2 for further details). Thus, the first step is to have the vision, leadership, and political commitment towards climate neutrality.

9.1 Understanding Planning and Investment Readiness

Most cities are learning how to cope with a growing demand for services and infrastructure to improve quality of life. This demand calls for a smart use of the scant resources of a city to leverage financing following a blended finance approach (see Section 9.3 below), combining long-term financing from eligible financial institutions (FIs), such as the European Investment Bank, with EU grant financing, attracting loans or equity investments from public authorities and private financiers (see, e.g., EU blending facilities). The decisions that are taken today create a pathway of development that can be costlier if they are not properly assessed. Examples of this include investment in parking lots in city centres that later are not used due to traffic restrictions (Szarata et al., 2014), or delaying the introduction of zero-emission building codes that create green jobs, but also cause a long-term lock-in effect in terms of energy consumption and GHG emissions. Thus, improving financial and managing capacities at the city level needs to include an understanding the multiple benefits of early adoption of climate neutrality, including: more affordable financing; accessing an ample and diversified investor base; a thriving environment for entrepreneurship; and improved cost-effectiveness (from the citizen's perspective).

Transitioning to climate neutrality is not an easy process. It requires learning, experimentation, reallocating funding and assuring that no one is left behind. To better understand its preparedness for embarking on this process, a city should assess its existing institutional, technical, financial, and regulatory capacities. According to a survey implemented by the European Investment Bank, municipalities in Europe consider that investment arrangements are inadequate to meet future challenges, with major barriers to move forward such as lack of funds, regulatory red tape, and scarcity of technical skills to execute projects (European Investment Bank, 2021a). In this context, for many cities the climate neutrality ambition will require also enhancing existing capacities and acquiring new skills to mobilise the resources commensurate with this challenge.

Figure 14. Investment gaps (2017 – 2019).



Source: McGoldrick, 2021.

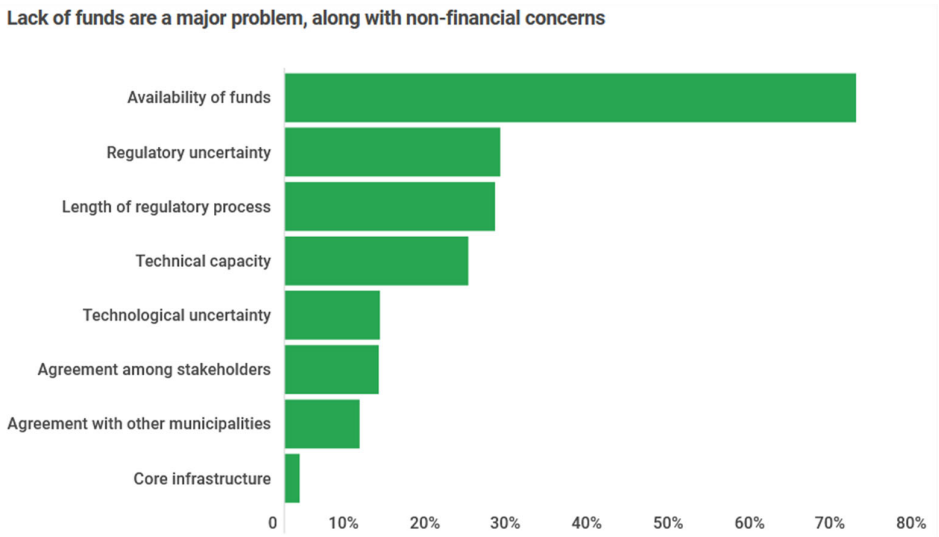
The challenge of transitioning to urban climate neutrality is also about understanding the nature of urban infrastructure and service provision gaps. The EIB also found that, even before the pandemic, municipalities were slightly or substantially underinvesting in areas related to climate change adaptation and mitigation (see also European Environment Agency, 2020b). This means that while local authorities are aware or have a set of projects and priorities, these don't materialise due to the complexities of limited access to funding, a deterrent regulatory environment for investment, and limited technical capacities. Thus, investment readiness is a framework to understand the underlying conditions that can limit the provision of infrastructure and service in your city.

Investment readiness encompasses an understanding of the financial, technical, regulatory, and institutional constraints that hinder investment in priority areas. In practical terms, investment readiness is all about the following questions:

- What do we want to achieve?
- Does the city have the money to pay for it?
- Is there a firm interested in providing this service?
- Are there enough competitors in this segment?
- Do I have capacities to attract, supervise and enforce contracts with the private sector?
- Do I need the buy-in from the national government?
- Who can help me in getting financing?
- Do I need to report this to anyone?

These questions can be grouped under five categories[35] helping a city in understanding its level of investment readiness, and steering efforts considering the strengths and areas of opportunity.

Figure 15. Barriers to investment.



Source: McGoldrick, 2021.

Table 9. Guiding questions to assess investment readiness.

Category	Guiding questions
Value proposition	How can a service or infrastructure benefit citizens? How does it contribute to climate neutrality, and who can implement it? How does this service or infrastructure address climate neutrality?
Financial capacity and business model	How a service or infrastructure can be operated and by whom? Does it create a source of revenue or requires financial transfers? Does the city have the resources to pay for this service? How can the private sector finance and pay for this service?

[35] Adapted from Innovate UK., 2020.

Category	Guiding questions
Market structure	Is there a demand for this service? How is the service currently provided? Who are the competitors? Are citizens willing to pay? Is there a regulation that hinders the transition to climate neutrality?
Barriers and gaps	Is the technology behind a solution proven? Is it necessary to carry out feasibility studies to move forward? Are there private sector operators interested in this business? How does citizen behaviour impact effective implementation?
Management and governance	As a city, do I have the capacities to manage this service? Who in the city has a say in the decision-making process? Are the city assets and in-kind resources priced in relation to this service? What is the regulation for using public funds in engaging with the private sector? How does the city assure citizens' involvement? How is the GHG emissions reduction monitoring, reporting and verification (MRV) performed?

Source: Own work.

Given these investment readiness categories, cities can undertake a self-assessment on where they currently stand. This assessment will help in creating or strengthening their planning, investment, and resource mobilisation capacities. Typically, these capacities are scattered in multiple business areas, such as mobility or waste management, overseeing technical performance, while other units are more concerned about financial performance or revenue generation. Climate neutrality is also an opportunity to streamline the financial and technical performance of a city, as it calls for an institutional architecture for disclosing how money is used to fight climate change, while providing environmental, economic, and social benefits.

In order to facilitate investment readiness assessments three tools are available to help cities in understanding their point of departure:

— The **Sustainable Finance Taxonomy** (Regulation (EU) 2020/852) was designed to reorient capital flows facilitating cross-border sustainable investment, while also helping in determining whether an economic activity qualifies as environmentally sustainable. The taxonomy establishes environmental objectives for climate mitigation, adaptation, protection of water and marine resources, circular economy, and pollution prevention. As such, the Taxonomy can be used by cities as a framework to assess their current position and track progress in terms of climate and sustainable investment towards climate action.

— The **EU Taxonomy Compass** (https://ec.europa.eu/sustainable-finance-taxonomy/tool/index_en.htm) is a tool that helps citizens, investors, and governments in better understanding how activities substantially contribute and what criteria they have to meet to be considered as sustainable investments.

— The **Bankability Checklist** (ICLEI TAP, 2021), developed by ICLEI´s Transformative Actions Program, is another tool that can complement the EU Taxonomy Compass, and it is available for cities in assessing their level of investment preparedness including concepts as political commitment, investment maturity, business model, technical, financial, and economic viability, replicability, and scalability, as well as social benefits.

