Thematic areas for services definition

Deliverable D10.1

Version N°5

Authors: Hukkalainen Mari (VTT)

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Abbreviations and acronyms

Acronym	Description
AFOLU	Agriculture, Forestry and Other Land Uses
AI	Artificial Intelligence
APP	Application
BSO	Building Stock Observatory
CCAM	Cooperative Connected and Automated Mobility
CCC	Climate City Contract
CEAP	Circular Economy Action Plan
CHP	Combined Heat and Power
DH	District Heating
DHN	District Heating Network
DH&C	District Heating and Cooling
DH&CN	District Heating and Cooling Network
DNSH	Do no significant harm
EC	European Commission
EE	Energy Efficiency
EED	Energy Efficiency Directive
EEOs	Energy Efficiency Obligation schemes
EPAH	Energy Poverty Advisory Hub
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certificate
ESCO	Energy Service Company
EU	European Union
EV	Electrical Vehicle
FITs	Feed-In Tariffs
GHG	Greenhouse Gas
GI	Green Infraestructure
GOV	Governance Regulation
ICT	Information and Communications Technology
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
ISO	International Organization for Standardization
ITS	Intelligent Transport System
LED	Light Emitting Diode
LTRS	Long-term Renovation Strategy
MaaS	Mobility as a Service
MEL	Monitoring, Evaluation and Learning
MSW	Municipal Solid Waste
NBS	Nature-based solution
NECP	National Energy and Climate Plans
NZC	Net Zero Cities project
NZEB	Nearly Zero-Energy Building
PDA	Project Development Assistance
PEB	Positive Energy Building
PED	Positive Energy District
PEN	Positive Energy Neighbourhoods
PPP	Public Private Partnership
PV	Photovoltaic
RED	Renewable Energy Directive
RES	Renewable Energy Source
R&I	Research and Innovation
RUP	Re-naturing Urban Plan
SECAP	Sustainable Energy and Climate Action Plan
SDG	Sustainable Development Goals

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SUDs	Sustainable Urban Drainage System
SUMP	Sustainable Urban Mobility Plan
TBS	Technical Building Systems
TRL	Technology Readiness Level
TSC	Technical Screening Criteria
V2G	Vehicle-to-grid
VAT	Value Added Tax
WP	Work Package
ZEB	Zero-Energy Buildings

Summary

This deliverable defines the thematic areas of the Net Zero Cities (NZC) project for the Work Package 10. WP10 provides state of the art expert services on thematic areas, supporting climate neutral cities development through a solutions catalogue and different services at different levels to be provided through the Portal and Platform. This deliverable is the output of task 10.1, and it aims to set a starting point for designing the expert services to be provided for the cities participating in NZC activities.

This report establishes a preliminary taxonomy of different thematic areas in NZC and defines pragmatic classification of solutions and concepts. The thematic areas address some of the most relevant sectors needed in the climate neutral city transition (built environment, energy systems, mobility and transport, green industry) and enabling fields (circular economy, nature-based solutions, and digital solutions). In addition, mapping of the associated co-benefits, synergies and impacts has started for the different actions covering climate resilience, environment (water, land, and ecosystems), food supply and production, socio-economic and health co-benefits, ensuring a cross-sectoral integration.

Keywords

Taxonomy, thematic area, solution, service, concept, co-benefit

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Introduction

WP10 “State of the art expert services on thematic areas” is aimed at sourcing proven solutions (above Technology Readiness Level/TRL[1] 4) that can support cities in their climate neutrality pathway. WP10 designs services to facilitate cities’ local demonstration and uptake through a solutions catalogue and different services at different levels to support cities. It also assesses co-benefits of the solutions, as well as the relation and integration or combination between different solutions, including data spaces, to provide concepts or packages of solutions to be implemented together to meet a certain city challenge or need.

The main objectives of WP10 are:

- **Map and characterise proven solutions in the defined thematic areas** (i.e. relevant sectors needed in the climate neutral city transition: built environment, energy systems, mobility and transport and green industry; and enabling fields: circular economy, nature-based solutions, and digital solutions), as well as the requirements for the **suitable design environment**. The latter refers to the needed context for the successful, systematic deployment of the solutions in terms of policy, governance and regulatory aspects, finance and business models, citizen and stakeholder engagement, social innovation methods, metrics and technical foundations including cross-cutting elements such as data spaces and interoperability mechanisms. This design environment will be done in collaboration with other work packages (WPs) through integration and alignment of development in the related WPs
- Map and analyse how cities can achieve different **co-benefits** when deploying solutions.
- Design **3 levels of services** for the cities, with different access to information or support, according to their way or degree of engagement in the Climate City Contract (CCC), with NZC project and Cities Mission. The services designed in WP10 will feed WP3, which is in charge of the One-stop-shop Platform design and development (first approach of services levels from WP10, to be delivered through the Platform in WP3 is shown Figure 1 below) and will integrate the different WP10 level of services into the platform and portal.

[1] Horizon Europe, General Annex B: Eligibility, Technology Readiness Levels: https://ec.europa.eu/research/mariecurieactions/sites/default/files/2021-06/wp-13-general-annexes_horizon-2021-2022_en.pdf

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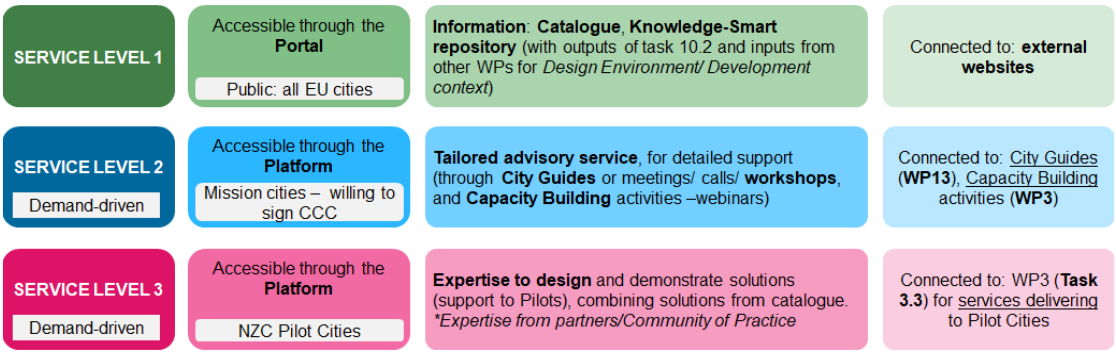

Figure 1: Service levels in WP10 to be deployed through the One-stop-shop Platform (and Portal)

The catalogue, as the first service level, will support innovative and interoperable technical and non-technical local climate actions that build on European Research & Innovation (R&I) including transport and mobility, energy, buildings, industry, as well as food, water, and health; and exploiting the benefits of enablers such as digital, nature-based, and circular innovation. Externalities will be assessed and, for each innovation, any risk on infringing of the DNSH (Do No Significant Harm) principle when deploying in a city environment will be identified and tagged.