— The **City Maturity Model for Climate-Smart Urban Infrastructure** is another useful tool for cities developed by the Cities Climate Finance Leadership Alliance. This tool helps cities in assessing climate investment preparedness with a holistic view that integrates strategic, regulatory, financial, and operational under 12 practical dimensions (Cities Climate Finance Leadership Alliance, 2021).

9.2 Engaging with investors and citizens under a common partnership

To manage the costs required to achieve the transition, cities can establish climate neutrality investment units where climate action plans can be integrated with other city priorities (e.g., transport, energy efficiency, waste management, job creation/entrepreneurship). With this integration process, synergies can be harnessed together with investment opportunities. A climate neutrality investment unit can be a public-private partnership with a mandate for promoting investment, facilitating access to financing, engaging with citizens, and tracking progress towards climate goals.

Box 20. Public-private partnerships for building renovation

Under the leadership of the City of Olot in Spain, a public-private partnership was set up to promote energy efficient housing upgrades, engaging with citizens, contractors, and financiers working together under one roof. These stakeholders are coordinated by the Euro PACE Foundation, which provides technical assistance with funding from the European Commission, while private investors and financial institutions provide funding that considers the characteristics of building retrofits. This sort of PPP is also called a one stop-shop, as city authorities set a table where citizens can meet and select different financial products, obtain grants, and have technical assistance in choosing approved contractors. The one-stop shop was key as with city support, citizens could solve questions regarding energy efficiency retrofits and renovations. Contractors were also brought to this one-stop shop, so they were approved and get standardized contracts in providing legitimate and effective technology and service providers, reducing the risk for citizens of providing faulty services. Lastly, the overall institutional arrangement reduces the perceived risks from financiers in participating in this market segment.[36]

An investment unit could start by having a series of projects with different levels of readiness. This will help cities to better customise the climate performance of a project with the specific demands and opportunities in the financing landscape. Projects and initiatives that incorporate green and climate credentials are in high demand from the investor community (including the European Central Bank). Projects' alignment with the EU Sustainable Finance Action Plan, creates an attractive opportunity for cities to access financing in more favourable terms (Giorgi, 2021). These credentials foster compliance with international standards recognised by the investor community. For example, the Climate Bonds Certification Scheme provides a method for verifying that the money (proceeds) raised in capital markets is devoted to a set of measures, such as low-carbon transport, zero-carbon buildings, waste, and water infrastructure, as well as renewable energy and energy efficiency. This sort of certification improves the trust of investors in the financial and managerial capacity of cities as project sponsors, resulting in reduced perceived risk. Salzburg, Copenhagen, Cork, Bergen, Porto, Lisbon, and Alicante are some of the cities using this certification to finance the development of new buildings and retrofitting existing buildings, aiming at zero carbon in 2050 (Climate Bonds Initiative, Buildings).

The EIB considers that having a solid medium term capital investment planning process is a key element of success in linking investment to projects (European Investment Bank, 2016). To improve this planning, city investment units need to review the pipeline of projects to ensure that climate neutrality is embedded not only in the climate action plans, but also in sector-specific plans, such as Sustainable Urban Mobility, Waste Management and Energy Efficiency plans. In addition, climate projects should be related to innovation, entrepreneurship, social welfare, and public-sector management plans. These plans can be enhanced and improved with a lens on investment readiness, differentiating individual projects to be presented to investors, financial and technological partners, as well as citizens. It is safe to assume that each individual project will be analysed externally in the light of the creditworthiness of the city (Abdellah, 2021), as well as the financial and managerial capacity to enforce contracts and other due diligence procedures. Thus, a more refined level of detail under each project will help in identifying the right combination of market and regulatory instruments that can be used for financial mobilisation. The following list of steps can facilitate the introduction of climate neutrality in the investment process:

1) **Define a climate neutrality focal point**. This is a resource office, where different parts of the city can solve questions and obtain guidance. Ideally, this focal point can become a one-stop shop connecting citizens, technology providers, financing, and reporting. There can be benefit in allocating an economic development department (or equivalent) to lead this aspect.

2) **Prioritise projects to be included in the Climate City Contract** (see Section 1.2 above, Part I of this document). These measures have a high-level of acceptance from citizens and the private sector, but also report a positive investment – emissions reduction relationship.

3) **Introduce climate neutrality in your sources of revenue**. There are multiple market and regulatory mechanisms to create sources of revenue as means to reach climate neutrality. These sources of revenue will be used to finance the transition to climate neutrality by integrating the polluter pays principle, but also the creation of green jobs and improving the quality of life.

4) **Reach out to financial institutions.** Several financial institutions, including banks, private equity funds, and pension funds have a climate target, so they have technical assistance and financial products that will help you in financing the services and infrastructure your city needs.

[36] See more information at https://europace.gnesolutions.com.

5) **Engage with the investor community.** This entails opening a dialogue on how to better introduce climate neutrality in city investment, including supervision and reporting. Developing climate neutrality investment criteria, as well as selecting projects to have an investment-ready pipeline can be challenging for cities, citizens, and investors, particularly as there are very few blueprints to follow. A simple approach to follow is by communicating how a project is expected to perform in terms of carbon emissions through concept notes, defining how a project will provide benefits, estimating the costs, and the involvement of potential financing and investing entities.

6) **Establish market and regulatory mechanisms to earmark funds generated in the city.** This means that the city must improve fiduciary capacities to collect and disburse funding for the multiple measures of a Climate City Contract. This can be done with special-purpose vehicles that aggregate projects or consider multiple sources of financing.

7) **Communicate and engage with the public**. It is key to ensure that the city provides continuous information on how the money raised either through investors or through city finances is used in the transition to climate neutrality. Explicit communication must have considerations for job creation, quality of life, city renewal, and other co-benefits.

9.3 Financial products, instruments and mechanisms linking investment with climate action

Climate neutrality calls for the extensive use of financial, regulatory and market mechanisms to fund services and infrastructure. The concept of blended finance is important, as it encompasses the use of public and private resources to leverage additional financing using multiple financial products. Further, blended finance also considers how private and public operators can have an active role in developing plans as well as implementing them. While initial costs are related to putting together and refining this climate neutrality plan, most of the resources will be dedicated to the implementation of it. This implementation shall be coordinated by the city, while the operation and financing could be done by public or private firms, as well as citizens.

In this context, a city needs to look at the upstream financing and available instruments that can pay for project preparation first and defining the institutional architecture for implementation at later stages. Project preparation finance will come fundamentally from grants and technical assistance, including those resources from the Mission. Implementation of the climate neutrality plan has a blended financial perspective, as it requires mobilising public and private resources through the use of tax and grants, the development of dedicated public-private trust funds or revolving funds, that can provide loans and credit-enhancement tools, such as guarantees. As part of the design of its climate neutrality plan a city should also look at the regulatory instruments that give support to the long-term commitment of a city, reducing the risks associated with new business models and technologies, as well as increasing the credibility of a city in fostering behavioural change. An adequate combination of these two aspects is fundamental for scaling up financing and introducing measures that comply with the dual objective of creating a source of revenue and moving towards climate neutrality. In this section financial products are presented, together with market and regulatory instruments and mechanisms that have proven to be effective in fighting climate change. **Table 8** in Section 9 above provides a list of financing instruments, together with application examples.

While some financial products are more common at the city level, such as loans and grants, others are not that visible, such as private equity funds or guarantees, however they provide a substantial push in scaling up resource mobilisation. For example, following a blended finance approach, the EU budget will provide EUR 503 billion to the European Green Deal Investment Plan, with a multiplying effect of 1:2, resulting in additional investment worth more than EUR 1 trillion, enabled partially by the use of financial guarantees (European Commission, 14 January 2020). Therefore, the selection of different financial instruments has an effect on the total investment dedicated to climate neutrality. As such, cities are challenged to have an analytical framework to assess how their own resources and access to grants and technical assistance can be used to foster a multiplying effect down the road through loans, guarantees and private equity participation (thus maximizing the value for money invested). This analytical framework should also consider how taxation affects financial products differently, which can deter climate investments. For example, EU firms cited uncertainty about regulation and taxation (43%), followed by investment costs (41%) as the main obstacles to climate investment, preventing firms from getting a full picture of the expected cost benefits before investing (European Investment Bank, 2021b). Thus, the way financial products are structured is important as it can change the mobilisation impact they have in bringing additional resources to the table.

The investments needed in the EU to deliver the green transition and digital transformation are concentrated in the building and transport sectors (EURE, 2021), so most of the instruments and mechanisms are centred in these areas. These instruments and mechanisms are effective in changing behaviour, supporting the introduction of technology and new business models, tracking job creation, and communicating the use of the resources raised through them, in the fight against climate change. The following is a list of proven instruments that comply with these conditions:

Table 10. Instruments and mechanisms for climate action.

Instrument	Concept	Use
Public Private Partnerships (PPPs)	PPPs are a flexible mechanism for climate action in services and infrastructure, as the city fosters climate innovations, and the private sector is challenged to come up with a solution that provides the best value for money.[1]	Europe has extensive experience in managing complex, long term and far-reaching PPPs with strong private sector involvement.[2] This experience includes roads, hospitals, schools, as well as social housing, and waste management, upgrading the provision and quality of a service, where climate action is an extra layer of considerations. PPPs case studies include the construction of a motorway in the Netherlands[3] introducing considerations for CO2 reductions, as well adaptation measures, such as the Cloudburst Plan in Copenhagen.[4]
Special-purpose financial vehicles (SPVs)	These are typically trust funds and revolving funds managed by a city or an asset manager. They are used to collect funding and financing from multiple sources, including tax earmarking, while isolating operational and financial risks.	SPVs have been used in district recovery, urban renewal and building renovations as they provide a financial structure for joint ventures and risk sharing. SPVs can be capitalised with green and climate bonds. The Green for Growth Fund is a SPV launched by the EIB and KfW, with public and private participation in investments in energy efficiency in Southeast Europe, e.g., the Green for Growth Fund (https://www.ggf.lu).
Green & Climate Bonds	Green & climate bonds are debt instruments that are traded in capital markets. These bonds are in high demand from a growing investor community and can help in obtaining better financing terms.	These bonds are certified and verified by third parties assuring that the proceeds raised in capital markets are legitimately used for green or climate purposes. Over 80 Climate Certified Bonds linked to low carbon buildings have been issued since 2015 globally.[5] One of the latest issued by Vonovia for EUR 600 M to improve energy efficiency of buildings.[6]
On bill finance	This is a method to finance a service or product through a utility that is paid back by a consumer through a utility or service bill.	Examples of this include more energy efficient appliances (washer, TV, fridge), air conditioning, heating systems, among others. The UK Green Deal facility provides loans that can be repaid via a charge on an energy bill, working with an extensive network of providers.[7]

Instrument	Concept	Use
On tax financing	This is a method similar to on-bill financing, but it collects payments through municipal taxes, charged to the title of a property instead of a person.	Weather insulation and energy efficiency measures in the built environment are starting to use this instrument. Private equity funds are becoming active in building renovation in Europe through Property Assessed Clean Energy (PACE) financing. The EuroPACE (https://www.gnesolutions.com/europace) foundation is taking the lead in modifying tax codes to introduce on-tax financing for building retrofits.
Energy service companies (ESCOs)	These companies offer to reduce energy bills by introducing energy efficiency measures in buildings, transport, or industry, and being paid back with the associated savings.[8]	ESCOs have been used in the industrial sector, public works (street lighting, water pumping), as well as in public and private buildings.[9] Stuttgart introduced a municipal ESCO providing a standardized energy renovation package for households, without the need to face upfront costs. Homeowners pay a monthly service fee through energy supply contracting.[10]
Energy savings insurance	This approach builds upon contracts that assure a minimum energy efficiency performance of a service or infrastructure, typically offered in collaboration with ESCOs.	Energy performance contracts are being introduced in building management, as a strategy to improve financial planning, reduce energy costs, and reduce carbon emissions. While conceptually attractive, they are relatively new. Energy Savings Insurance is being implemented in Italy, Portugal and Spain targeting small and medium-sized enterprises by the Basel Agency for Sustainable Energy.[11]
Crowdfunding	Energy communities are based on crowdfunding schemes, where citizens can invest in their own energy generation, with a focus on renewable sources. Energy communities can be a financially viable business and generate green local jobs.[12]	It is estimated that energy communities can manage more than 17% of installed wind capacity and 21% of solar by 2030.[13] Some cities are supporting energy communities by joining and endorsing them, supporting the deployment of micro-grids, and taking advantage of vacant space in public buildings, such as solar roofs. Som Energia is a success story of a renewable energy cooperative in Spain, with more than 73 000 shareholders, including city agencies. The cooperative has multiple facilities producing more than 18,5 GWh per year that are commercialized through more than 130 000 contracts.[14]

Instrument	Concept	Use
Tax incentives	Tax incentives are temporary and can induce an increased demand for a certain service or product to kickstart it.	Tax incentives have been used in renovating abandoned districts, but also in providing lower property taxes to incentivise the use of solar power or having vertical or roof gardens. Carbon taxes have been used to capitalise funds that are returned to the economy in the shape of grants, for example for supporting an electric vehicle upgrade in households. Denmark imposes a higher tax to internal combustion engines in cars, and a lower tax on electric vehicles. At the same time, collected taxes are returned to society in the shape of grants for buying an electric vehicle.[15]

[1] ERTRAC, 2013.
[2] Lund et al., 2020.
[3] GPP2020, 2016.
[4] OECD, 2018.
[5] Climate Bonds Initiative, Certified Bonds.
[6] Vonovia SE, 2021.
[7] GOV.UK, Green Deal: energy saving for your home.
[8] Bertoldi et al., 2019.
[9] Directive (EU) 2019/944.
[10] Energy Cities, 2017.
[11] Cordis, Driving Investment in Energy Efficiency through Energy Savings Insurance in Europe.
[12] Caramizaru and Uihlein, 2020.
[13] European Commission. 2016.
[14] Som Energia, 2021.
[15] Radnall, 2020.

Source: Own work.

9.4 Non-financial mechanisms that catalyse climate investment

Cities have at their disposal other mechanisms that are not necessarily financing a project, but help in catalysing investment by providing a demonstrative effect, supporting market penetration, reducing perceived risk, bringing stakeholders together, and motivating behavioural change in the demand for services, products, and infrastructure. These mechanisms are a combination of regulation with market forces, creating a series of incentives and disincentives associated with the functioning of the city.

— **One-stop shops** have been used in the built environment supporting the required renovation wave, particularly as COVID19 exposed how relevant indoor quality of life can be, but also other external shocks such as heatwaves or floods. A one-stop shop facilitates access to financing by blending public and private resources, including the use of climate bonds[37] in retrofitting apartments, as well as upgrading buildings and entire neighbourhoods. One-stop shops can be used in public, commercial, and residential buildings that combine technical, regulatory and financial resources, through mechanisms that facilitate access to information about potential improvements, the return on investment, the need for external financing as well as investor involvement (BozaKiss et- al., 2021). A one-stop shop can be set up by the city in the housing or land-use planning office, standardising renovation or retrofit contracts, keeping a record of technology or service providers, and linking with banks and potential investors.