Thus, the catalogue will be accessible through the Portal, available to any city, and navigable in a dynamic way through the different tags that each solution will have. This means that the taxonomy behind is a way to structure the content and solutions for the back-end deployment of the portal and organisation of the data. Therefore, any other structuring of the information is also valid, and the tags will allow cities to make their search towards climate neutrality according to their interests, needs, challenges, co-benefits to achieve, etc. A key point would be to align such tags and other metadata models with other catalogues (see Section 3.3), and build automated data exchanges, to ensure minimal semantic interoperability in accordance with the proposed European Interoperability Framework for Smart Cities and Communities (EIF4SCC)[2]. This would enable federation of catalogues beyond the one on the NZC Portal and support the idea of a European Digital Single Market supporting climate neutrality.

1.1 Developing a taxonomy for the thematic areas

This deliverable is a result from “Task 10.1 Taxonomy of thematic areas”, which focuses on refining the taxonomy of the NetZeroCities thematic areas defined at the proposal stage of the project. A taxonomy is understood as “a classification system for sustainable activities” according to the Technical Expert Group (TEG) on Sustainable Finance (TEG, 2020). The method applied by NZC to establish this initial taxonomy is on one hand very simple: It brings together previous attempts to identify relevant categories to characterise both application domains (thematic areas) and aspects of enablers (technical and non-technical) as well as solutions or even products. What is less simple is that these categories cannot be organised hierarchically, like in a strict, authoritative division relating e.g. to sectors, because there may be overlaps and similarities that are essential to capture.

The approach is therefore to apply conceptual clustering based on tags or categories as metadata describing prototypical exemplars of thematic areas, enablers, solutions and products. This type of dynamic classification will allow the knowledge repository to be delivered by T10.2 to facilitate a recursive research of solutions by cities (in different ways: by keywords, by technical description, by co-benefits, by challenges to address, etc.).

While the starting point is that relevant ontologies are found in existing standards, policy and academic and commercial frameworks, the complexity – and even contradiction between them – is so high that

[2] Proposal for a European Interoperability Framework for Smart Cities and Communities (EIF4SCC): https://living-in.eu/news/proposal-european-interoperability-framework-smart-cities-and-communities-eif4scc-published

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we suggest taking a more pragmatic and evolutionary approach. This will allow for both sectorial specialisation and at the same time addressing cross-cutting, common concerns, to avoid sub-optimisation.

This deliverable is a first attempt at gathering and structuring climate neutrality knowledge, while also addressing different sectors and enabling fields. It will be the basis for the subsequent tasks: Task 10.2 for the catalogue of solutions and Task 10.3 for the technical service definition. In the former one, the Solutions Catalogue will be deployed and developed, with a specific list of solutions within each thematic area and categories (presented in the present document) as well as a Solution Card for each of them to characterise the solutions from the technical perspective. These solutions will be then complemented to match the systemic approach required for its successful deployment, including the design environment (or development context) with the links and inputs from other WPs related to policy and governance, regulatory aspects, finance and business models, citizen and stakeholders' engagement, social innovation, and metrics. Furthermore, concept or solution package cards could be performed where information from different cards is integrated in a single integrated concept (e.g., Positive Energy District). The integration among WPs will be done by establishing common parameters (or attributes) defined in collaboration with the related WPs, to be able to link that suitable holistic design environment to complement the technical specificities of the solutions provided as first step (Figure 2). This will be done on a baseline of existing European R&I.

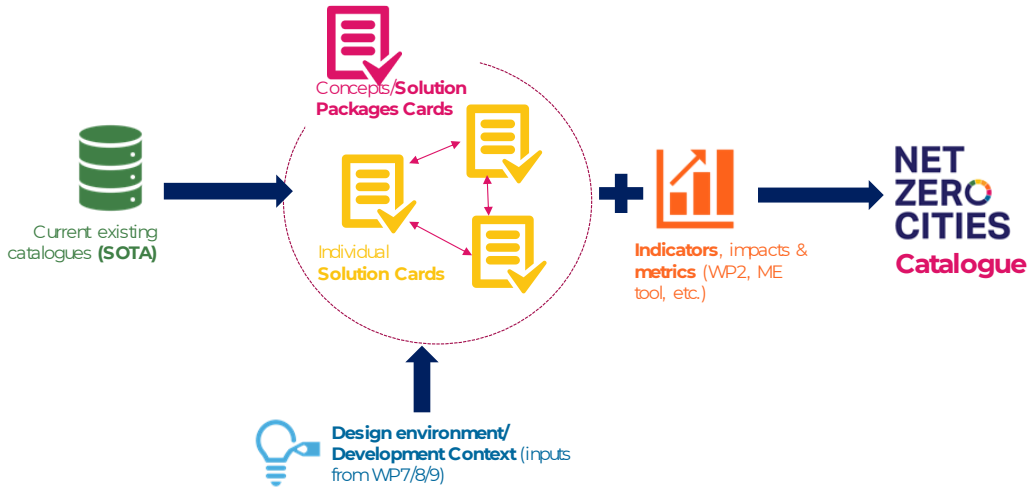

Figure 2: WP10 catalogue data inputs and organisation of the different attributes.

In this deliverable, we will present a preliminary taxonomy of the different solutions, concepts and areas needed in the climate neutral city transition: built environment, energy systems, mobility and transport and green industry; and enabling fields: circular economy, nature-based solutions, and digital solutions, as well as the requirements for the suitable design environment. When developing the taxonomy, associated co-benefits have also been considered, including synergies and impacts of the different actions covering climate resilience, environment (water, land, and ecosystems), food supply and production, together with socio-economic and health co-benefits ensuring a cross-sectoral integration. Across all solutions, we will specifically highlight cross-cutting questions such as the governance and regulatory requirements of a solution (inputs from WP13 and WP14), the potential to attract private/public capital, and suitable financing or business models (inputs from WP7), methods to engage citizens and local stakeholders, as well as methods to involve them in participatory co-design or co-creation activities (inputs from WP8), information on the participatory and Social Innovation tools used (inputs from WP9), scalability options (inputs from WP5) and additional learnings gathered by those that implement them. All these questions will be part of the design environment/development context attributes of the Solutions Cards.

This taxonomy will be a starting point for designing the WP10 services. While the proposed taxonomy is meant to classify and collect the sector specific solutions needed in the climate neutral cities, it aims at the same time at a holistic approach. In their journey towards climate neutrality, cities are expected to require support in systemic approach and development. In the taxonomy, there are solutions and

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concepts that need interoperability and system integration between different (traditional) technology areas and city's operative departments. We are investigating the best available solutions to take these views and needs into account also in WP10.

The work presented in this document will continuously evolve as to build on the results of the related WPs and tasks within WP10. Thus, this deliverable should be considered as a starting position report that enables a speedy start for WP10 work and related tasks.

1.2 Structure for the deliverable

This deliverable begins with an introduction of the WP10 objectives and the specific objectives of the first task 10.1 (section **Erreur ! Source du renvoi introuvable.**). That first section includes the links with other Work Packages and a terminology of the main concepts used in the document.

Section 2 introduces the most relevant work that has been considered when starting the work in task 10.1, including the EU taxonomy (Section 2.1), the info kit for the cities by the Cities Mission (Section 2.2), existing platforms with different structures (Section 2.3), and existing definitions on co-benefits (Section 2.4).

Then, section 3 presents the taxonomy itself for the thematic areas for NetZeroCities service definition. The taxonomy for each thematic area, both sectoral and enabling fields, are presented in the subsections, including an overview in the first one (section 3.1). Finally, the cross-sectoral approach is discussed in Section 4 with the aim to summarise the essential connections within the project, and Section 5 concludes the findings.

1.3 Links with other Work Packages

The following links to other work packages have been identified and the required partner contributions have been considered in this deliverable:

- WP2: to bring the needed metrics and methodologies from WP2 to WP10, to assess solutions in T10.2 when needed. AIT is the ambassador of WP2vsWP10 link and ME, Polimi, VTT and CARTIF will help AIT on finding synergies.
- WP3 as the main orchestrator of the service delivery to cities it will take the knowledge repository from T10.2 and services definition from T10.3 to include it in the web portal and platform, respectively. Partners from WP10 can be called by other WPs to deliver a service to the cities, if requested. LGI is the ambassador of WP3vsWP10 link and TNO will help LGI on finding synergies (and capacity building activities).
- WP10 taxonomy will feed the elaboration of the WP4 criteria (WP4 - Selecting and coordinating Cities for Pilots). UPM will work as ambassador of WP4vsWP10 link with CKIC as supporting partner.
- WP5 will ensure that scaling of impact beyond individual installations actually happens; the NZC Catalogue and Expert Services are essential for this to happen. OASC will work as ambassador between WP5 and WP10.
- WP6 will be the main overall systemic transformation orchestrator and will ensure a systemic design is considered within WP7 to WP10. It will also help on linking solutions and services between the WPs as well as defining systemic pathways for cities. CKIC will work as ambassador, supported by TEC, Rupprecht and VTT
- WP7 will work on funding opportunities and business models e.g., through factors that can ease (or challenge) the access on funding and the costs of loans, which should be linked to solutions of WP10 (through the design environment of the solutions). EnC will work as ambassador of this link, supported by CEREMA, ME, and Polimi.

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- WP8 will work on stakeholder and citizen engagement, which should be linked to solutions of WP10 (through the design environment of the solutions). Polimi will work as ambassador of this link, supported by ME and LGI.
- WP9 will work on social innovation, which should be linked to solutions of WP10 (through the design environment of the solutions). WP9 is already mapping case studies which will be linked if the social innovation has been applied to achieve a WP10 solutions or thematic area. Polimi will work as ambassador of this link, supported by ME, TNO and LGI.
- WP13 will identify cities needs and gaps, which could help WP10 on designing services for cities to overcoming those gaps. RCN will work as ambassador of this link, supported by EnC and EIT-UM.

Figure 3 summarizes the links between the different WP10 tasks.

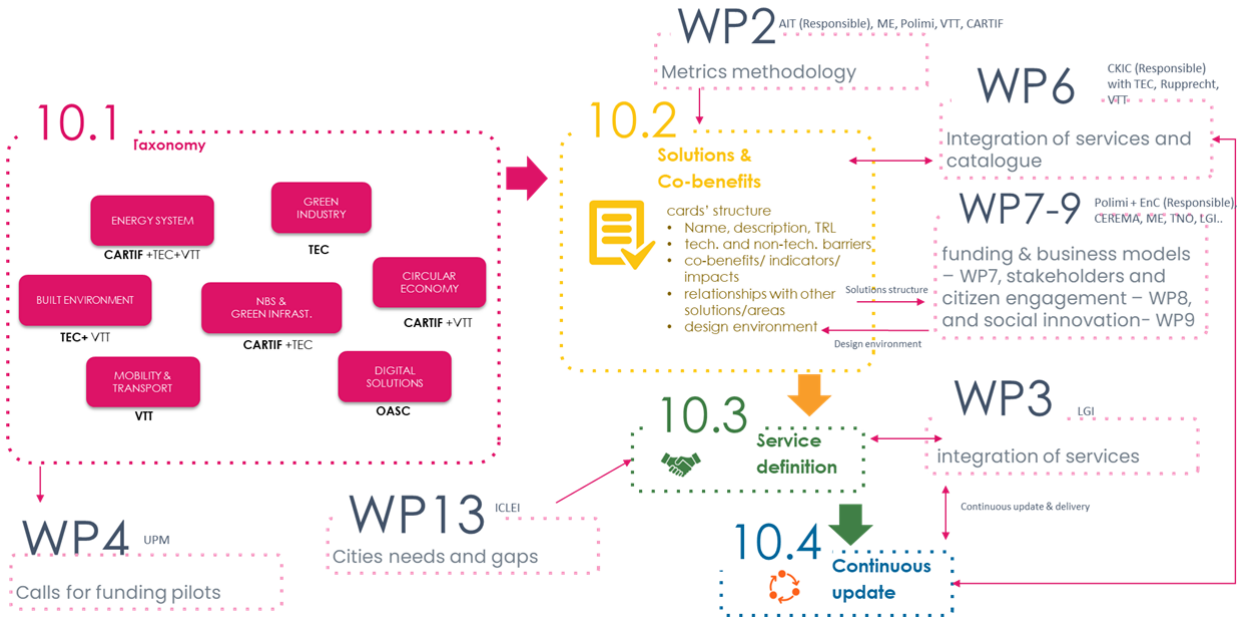

Figure 3: WP10 links with other WPs

Figure 4 shows the different ambassadors (people from WP10 that will bring key issues from other WPs where they are involved). The main ambassador is responsible of updating progress from other WPs that might be relevant to WP10 ensuring the input-output and discussions between WP10 and their respective WP are performed. The role of the rest of the partners mentioned is to help the ambassador in ensuring the links and synergies happen, if needed.

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Figure 4: WP10 ambassadors to the most related WPs

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1.4 Terminology

The following terminology is used in this work:

Taxonomy: a systematic classification of technologies, solutions, and concepts relevant in the transformation of cities towards climate neutrality. A taxonomy is understood as "a classification system for sustainable activities" according to the Technical Expert Group (TEG) on Sustainable Finance (TEG, 2020).