— The **real estate market** is very sensitive about information driving property prices. Standardized energy and water efficiency labelling schemes reduce information asymmetries, indicating how a property ranks in sustainability terms, creating value in the long-term for the real estate market, as

[37] See Climate Bonds Initiative, 2021, for a list of cities where this certification is available.

well as local taxes. While the legislation under the Energy Performance of Buildings Directive (Directive (EU) 2018/844) provides guidance on how to report this, cities can require real estate transactions to embed energy efficiency certificates as a standardised approach to understand the environmental performance of a property, with the added value of having information on the operational costs associated with inefficient buildings. The first step in labelling schemes is energy audits to help realise the opportunities to save money and energy. Energy audits have been subsidised for households and industry (particularly in Eastern Europe) resulting in larger investment packages for gradual implementation (Kalantzis & Revoltella, 2019).

— Climate action should also be integrated in the **procurement of goods and services**. Ranging from electricity and the local transport fleet to printer paper, cities can upgrade the procurement process to be compliant with climate neutrality commitments, creating incentives along local value chains. Climate neutrality procurement requires a carbon footprint for contractors, which is widely available in the market or can be retrieved using publicly available carbon calculators. Green procurement in Europe is a voluntary instrument, however, the Directive 2014/24/EU provides guidance on how to purchase goods or services, which are not currently available on the market, allowing for research and development (R&D), piloting and subsequent purchase of a new product, service or work. This is achieved by establishing a structured partnership or performing market consultations with suppliers in order to get advice.[38] Cities have at their disposal a green procurement toolkit developed by the European Commission, including case studies, guidance and a helpdesk (European Commission, 2019). While changing the market of goods and services is a lengthy process, climate neutrality procurement is all about sending signals to contractors and service providers that a city is gradually transitioning to a more sustainable consumption model.

— **Transport** is one of the most challenging sectors in reducing carbon emissions, due to a growing demand for mobility services despite technological innovations. The transport sector is also relatively easy to track, as vehicles can be monitored for energy consumption, which can be taxed. Further, when a new mobility service or infrastructure is in place, property values tend to increase, which calls for value capture mechanisms, increasing the property tax base. Climate neutrality financing in this sector requires a scheme that transfers money from the collected resources in parking facilities and street parking, as well as zero-emission zones towards the use of electric vehicles, integrated public transit, and shared mobility, as building blocks towards low-carbon mobility in the city (Alonso Raposo et al., 2019).

Box 21. Land value capture in Denmark

Land value capture has been used extensively in the provision of infrastructure and services in Aarhus and Orestad. This requires a long-term planning and collaborative effort, focusing on reaching consensus before development plans are commissioned. A public company is in charge of managing land planning, independently from political processes, providing a role for the private sector on building housing efficiently. Land value capture also works as it distinguishes between property taxes levied on the home, retained by the local authority, and taxes on the land, which goes to the national government for redistribution. This formula has helped in recovering the costs of infrastructure by taxing developers and owners, while also keeping the commitments of having at least 25% of affordable housing (Falk, 2020).

Financial and technical resources are available for kickstarting the integration of investment packages through the Mission, linking financial products, instruments, and mechanisms with the Climate City Contracts that will be developed by Mission Cities. Technical advice is further available from the European Commission and other institutions like the European Investment Bank Group, through multiple project preparation facilities and financing windows, including Horizon Europe, ELTIS, ELENA, CIVITAS, Smart Cities Marketplace, EIT Climate KIC, Intelligent Cities Challenge, European City Facility, JPI Urban Europe, Positive Energy Districts, Green City Accord programmes and facilities. The European Commission is also deploying the Mission as an overarching framework to tackle the financial, regulatory, and technical challenges in accessing the financing that is needed for a green recovery and climate action. Climate neutrality is about leadership, political will, and taking the opportunity to improve the quality of life of citizens, creating jobs, fostering innovation, and mobilising investment.

[38] Articles 31, 40 of Directive 2014/24/EU of the European Parliament and of the Council of 26 February 2014 on public procurement.

10 Summary – join the Mission to become climate-neutral by 2030

Stepping on the throttle of climate neutrality represents a unique occasion for armouring cities against climate change and preventing higher future costs. While the commitment is significant, innovation, job creation, improved environment for investment and entrepreneurship are only a few of the benefits of early action. Accelerating the transition to climate neutrality activates synergies and self-empowering mechanisms whose impacts are seldom compartmentalized, rather they very often transcend sectoral boundaries. This minimises the risk of trade-offs, spill over effects and counterproductive actions as the transformative process moves across different sectors towards the same direction.

For instance, by supporting well-connected neighbourhoods, early-starters will benefit from more active and healthy peripheries as well as reduced commuting time. By stimulating energy-efficient solutions and the re naturalization of urban spaces, early starters will safeguard social prosperity and citizen's health. Further, by streamlining their administrative process, early starters will increase their visibility, their leadership and will buffer competences and skills. An early transition to climate neutrality also requires the involvement of citizens in their different roles as political agents, users, producers, consumers and visitors. In these capacities, citizens have a huge impact on the environment and climate, and they can take an active role to drive the transition to climate neutrality as co-designers, co-creators, co- implementers and co-beneficiaries.

Indeed, the co-benefits of taking early action towards climate neutrality include, but are not limited to: enhanced attractiveness, boosted local businesses, increased technological readiness, lower future maintenance costs, increased property value, better air quality and health, improved land use management, greater biodiversity, enhanced stability of the urban infrastructure, safer and more accessible public transport, improved participation, interaction, and awareness among citizens, healthier and more active lifestyles, better education, more social cohesion, and less poverty.

The Cities Mission represents a major opportunity for the European Commission, Member States, regional and local authorities, the private sector and citizens to forge a new and innovative partnership, to deliver on their full potential, and lead the world in the necessary transition. Mayors are thus encouraged to step up and commit to holistic, creative and bold action now, to be highly visible front-runners, ensure a future-proof governance, and pave the way for other cities to follow.

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List of abbreviations and definitions

AFOLU	Agriculture, forestry and other land uses
BRT	Bus rapid transit
CCC	Climate City Contract
CEAP	Circular economy action plan
CO2e	Carbon dioxide equivalent
CoM	Covenant of Mayors
COP	Conference of Paris
DAC	Direct air capture
EED	Energy Efficiency Directive
EGD	European Green Deal
EPC	Energy Performance Contracting
EPDB	Energy Performance of Buildings Directive
ESA	Energy service agreement
ESCO	Energy service company
EU ETS	EU Emissions Trading Scheme
EV	Electric vehicle
FUA	Functional Urban Areas
GCoM	Global Covenant of Mayors
GHG	Greenhouse gas
GPC	Global Protocol for Community-Scale Greenhouse Gas Emission Inventories
HAWT	Horizontal axis wind turbines
HE	Horizon Europe
IPPU	Industrial Process and Product Use
LAU	Local Administrative Authorities
LTO	Landing and taking-off
M&E	Monitoring and evaluation
MaaS	Mobility-as-a-Service
MIMs	Minimum Interoperability Mechanisms
MS	Member State
NZEB	Nearly Zero Energy Buildings
OASC	Open and Agile Smart Cities
OBF	On-bill finance
PACE	Property Assessed Clean Energy
PCP	Pre Commercial Procurement
PEB	Positive Energy Buildings
PPI	Public Procurement of Innovative Solutions
PPP	Public Private Partnerships
PULL	Peri-urban living lab

PV	Photovoltaic
R&I	Research and innovation
REC	Renewable energy credit
RED	Renewable Energy Directive
SDG	Sustainable Development Goals
SPVs	Special-purpose financial vehicles
SRI	Smart readiness indicators
SUD	Sustainable Urban Development
TOD	Transit Oriented Development
VAWT	vertical axis wind turbine
WWTPs	wastewater treatment plants
ZCBs	Zero Carbon Buildings
ZEDs	Zero Energy Districts

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Annexes

Annex 1. Guidance and tools for cities

Table 11. Guidance and tools for cities: Urban Climate Neutrality and Climate Action.