Area/thematic area: sectors and enabling fields that group technologies and solutions.

Solution: In NZC's WP10 context, 'solution' typically refers to a technology or a combination of technologies that contribute to carbon emission reduction in a city while, complying with the DNSH principle. In addition, WP10 will work with WP6-9 and 12 to include 'solutions' in terms of measures (models) for e.g. social innovation, finance, a strong system lens, participation and accessible communication that, likewise, on their own or in combination with technologies, contribute to carbon emission reduction in a city while complying with DNSH principle.

Concept: a principle or an idea (which supports climate neutral city targets, e.g., Positive Energy District, Nearly Zero Energy Building, e-mobility, heating islands, NEXUS-approach, etc.) that can combine several solutions together.

Service: an exchange (e.g., of information) between the WP10 experts and the cities to support the planning, implementation, and design of pilots and/or Climate City Contract (CCC) of those cities. NetZeroCities Project, and specifically WP10, supports cities by providing different services, e.g., by providing access to information about solutions and concepts that support climate neutral city development.

Co-benefits: The positive effects that a policy or measure aimed at one objective might have on other objectives, irrespective of the net effect on overall social welfare. (IPCC, 2018) More insights in section 3.4.

Impact: The effect of a solution in achieving a specified objective and/or dealing with an urban challenge; evidenced as a change or any significant harm to any of the environmental conditions (that affect the environmental objectives of the EU taxonomy), or any other social, economic, and ecological conditions and functions. This way the DNSH principle will be followed a priori (Raymond et al., 2017ab).

Platform: A set of capabilities that are common to delivering a number of otherwise unrelated solutions or services in a way which is more optimal compared to provisioning the solutions or services individually.

For NBS only:

Assets: Green infrastructure that is delivering a function or functions in an area of identified need. For example, woodland that is intercepting and storing water in an area of flood risk is a water management asset; it is providing functions that help to reduce the risk of flooding.

Challenges: different fronts to contributing to climate mitigation and adaptation.

Ecosystem services: The contributions of ecosystem structure and function, in combination with other inputs, to human well-being (Buckhardt et al., 2012).

Nature Based-Solutions (NBS): The Commission defines nature-based solutions as "Solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions."[3]

[3] https://ec.europa.eu/info/research-and-innovation/research-area/environment/nature-based-solutions_en

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2 Background

2.1 EU taxonomy

The Taxonomy Regulation[4] was published in the Official Journal of the European Union on 22 June 2020 and entered into force on 12 July 2020[5]. Article 6.1a. sets the conditions that an economic activity has to meet in order to qualify as environmentally sustainable: make a substantive contribution to one of six environmental objectives (Figure 5), do no significant harm (DNSH) to the other five, and meet minimum safeguards. The Taxonomy Regulation establishes six environmental objectives:

- Climate change mitigation: understood as "the process of holding the increase in the global average temperature to well below 2 °C and pursuing efforts to limit it to 1,5 °C above pre-industrial levels, as laid down in the Paris Agreement"
- Climate change adaptation: understood as "the process of adjustment to actual and expected climate change and its impacts"
- The sustainable use and protection of water and marine resources
- The transition to a circular economy. Circular economy "means an economic system whereby the value of products, materials and other resources in the economy is maintained for as long as possible, enhancing their efficient use in production and consumption, thereby reducing the environmental impact of their use, minimising waste and the release of hazardous substances at all stages of their life cycle, including through the application of the waste hierarchy"
- Pollution prevention and control (of substances, vibrations, heat, noise, light or other contaminant present in air, water, or land)
- The protection and restoration of biodiversity and ecosystems

Figure 5 shows the summary of EU environmental objectives.

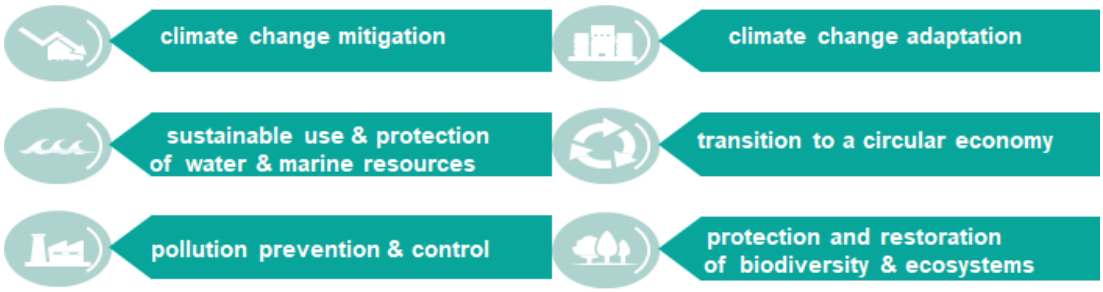

Figure 5: EU environmental objectives according to EU Taxonomy (Final report of the Technical Expert Group on Sustainable Finance, March 2020)

For an activity to qualify as sustainable it cannot cause significant harm to any of the other Taxonomy objectives. For each activity, the Technical Screening Criteria (TSC) lay out thresholds to define compliance with **do no significant harm (DNSH)** principle. According to Article 17, taking into account the life cycle of the products and services provided by an economic activity, including evidence from existing life-cycle assessments, that economic activity shall be considered to significantly harm in line with the principles detailed in Table 1.

Table 1: DNSH for each environmental objective (source: Regulation (EU) 2020/852)

[4] https://ec.europa.eu/info/law/sustainable-finance-taxonomy-regulation-eu-2020-852_en
[5] Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019/2088 (Text with EEA relevance)

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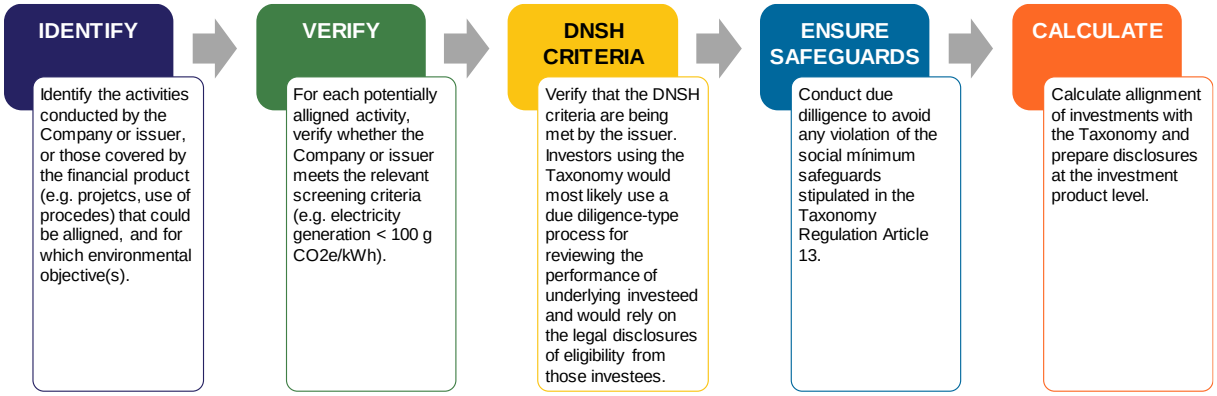
Environmental objective	Activity to be considered significantly harm
Climate change mitigation	Any activity that leads to a significant greenhouse gas emissions on a lifecycle basis (the scope of the assessment should encompass the production, use and end-of-life phases – wherever most harm is to be expected[6]).
Climate change adaptation	Any activity that can increase adverse impact of the current climate and the expected future climate, on the activity itself or on people, nature or assets.
Sustainable use and protection of water and marine resources	Any activity that is detrimental to the good status or the good ecological potential of bodies of water, including surface water and groundwater; or to the good environmental status of marine waters.
Circular economy	Any activity that a) leads to significant inefficiencies in the use of materials or in the direct or indirect use of natural resources such as non-renewable energy sources, raw materials, water and land at one or more stages of the life cycle of products, including in terms of durability, reparability, upgradability, reusability or recyclability of products; or b) leads to a significant increase in the generation, incineration or disposal of waste, with the exception of the incineration of non-recyclable hazardous waste; or c) leads to long-term disposal of waste causing significant and long-term harm to the environment.
Pollution prevention and control	Any activity that leads to a significant increase in the emissions of pollutants into air, water or land, as compared with the situation before the activity started.
The protection and restoration of biodiversity and ecosystems	Any activity that is significantly detrimental to the good condition and resilience of ecosystems; or detrimental to the conservation status of habitats and species, including those of Union interest.

The experience collected from the field by various NZC partners in previous activities shows that the application of the DNSH principle is not simple in practice (e.g. carbon capture, biomass). Therefore, its application methodology will require more efforts in future WP10 activities in collaboration with WP2 on evaluation methodologies. Additionally, it is worth mentioning that not only the environmental criteria mentioned in the EU taxonomy are relevant in NZC project, but we will also consider e.g. gender and diversity aspects in selection of carbon-neutral city solutions.

In the final report of the Technical Expert Group on Sustainable Finance released in March 2020, a 5-step check process can be followed to apply the EU taxonomy (Figure 6).



[6] C(2021) 1054 final link: https://ec.europa.eu/info/sites/default/files/c2021_1054_en.pdf

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Figure 6: 5-step check process to apply the EU taxonomy (Based on Final report of the Technical Expert Group on Sustainable Finance, March 2020)

The technical guidance on the application of DNSH released in a Commission Notice includes a decision tree to help Member States (and therefore, stakeholders), to perform the DNSH assessment to every activity supported in a Recovery and Resilience Plan (RRP) (European Commission, 2021a). This decision tree drives into the checklist to measure the impact assessment on the DNSH principle (Figure 7).

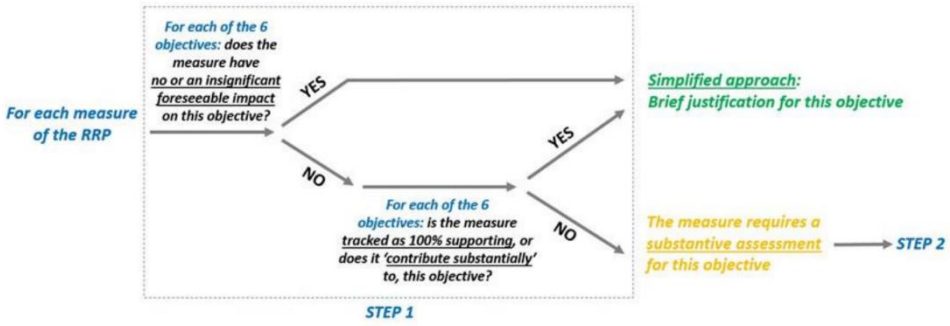

Figure 7: Decision tree (Commission Notice Technical guidance on the application of "do no significant harm" under the Recovery and Resilience Facility Regulation, February 2021)

NetZeroCities platform will guide cities and stakeholders through the existing solutions to undertake actions to achieve emission neutrality. These actions are supposed to respect climate and environmental priorities of the Union and cause no significant harm to them.

The other outcomes of the regulatory work presented by the Technical Expert Group on Sustainable Finance (e.g. EU Green Bond Standard, Methodologies for EU climate benchmarks and disclosures for benchmarks, Guidance to improve corporate disclosure of climate-related information) are out of the scope of this report and will be addressed in other relevant NZC activities (e.g. WP7 Financing the ambition).

2.2 European Mission – Info Kit for Cities

At the level of cities, there is currently no definitive agreement on how climate neutrality targets are implemented. Differences in the definition of neutrality may also lead to very different climate ambitions and actions. It is possible that "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), therefore specifying these aspects by identifying gaps, scopes and sectors is critical and 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 (European Commission, 2021b):

- 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;

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- Emissions from chemical processes in industry (collectively referred to as Industrial Process and Product Use or 'IPPU') within the city boundary.

The EU Info Kit for Cities (European Commission, 2021b) is aligned with Net Zero Cities Thematic Areas, which will tackle one or more of the sectors and sources within the city's boundaries, integrating them by means of digital solutions (Figure 8).

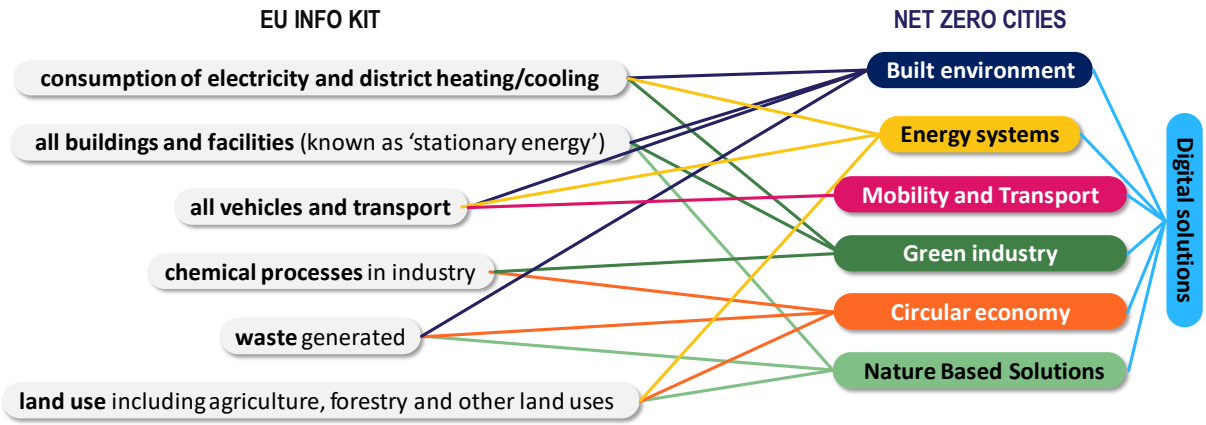

Figure 8: Preliminary relationships between the EU Info Kit and Net Zero Cities Thematic Areas