Urban Climate Neutrality and Climate Action			
Name	Description	Link/reference	Type of resource
2006 IPCC Guidelines to compile National Greenhouse Gas Inventories	2006 IPCC Guidelines to compile National Greenhouse Gas Inventories	https://www.ipcc-nggip.iges.or.jp/public/2006gl/	Guideline
Athena eco calculator for commercial and residential assemblies	Calculator for a quick snapshot of building footprint	http://www.athenasmi.org/our-software-data/ecocalculator/	Tool
Athena Impact estimator for buildings	Stand-alone program that allows users to model their own custom assembly and envelope configurations	http://www.athenasmi.org/our-software-data/impact-estimator/	Tool
C40's Knowledge Hub	Insights and practical resources from leading climate cities	https://www.c40knowledgehub.org/	Resource library
C40's Climate Action Planning Resource Centre	It brings together a wide range of resources and tools to support city climate planners in the process of delivering action consistent with the objectives of the Paris Agreement	https://resourcecentre.c40.org/resources	Resource library
Carbon Calculator	The Climate Alliance Carbon Calculator allows municipalities to calculate the CO2 emissions associated to the energy consumption that takes place in their territory by sector and by energy carrier	https://www.climatealliance.org/activities/tools-and-methods/carbon-calculator.html	Tool

Urban Climate Neutrality and Climate Action			
Name	Description	Link/reference	Type of resource
ClearPath GHG Inventory Tool	ClearPath Global is an online GHG inventory tool for local governments worldwide	http://www.clearpath.global/	Tool
Climate Alliance tools and methods	The tools on offer fulfil a wide variety of needs in municipal climate action and cover the varied requirements and starting points of member cities and towns: from general instruments to specialised, and from aides for beginners to full support for climate action communities	https://www.climatealliance.org/activities/tools-and-methods.html	Tool
Defining carbon neutrality for cities and managing residual emissions: Cities' perspective and guidance	The document includes guidelines on how to plan, report on progress and achieve carbon neutrality	https://www.c40knowledgehub.org/s/article/Defining-carbon-neutrality-for-cities-and-managing-residual-emissions-Cities-perspective-and-guidance?language=en_US	Guideline
EBRD Green Cities policy tool	Effective Policy Instruments for Green Cities	https://www.ebrdgreencities.com/policy-tool/	Tool
Eurocities resource library	Eurocities' website contains information on six focus areas: Inclusive cities, prosperous cities, healthy and moving cities, vibrant cities, localising global challenges, innovative city governments	https://eurocities.eu/about-us/	Website
European Covenant of Mayors library and webinar recordings	European Covenant of Mayors library and webinar recordings on different topics related to local climate action	https://www.covenantofmayors.eu/support/library.html	Library/Webinars
European Covenant of Mayors e-learning tool	Dedicated module on mitigation, adaptation, and energy poverty. Available in MyCovenant and EU Academy.	https://academy.europa.eu/	Webinar/course

Urban Climate Neutrality and Climate Action			
Name	Description	Link/reference	Type of resource
The GCoM City Journey	Cities can pledge to reduce greenhouse gas emissions, enhance resilience to climate change, and track their progress transparently. The City journey is divided into various steps: Commit, Assess, Set Goals and Targets, Develop an Action Plan, Implement, Monitor and Report, Validate and Update	https://www.globalcovenantofmayors.org/journey/#1594376564336-552a1d5f-aad4	Website
GHG Contribution Analysis toolkit	Toolkit designed to assist communities in the application of GHG Contribution Analysis	https://icleiusa.org/ghg-contribution-analysis/	Tool
Global Protocol for Community-Scale Greenhouse Gas Emission Inventories	GHG Protocol standard developed by C40, World Resources Institute and ICLEI - Local Governments for Sustainability. The GPC provides a robust framework for accounting and reporting city-wide GHG emissions	https://resourcecentre.c40.org/resources/measuring-ghg-emissions	Tool
Google Environmental Insights Explorer	The insights are a modelled estimate based on actual measurements of activity and infrastructure	https://insights.sustainability.google/	Empirical/reported data in real cases
Guidebook 'How to develop a Sustainable Energy and Climate Action Plan (SECAP)', Part 1	Part 1: The SECAP process, step-by step toward low-carbon and climate resilient cities by 2030	https://op.europa.eu/en/publication-detail/-/publication/338a9918-f132-11e8-9982-01aa75ed71a1/language-en	Guideline
Guidebook 'How to develop a Sustainable Energy and Climate Action Plan (SECAP)', Part 2	Part 2: Baseline Emission Inventory (BEI) and Risk and Vulnerability Assessment (RVA)	https://publications.jrc.ec.europa.eu/repository/handle/JRC112986	Guideline

Urban Climate Neutrality and Climate Action			
Name	Description	Link/reference	Type of resource
Guidebook 'How to develop a Sustainable Energy and Climate Action Plan (SECAP)', Part 3	Part 3: Policies, key actions, good practices for mitigation and adaptation to climate change and Financing SECAP(s)	https://op.europa.eu/it/publication-detail/-/publication/fd75e1e2-f132-11e8-9982-01aa75ed71a1	Guideline
Green City Tool	It is a self-assessment and benchmarking tool for cities that gives them information on their status on various topics (mobility, governance, water, climate change mitigation and adaptation)	https://webgate.ec.europa.eu/greencitytool/home/	Tool
Guidebook for achieving carbon neutrality by 2050	The Guidebook describes the key steps in the planning process, along with important considerations in each step while presents best practices to inspire cities and regions to better design actions as part of their decarbonisation process	https://fedarene.org/wp-content/uploads/2021/06/Guidebook_for_Achieving_Carbon_Neutrality_by_2050.pdf	Guideline
ICLEI Europe resource library	Library of publications and tools for cities on all sectoral and horizontal topics related to climate neutrality	https://iclei-europe.org/publications-tools/	Resource library
Indicators for Sustainable Cities	Listing scalable, easy-to-use indicator frameworks for sustainable cities including, but not inclusively focusing on, urban mobility	https://ec.europa.eu/environment/integration/research/newsalert/pdf/indicators_for_sustainable_cities_IR12_en.pdf	Tool
Innovating Cities resources	The EU's innovating cities initiative promotes an integrated vision of innovative urban planning and design that involves citizens as 'city makers' who innovate and participate in governance and policymaking	https://ec.europa.eu/info/research-and-innovation/research-area/environment/urban-development/innovating-cities_en#jpi-urban-europe	Website