Furthermore, according to the info kit for Cities, the co-benefits of taking early action towards climate neutrality include, but are not limited to:

- enhanced attractiveness of cities
- 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 (*public health and wellbeing*)
- better education
- more social cohesion
- less poverty

Additional co-benefits include better waste management and water quality and management. Certain co-benefits are specific to the solutions adopted (Raymond et al. 2017b), such as the provision of Ecosystem Services derived from the adoption of Nature-Based Solutions. Section 3.4 reviews also different ways of identifiying and tagging co-benefits. A unique list of co-benefits will be delivered by T10.2 as a collaborative work between WP10 partners and other WPs.

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2.3 Existing platforms and organisation of the platform

In this section, different platforms at European level have been reviewed with two purposes: how a platform could be set up and platforms that touch upon similar thematic areas. It will serve as inspiration for the specifications of the smart repository (D10.4 due in March 2022), how the data could be organised and showed to the user (in this case cities and pilots).

2.3.1 Nature-based solutions platforms

The European Union has considered nature-based solutions (NBS) as a fundamental tool in the pursuit of its main policy priorities. Consequently, numerous projects and initiatives have promoted the development and study of NBS in recent years. One of the priorities has been the dissemination and generalisation of the use of NBS by stakeholders, for which some of these initiatives have launched platforms for accessing the information on NBS with a focus on a specific thematic area.

The most relevant NBS platforms to date are described below.

- **Think – Nature**

ThinkNature, is a multi-stakeholder communication platform supporting the understanding and promotion of Nature based Solutions (NBS). Think Nature was replaced by the current Network Nature, responsible for, among others, to synthesize & strengthen the NBS evidence base by gathering experiences, knowledge, tools and services from over 30 Horizon 2020 projects. Although Network Nature is more recent, the browsing and data organisation within ThinkNature was considered more interesting as it includes an NBS search tool. Both platforms will be reviewed later on in T10.3 (for D10.4) for showing the pros and cons of different platforms and decide on how NZC will organise the data.

Figure 9: Project logo
(Source: Project website)

Figure 10: NBS Projects Map View

The platform allows users to search by map and by data filtering. The filters include the following:

- Project type
- Participant type
- Countries
- Topics

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- Budget
- Call date
- Project start date
- Project end date

Topic filters include: Circular economy, Climate action, Cultural heritage, Earth observation, Natural and cultural assets, Natural resources and ecosystems, policy support, raw materials, SME instrument and water.

❖ **Oppla**

Oppla offers a repository of EU Case Studies for NBS that can be use searching by Scale and type of Case Studies (NC & ES Case Study, NBS Project Case Study and NBS City Overview Case Study).

Figure 11: Project logo (Source: Project website)

Figure 12: Case Studies Map View

❖ **Nature4Cities**

Nature4Cities is a Horizon 2020 EU-funded Research & Innovation project, creating a comprehensive reference Platform for Nature Based Solutions (NBS), offering technical solutions, methods and tools to empower urban planning decision making. This will help addressing the contemporary environmental, social and economic challenges faced by European Cities.

Figure 13: Project logo (Source: Project website)

Nature4Cities platform provides a browser for NBS. Solutions can be browsed by co-benefits or by any of the categories listed below. NBS are classified according to the following hierarchy:

Category:

- Objects, shapes, physical projects, construction
- Actions and strategies

Subcategory:

- On the ground
- Water

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- On the buildings
- Urban management
- Waste management
- Protection and conservation strategies
- Urban planning strategies
- Classes
- Parks and gardens
- Structures associated with urban networks
- Structures characterized by food and resources production
- Ecological restoration
- Choice of plants
- Systems for erosion control
- Solution
- Large urban public park
- Wood
- Urban orchard
- Soil and slope revegetation
- Structural soil
- Reopened stream

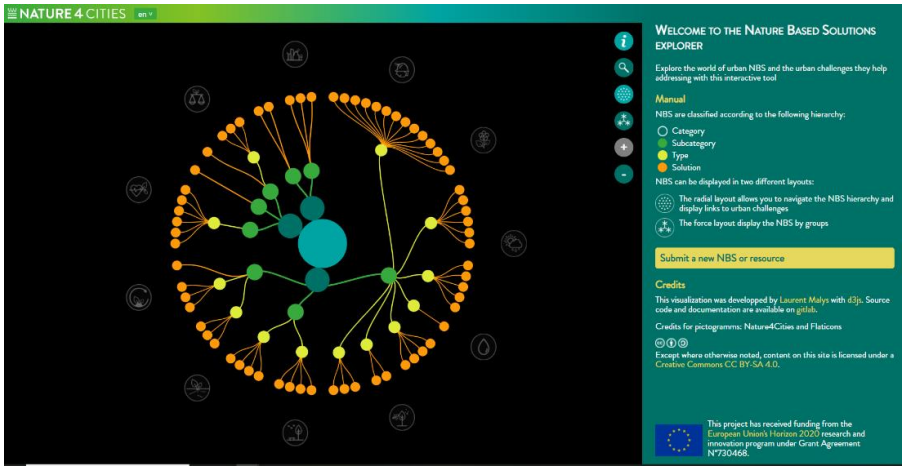

Figure 14: NBS Explorer

2.3.2 Other platforms

❖ **CITYxCITY Catalogue**

The CITYxCITY Catalogue of solutions and products is special in the sense that it is maintained by a network of cities, Open & Agile Smart Cities (OASC), to provide a trusted reference for peers. Filtering

can be done based on impact area (SDG), specific challenges addressed (including carbon neutrality) and the cities/locations of deployment. The categories follow the NZC principle of tags and keywords.

Figure 15: OASC CxC Catalogue (http://catalogue.city)

- **Tech4Good Marketplace**

The Tech4Good Marketplace contains solutions and products which are accessible and affordable and address local needs, including carbon neutrality. It is linked to the EU 100 Intelligent Cities Challenge, one of the precursors of the Cities Mission. Solutions and products can be filtered using the principles being followed by NZC Catalogue.