Urban Climate Neutrality and Climate Action			
Name	Description	Link/reference	Type of resource
IPCC emission factor database	International library of emission factors to estimate greenhouse gas emissions	https://www.ipcc-nggip.iges.or.jp/EFDB/main.php	Tool
JPI Urban Europe	Available projects and case studies on JPI Urban Europe	https://jpi-urbaneurope.eu/projects/	Case study/best practice
Knowledge Hub on Local Finance	The first knowledge platform dedicated to local finance. Highlighting innovative solutions developed by local governments, national governments, public and private financial institutions and civil society	https://localfinancehub.org/	Website
Mitigation Goal Standard Guidance	Guidance for designing national and subnational mitigation goals and a standardized approach for assessing and reporting progress	https://ghgprotocol.org/mitigation-goal-standard	Guideline
Planning for Climate Change: Guide	Framework for city planners to better understand, assess and take action on climate change at the local level - it includes specific sections on vulnerability assessments	https://unhabitat.org/planning-for-climate-change-guide-a-strategic-values-based-approach-for-urban-planners	Methodology
Planning for Climate Change: Toolkit	Framework for city planners to better understand, assess and take action on climate change at the local level - it includes specific sections on vulnerability assessments	https://unhabitat.org/planning-for-climate-change-toolkit	Tool
Policy and Action Standard Calculation Tool	This tool helps countries and cities estimate the greenhouse gas effect of policies and actions	https://ghgprotocol.org/policy-and-action-standard	Guideline

Urban Climate Neutrality and Climate Action			
Name	Description	Link/reference	Type of resource
Resources of the European Climate Pact	The European Climate Pact is a platform to work and learn together, to develop solutions and build networks for real change	https://europa.eu/climate-pact/resources_en	Website
Smart Cities Information System. Self-reporting guide	A self-reporting tool that is the link between the information and outputs from the projects within the scope of Smart Cities Information System and the stakeholders	https://smart-cities-marketplace.ec.europa.eu/insights/publications/self-reporting-tool-srt-guide	Tool
Sustainable Energy and Climate Action Plan Template	Excel-based tool to compile a GHG city-wide inventory following the European Covenant of Mayors methodology (currently under revision)	https://www.covenantofmayors.eu/support/adaptation-resources.html	Tool
The GCoM Resources Library	A resources library containing documents and tools to support actions of cities. Results/resources can be filtered by Region, Step, Tag and Topic	https://www.globalcovenantofmayors.org/resources-library/	Website
The human-centred city. Opportunities for citizens through research and innovation	High-Level Expert Group report that provides a vision for European cities of the future and recommends how EU-funded research and innovation can assist cities in their transition	https://op.europa.eu/en/publication-detail/-/publication/5b85a079-2255-11ea-af81-01aa75ed71a1/language-en/format-PDF/source-search	Publication

Source: Own work.

Table 12. Guidance and tools for cities: Transport.

Transport			
Name	Description	Link/reference	Type of resource
CIVITAS projects, thematic areas and mobility solutions	The work of CIVITAS and its projects concerns itself with ten core thematic areas spanning the whole urban mobility spectrum and planning cycle. Explore the individual thematic area pages below for more information.	https://civitas.eu/thematic-areas	Website
EIT Urban Mobility living labs and test beds	The Living Labs Knowledge Base Platform is a collection of both living lab learning practices and living lab management tools. The living lab management tools are a collection of best practices, recommendations on how to set up and operate a mobility living lab, how to upscale, allow for citizens engagement, co-create with the end user, and evaluate impacts	https://www.eiturbanmobility.eu/city-club/mobility-living-labs/	Empirical/reported data in real cases
Eltis City Database. Sustainable Urban Mobility Plans (SUMP)	The Eltis City Database is a valuable resource of over 1 000 European city profiles and their SUMPs.	https://www.eltis.org/mobility-plans/city-database	Website
MobiliseYourCity Emissions Calculator	Inventory of current emissions, to project BAU until 2050 or model a climate-friendly modality system	https://www.mobiliseyourcity.net/mobiliseyourcity-emissions-calculator	Tool
Mobility actions and awards of the European mobility week	The action promotes a behavioural shift towards a more sustainable urban mobility culture and is of a promotional rather than a technical nature (i.e., technical innovations themselves will not be recognised)	https://mobilityweek.eu/about-mobilityactions/	Case study/best practice

Transport			
Name	Description	Link/reference	Type of resource
POLIS Network (Topics)	POLIS is the leading network of European cities and regions working together to develop innovative technologies and policies for local transport. Available material on their website	https://www.polisnetwork.eu/what-we-do/topics/	Website
Port Emissions Toolkit	Guide on the assessment of port emissions and the development of port emissions reduction strategies	https://glomeep.imo.org/wp-content/uploads/2018/10/port-emissions-toolkit-g1-online.pdf	Methodology
Showcases and documents from Zero emissions waterborne transport	Showcases and documents available on the website	https://www.waterborne.eu/showcases	Website
Sustainable Urban Mobility Indicators (SUMI)	Sustainable urban mobility indicators are a useful tool for cities and urban areas to identify the strengths and weaknesses of their mobility system and to focus on areas for improvement	https://ec.europa.eu/transport/themes/urban/urban_mobility/sumi_en	Tool
SUMP self - assessment tool	Self-assessment tool to asses strategic mobility plan or evaluate planning activities in general	https://www.sump-assessment.eu/English/start	Tool
Transport carbon tool for local authorities	Provides a detailed list of indicators and the methodology to calculate them regarding sustainable mobility	https://www.eltis.org/sites/default/files/trainingmaterials/smp2.0_sustainable-mobility-indicators_2ndedition.pdf	Guideline
Transport carbon tool for local authorities	Tool for local councils to calculate the potential effects of transport on carbon emissions in an area	https://www.gov.uk/government/publications/local-authority-basic-carbon-tool	Tool

Source: Own work.

Table 13. Guidance and tools for cities: Energy.

Energy			
Name	Description	Link/reference	Type of resource
Clean Energy for EU Islands (Support page)	The Island Clean Energy Transition Agenda is a strategic roadmap for the transition process towards clean energy. Its website contains the energy transition agenda, self-assessment tool, project support, webinars and financing	https://www.euislands.eu/energy-transition-agenda	Website
Empowering Cities for a Net Zero Future: Unlocking Resilient, Smart, Sustainable Urban Energy Systems	IEA report which through more than 100 examples and case studies, explores the wide range of opportunities, challenges and policy solutions that can help city-level governments capture the significant value of efficient and smart digital energy systems	https://www.iea.org/reports/empowering-cities-for-a-net-zero-future?utm_campaign=IEA+newsletters&utm_source=SendGrid&utm_medium=Email	Case study/best practice
Energy Cities resource library	Energy Cities' resources contain information divided by news, publications, best practices, webinars, interviews and topic	https://energy-cities.eu/	Website
Energy and Industry Geography Lab (EIGL)	JRC is creating EIGL that will be a specialised geospatial data management, visualisation and analysis tool that will allow the mapping of energy, industrial and other infrastructure, which in turn will support the transition towards climate-neutrality (expected late 2021)	https://europa.eu/eigl	Tool
H2020 Lighthouse projects	The Smart Cities and Communities lighthouse projects are funded by the European Commission through the Horizon 2020 research and innovation programme	https://www.smarter-together.eu/eu-smart-cities-and-communities	Empirical/reported data in real cases

Energy			
Name	Description	Link/reference	Type of resource
Investing in European Success : Innovating Cities in Europe and Worldwide	This booklet showcases 23 successful EU-funded projects on urban innovation that are transforming our cities into European and global actors pursuing open research and innovation, dealing with energy and climate, urban transport, nature-based solutions, green lifestyles in resilient cities, food, social innovation, well-being, cultural heritage and urban governance	https://ec.europa.eu/info/publications/investing-european-success_en	Case study/best practice
Pathfinder emissions Calculator	Embodied carbon, operational carbon, and sequestered carbon of a given landscape design	https://app.climatepositivedesign.com/	Website

Source: Own work.

Table 14. Guidance and tools for cities: Best practices, awards and general data.