Figure 16: Tech4Good Marketplace of the EU 100 Intelligent Cities Challenge (http://marketplace.intelligentcitieschallenge.eu)

- **EU Innovation Radar**

The Innovation Radar is a European Commission initiative to identify high potential innovations and innovators in EU-funded research and innovation projects, including those relevant to NZC and the Cities Mission. The goal is to allow every citizen, public official, professional and business person to discover the outputs of EU innovation funding and give them a chance to seek out innovators who could follow in the footsteps of companies such as Skype, TomTom, ARM Holdings, all of whom received EU funding in their early days. Innovations are tagged as in the NZC Catalogue, and categorised on maturity and thematic areas, including Smart and Sustainable Society.

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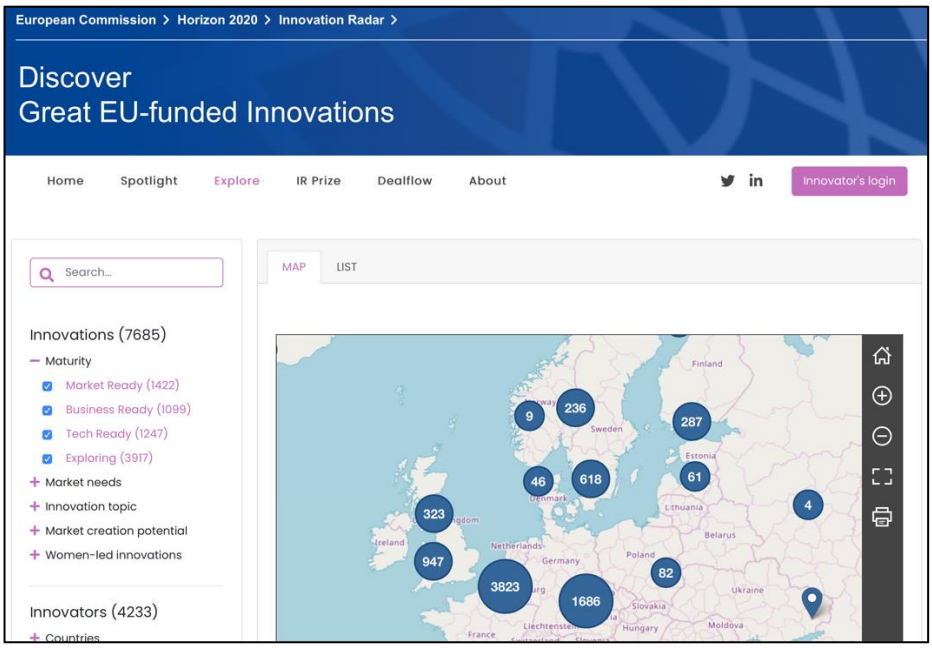

Figure 17: The European Innovation Radar, catalogue of excellent and available EU research and & innovation (http://innoradar.eu)

- **DEEDS, Dialogue on European Decarbonisation Strategies**

The Dialogue on European Decarbonisation Strategies (DEEDS) delivers state-of the art knowledge on decarbonisation pathways and facilitates knowledge co-creation with policy, business representatives, scientists, NGO's and other stakeholders." From this project, different pathways could be used for inspiring NZC grouping of solutions in T10.2.

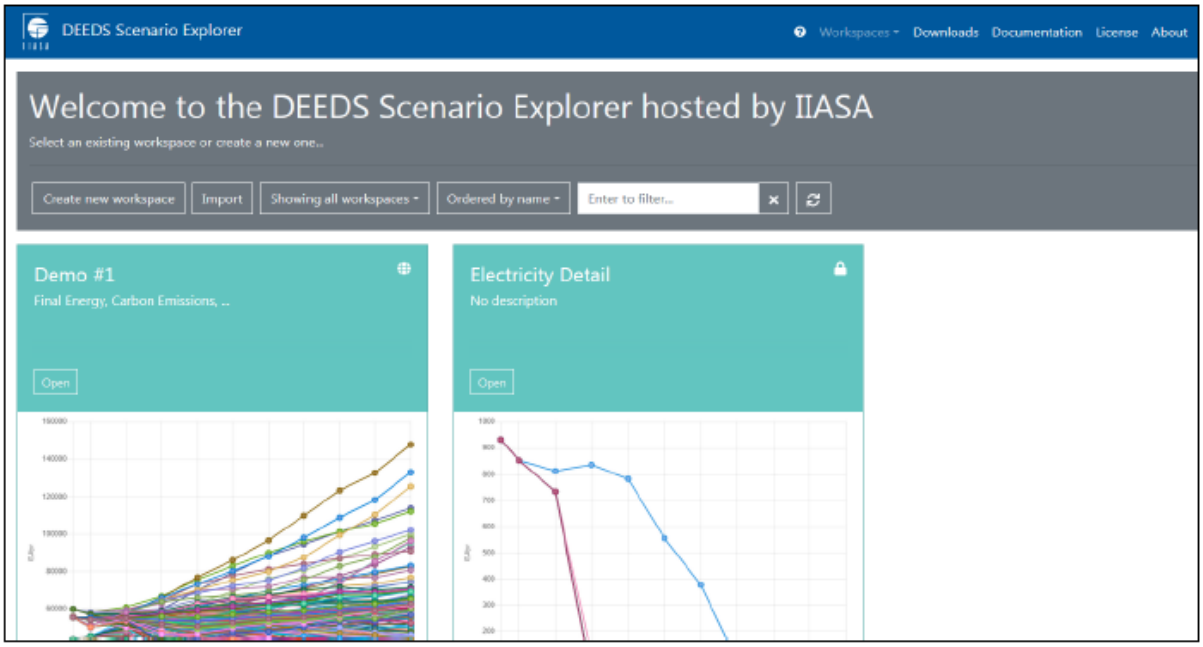

Figure 18: DEEDS, Dialogue on European Decarbonisation Strategies (overview of workspaces accessible to the user, http://deeds.eu/, and https://data.ene.iiasa.ac.at/deeds-explorer/)

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2.4 Defining co-benefits

Recent academic review on how scholars define the term ‘co-benefits’ revealed that there is no univocal definition of what it actually means. ‘Co-benefits’ is essentially an ‘umbrella’ concept that is contestable in its meaning due to its definitional ambivalence, multidimensional nature, normative character, and modification in due course of its evolution (Mayrhofer and Gupta 2016). The common ground in all approaches is, however, the elaboration of a ‘win–win’ strategy through which at least more than one objective is achieved through a single policy. In climate change studies, the term ‘co-benefit’ has been used to describe synergies between climate change mitigation/adaptation and other goals. On a general level, the co-benefits terminology has been used in different ways across different research fields.

In IPCC terminology, co-benefits refer to ‘the positive effects that a policy or measure aimed at one objective might have on other objectives, irrespective of the net effect on overall social welfare’ (IPCC, 2014, p. 14).

Mayrhofer and Gupta (2016) found five types of co-benefits in the climate change literature: climate-related, economic, environmental, social, and political & institutional (Figure 19). The co-benefits concept is complex and multidimensional as shown by the various goals that might count as a co-benefit in diverse policy areas such as economic, environmental, and social policy.