Best practices, awards, and general data			
Name	Description	Link/reference	Type of resource
100 Intelligent Cities Challenge, resources for cities	The Intelligent Cities Challenge (ICC) is a EC initiative that supports 136 cities in using cutting-edge technologies to lead the intelligent, green and socially responsible recovery	https://marketplace.intelligentcitieschallenge.eu/en	Website/best practice
Affordable Housing Initiative: Resources	This Initiative will pilot 100 lighthouse renovation districts focuses on creating quality, liveable, affordable homes for people and will mobilise cross-sectoral project partnerships	https://www.ourhomesourdeal.eu/affordable-housing-initiative	Empirical/reported data in real cases

Best practices, awards, and general data			
Name	Description	Link/reference	Type of resource
C40 Cities Bloomberg philanthropies awards (Resources)	The Awards recognise cities that have implemented outstanding projects, programmes, policies and practices to combat climate change, reduce climate risks and improve lives in their communities	https://www.c40.org/awards	Case study/best practice
CAIT Climate data explorer	National GHG emissions data source	https://www.wri.org/data/climate-watch-cait-country-greenhouse-gas-emissions-data	Other
Catalogue - Open & Agile Smart Cities	Catalogue of successfully deployed solutions for the digital transformation in cities and regions	https://catalogue.city/en	Case study/best practice
CDP's Open Data Portal	The data portal contains cities' publicly reported data through CDP and is freely available	https://data.cdp.net/	Empirical/reported data in real cases
Circular Cities and Regions initiative	Initiative supporting the implementation of local and regional circular economy solutions, funding, documents	https://ec.europa.eu/info/research-and-innovation/research-area/environment/circular-economy/circular-cities-and-regions-initiative_en#documents	Website
CIVITAS Awards	The CIVITAS Awards highlight some of the most ambitious, innovative, and successful sustainable urban mobility solutions carried out by cities across Europe	https://civitas.eu/awards	Case study/best practice
Climate Star Award	Project descriptions and details can be found in the Climate Star brochure	https://www.climatealliance.org/municipalities/climate-star.html	Case study/best practice
Climate-ADAPT	Knowledge library for cities on climate action with focus on adaptation and climate-resilience:	https://climate-adapt.eea.europa.eu/eu-adaptation-policy/sector-policies/urban	Resource library

Best practices, awards, and general data			
Name	Description	Link/reference	Type of resource
EC Consumer Footprint Calculator	Calculator allowing citizens to calculate the environmental impacts of their consumption pattern	https://knowsdgs.jrc.ec.europa.eu/cfc	Tool
EIT-Climate KIC (Deep Demonstrations content hub)	The Deep Demonstrations content hub contains stories, fact sheets, video and more information for each hub. There are eight hubs: Healthy, clean cities; long-termism; resilient regions; landscapes as carbon sinks; resilient food systems and diets; just transformation; circular, regenerative economies; resilient, net-zero emissions maritime hubs	https://www.climate-kic.org/programmes/deep-demonstrations	Case study/best practice
EIT-Climate KIC project on 15 climate neutral cities.	EIT Climate-KIC is working with 15 of the most ambitious mayors, municipalities and city communities in Europe to design portfolios of joined-up innovations capable of unlocking wholesale transformation across all city systems – from mobility to waste, from energy to health, and the built environment	https://www.climate-kic.org/programmes/deep-demonstrations/healthy-clean-cities/publications/	Case study/best practice
European Clean Hydrogen Alliance	The European Clean Hydrogen Alliance cooperates with investment and projects such as renewable hydrogen electrolysers for renewable hydrogen production. The strategy foresees the funding of pilots and large scale applications of local hydrogen clusters, such as remote areas or islands, or regional ecosystems –so-called “Hydrogen Valleys” In such cases, a dedicated hydrogen infrastructure can use hydrogen not only for industrial and transport applications, and electricity balancing, but also for the provision of heat for residential and commercial buildings.	https://www.ech2a.eu/	Website

Best practices, awards, and general data			
Name	Description	Link/reference	Type of resource
European Covenant of Mayors Case Studies	Urban adaptation case studies from European Covenant cities	https://www.covenantofmayors.eu/support/library.html	Case study/best practice
European Green Capital Award	Reward for cities which are making efforts to improve the urban environment and move towards healthier and sustainable living areas	https://ec.europa.eu/environment/europeangreencapital/	Case study/best practice
European Green Leaf Award	Competition aimed at cities and towns across Europe, with between populations of 20,000 and up to 100,000 inhabitants, that recognises commitment to better environmental outcomes, with a particular accent on efforts that generate green growth and new jobs	https://ec.europa.eu/environment/europeangreencapital/europeangreenleaf/	Case study/best practice
European Week of Regions and Cities: Resources	The European Week of Regions and Cities is an annual four-day event during which cities and regions showcase their capacity to create growth and jobs, implement European Union cohesion policy, and prove the importance of the local and regional level for good European governance	https://europa.eu/regions-and-cities/home_en	Website
GHG Inventory Development Process and Guidance	A list of emission sources and the associated emissions quantified using standardized methods and tools to help organizations screen emissions categories to identifying focus areas	https://www.epa.gov/climateleadership/ghg-inventory-development-process-and-guidance	Tool
Green City Accord, supporting documents	The Green City Accord is a movement of European mayors committed to making cities cleaner and healthier. It aims to improve the quality of life for all Europeans and accelerate the implementation of relevant EU environmental laws	https://ec.europa.eu/environment/green-city-accord_en	Empirical/reported data in real cases

Best practices, awards, and general data			
Name	Description	Link/reference	Type of resource
Green City Tool, European Commission	This tool is both a simple self-assessment and benchmarking tool for cities, and a source of information and advice for anyone wanting to learn more about how we can make cities greener and more sustainable.	https://webgate.ec.europa.eu/greencitytool/home/	Tool
Handbook of Sustainable Urban Development Strategies	Provides methodological support to cities, managing authorities and other stakeholders involved in the design and implementation of urban strategies under Cohesion Policy	https://publications.jrc.ec.europa.eu/repository/handle/JRC118841	Publication
Innovating cities policy report for EU R&I sustainable urban development	The report showcases and provides an EU-wide evidence base of the outstanding contributions of EU funded research and innovation in meeting urban societal challenges	https://ec.europa.eu/info/publications/innovating-cities-policy-report-eu-ri-sustainable-urban-development_en	Case study/best practice
Knowledge Centre for Territorial Policies	It aims to provide the state of play on how European Structural and Investment Funds support the integrated approach to urban and territorial development, including strategies directed at reaching urban climate neutrality	https://knowledge4policy.ec.europa.eu/territorial_en	Website
Knowledge materials of the European Network of Living Labs (ENoLL)	Public available knowledge materials like publications, podcasts, public webinars, toolkits and even e-courses	https://enoll.org/knowledge-materials/	Website

Best practices, awards, and general data			
Name	Description	Link/reference	Type of resource
LIFE program	The LIFE programme is the main funding instrument for environmental and climate action plans. Both public and private entities can apply by proposing innovative plans that help reaching the goals of the EU strategy. Specifically, the sub-program Climate Change Mitigation and Adaptation focuses on the reduction of GHG emissions, increasing resilience and raising awareness for the mitigation of climate change.	https://cinea.ec.europa.eu/life_en	Website
Next Generation EU	Next generation EU is the recovery instrument proposed by the European Commission to re-build Europe after the impact of the Coronavirus Pandemic. In particular, this program aims to give the funding and support for a fair socio-economic recovery, repair and revitalize the Single Market and to support the urgent investments, especially in the green and digital transitions, a key aspect for Europe's future prosperity and resilience. In the field of climate and urban transport, the investments are guided by the priorities that were stablished in the European Green Deal and in the Sustainable and Smart Mobility Strategy.	https://europa.eu/next-generation-eu/index_en	Website
RegioStars Awards	Awards identifying good practices in regional development and highlighting original and innovative projects which could be attractive and inspiring to other regions	https://ec.europa.eu/regional_policy/en/regio-stars-awards/2016/	Case study/best practice
Resources of the CDP Europe awards	Environmental awards of cities and companies for Europe's environmental leaders. There are three types of resources: Reports, videos and lessons learned	https://www.cdp.net/en/events/cdp-europe-awards	Other

Best practices, awards, and general data			
Name	Description	Link/reference	Type of resource
SAT4SUD	The tool designed to help local, Managing Authorities and relevant actors to anonymously self-evaluate sustainable urban development strategies. SAT4SUD is an under construction online tool that will be officially available via the Urban Data Platform website from November 2021.	https://urban.jrc.ec.europa.eu/strategies/en Data Platform	Tool
Smart Cities Marketplace	It is a major market-changing undertaking that aims to bring cities, industries, SMEs, investors, researchers and other smart city actors together	https://smart-cities-marketplace.ec.europa.eu/	Website
Smart City Guidance Package	The Smart City Guidance Package (SCGP) helps to plan and implement smart city and low energy district projects in an integrated way by describing common situations and giving real-life examples	https://smart-cities-marketplace.ec.europa.eu/news-and-events/news/2019/smart-city-guidance-package	Case study/best practice
STRAT-Board	It is an interactive mapping tool that offers a visual overview of almost all urban and territorial strategies currently implemented across Europe within Cohesion Policy 2014-2020	https://urban.jrc.ec.europa.eu/strat-board	Website
Summary for Urban Policy Makers. What the IPCC special report on global warming of 1.5C means for cities	The document identifies cities and urban areas as one of four critical global systems that can accelerate and upscale climate action, but recognizes this will require major transitions in how both mitigation and adaptation are undertaken	https://www.ipcc.ch/site/assets/uploads/sites/2/2018/12/SPM-for-cities.pdf	Case study/best practice
SUMP Award	The SUMP Award recognises local and regional authorities for excellence in sustainable urban mobility planning. Videos and case studies available on the website.	https://www.eltis.org/mobility-plans/project-partners/sump-award	Case study/best practice

Best practices, awards, and general data			
Name	Description	Link/reference	Type of resource
The European Capital of Innovation Awards	An annual recognition prize awarded to the European cities that best promote innovation in their communities	https://eic.ec.europa.eu/eic-funding-opportunities/eic-prizes/european-capital-innovation-awards_en	Case study/best practice
The Future of Cities Report	The main aim of this report is to raise open questions and steer discussions on what the future of cities can, and should be, both within the science and policymaker communities	https://publications.jrc.ec.europa.eu/repository/handle/JRC116711	Other
Transition toolbox	TOMORROW's toolbox provides the inspiration and guidance necessary to develop city's transition roadmaps. A set of guidelines on how to develop a transition roadmap will be published towards the end of the project (February 2022)	https://www.citiesoftomorrow.eu/resources/toolbox	Other
URBACT toolbox	Each tool in this toolbox is tailored to respond to 5 different stages of the public action-planning cycle, from the analysis of your challenge to the measurement of the impact achieved through the actions implemented	https://urbact.eu/toolbox-home	Website
Urban Innovative Actions (topics)	Urban Innovative Actions (UIA) is an Initiative of the European Union that provides urban areas throughout Europe with resources to test new and unproven solutions to address urban challenges	https://www.uia-initiative.eu/en/topics	Empirical/reported data in real cases
WWF One Planet City Challenge - Information for cities	WWF tools and resources for cities ready to commit to the challenge of keeping global temperature rise to under 1.5C	https://wwf.panda.org/projects/one_planet_cities/one_planet_city_challenge/information_for_cities/	Website

Source: Own work.

Annex 2. Glossary

Glossary of key definitions from the IPCC, relevant for the concept of climate neutrality

"Climate neutrality": Concept of a state in which human activities result in no net effect on the climate system. Achieving such a state would require balancing of residual emissions with emission (carbon dioxide) removal as well as accounting for regional or local biogeophysical effects of human activities that, for example, affect surface albedo or local climate.

"*GHG neutrality" or "net zero GHG emissions":* Condition in which metric-weighted anthropogenic GHG emissions associated with a subject are balanced by metric-weighted anthropogenic GHG removals. The quantification of net zero GHG emissions depends on the GHG emission metric chosen to compare emissions and removals of different gases, as well as the time horizon chosen for that metric.

"Negative emissions": Removal of GHGs from the atmosphere by deliberate human activities, i.e., in addition to the removal that would occur via natural carbon cycle processes.

"Sink": A reservoir (natural or human, in soil, ocean, and plants) where a GHG, an aerosol or a precursor of a GHG is stored.

Source: IPCC, 2018; IPCC, 2021b

Definitions/Glossary for the smart and digital solutions section[39]

"Artificial Intelligence": Generic term referring to any machine or algorithm capable of observing its environment, learning, and taking intelligent action or proposing decisions based on the knowledge and experience gained.

"Big Data": Information assets characterised by such high volume, velocity and variety that they require specific technologies and analytical methods for their transformation into value.

"Digital twins": a virtual representation that serves as a real-time digital counterpart of a physical object or process (Wikipedia, Digital Twin).

"Innovation procurement": procurement for buying the process of innovation (with (partial) outcomes) and/or buying the outcomes of innovation (European Commission, 2021f).

"Internet of Things (IoT)": a network of devices, such as vehicles, and home appliances that contain electronics, software, sensors, actuators, and connectivity which enable these things to connect, interact and exchange data.

"Living Lab": Living Labs (LLs) are defined as user-centred, open innovation ecosystems based on a systematic approach to user co-creation, integrating research and innovation processes in real life communities and settings (ENoLL, n.d., What are Living Labs)

"Open Innovation": Innovation paradigm appealing for "a distributed innovation process based on purposively managed knowledge flows across organizational boundaries, using pecuniary and non-pecuniary mechanisms in line with the organization's business model" (Chesbrough and Marcel Bogers, 2014).

"Pre-Commercial Procurement (PCP)" can be used when there are no near-to-the-market solutions yet and new R&D is needed. PCP can then compare the pros and cons of alternative competing solutions approaches. This will in turn enable to de-risk the most promising innovations step-by-step via solution design, prototyping, development and first product testing (European Commission, Procurement of ICT, n.d.).

"Public Procurement of Innovative solutions (PPI)" is used when challenges can be addressed by innovative solutions that are nearly or already in small quantity in the market and don't need new Research & Development (R&D) (European Commission, The Digital Europe Programme, n.d.).

"*Quadruple Helix":* an open innovation model where industry, government, academia, and citizens work together to co-create and drive structural changes far beyond the scope of what organizations can do on their own. It entails a high level of networking among all participants, including societal capital, creative commons, and communities (Curley and Salmelin, 2013).

[39] Mainly based on Vandecasteele et al., 2019, although other sources are mentioned, with specific references.

"Testbed": Testbeds are sites of urban development, in which experimentation constitutes an integral part of planning and developing the area (Berglund-Snodgrass & Mukhtar-Landgren, 2020).

"Smart City": Urban area that uses various types of sensors to collect data electronically to provide information, that is used to manage assets and resources efficiently. This includes data collected from citizens, devices, and assets that are processed and analysed to monitor and manage traffic and transportation systems, power plants, water-supply networks, waste management, law enforcement, information systems, schools, libraries, hospitals, and other community services.