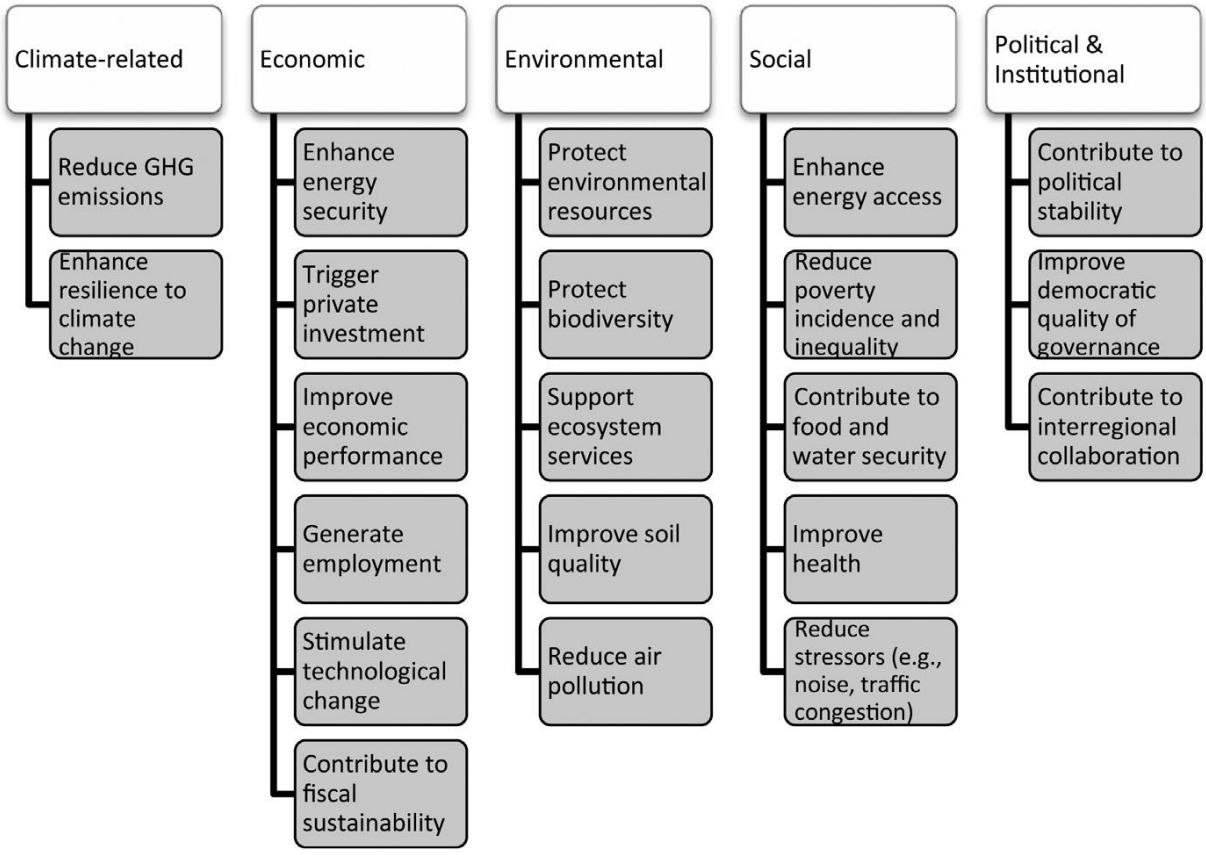

Figure 19: Types of co-benefits (Mayrhofer and Gupta 2016)

In the co-benefits literature focusing in climate change, Mayrhofer and Gupta (2016) identified three clusters. The first cluster refers to co-benefits as ‘climate co-benefits’. Here, the policies studied in these articles are not specifically designed to address climate change, but other development plans that might benefit climate. The second cluster refers to ‘development co-benefits’ as largely local impacts that are the result of specific climate change policies. The third cluster emphasises ‘climate and [other goal] co-impacts/co-benefits’ as policy measures that are designed to achieve two goals simultaneously.

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Although the co-benefits concept is a wide concept, it has attracted initially particularly natural science scholars, and subsequently mostly economic scholars and there is a lack of engagement by other academic scholars.

According to Tanner and Allouche (2011, p. 1), the dominant economic approaches (highlighting cost–benefit or cost-effectiveness analysis) tend to depoliticize the political argument of 'no-regrets' into an optimization approach that fails to include political realities.

EKLIPSE Methodology

The EKLIPSE (Raymond et al, 2017a) mechanism or methodology establishes 10 societal challenges and their sub-challenges that could be faced by nature. This classification allows a standardised method for the NBS's Monitoring, Evaluation and Learning (MEL) and facilitates measuring and shows how NBS projects fare against the identified indicators in delivering the multiple environmental, economic, and societal benefits.

Figure 20 shows the ten groups of co-benefits used in URBAN GreenUP project, which must be taken into account to reach the co-benefits positively. For example, in the case of Climate Mitigation and Adaptation were identified two main cp-benefits: mitigation and adaptation. These division of co-benefits are important and different from each other, whereas adaptation refers to "an adjustment in ecological, social or economic systems in response to observed or expected changes in climatic stimuli and their effects and impacts in order to alleviate adverse impacts of change or take advantage of new opportunities" but, mitigation refers to "the potential of reducing GHG emissions through the implementation of NBS at different spatial scales, thus contributing to the global challenge of reducing climate change".

Figure 20: The 10 climate resilience challenges and their sub-challenges considered in EKLIPSE

All these co-benefits of applying NBS, explained in detail in Subsection 4.7, consider impacts in all scales that could be grouped into mesoscale (regional, metropolitan, urban) and microscale (neighbourhood/street, building) also across the geographic and temporal scale.

In addition, it could be grouped as done in the URBAN GreenUP[7] project. The standardization of the method is one of the most relevant milestones of URBAN GreenUP objectives. For that reason, parameterisation within that project was performed, which allowed identifying the factors that influence each co-benefit, analyse and assess them in quantitative and/or qualitative, according to each case as well as evaluate the city depending on each city challenge and their own diagnosis. Within the project,

[7] https://www.urbangreenup.eu/

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Renaturalisation of Urban Plans, which focused on the implementation of NBS in urban and peri-urban areas, considered 4 main groups: Re-naturing urbanization, Singular green infrastructure, Water interventions and non-technical interventions. The later one aimed at promoting the goals and strategy of URBAN GreenUP among citizens and through participatory processes. These include several educational and engagement activities, as well as City coaching initiatives such as school ecological workshops and thematic meetings. The objective is to develop people's ecological reasoning and intelligence. Finally, Support activity will be offered to facilitate further re-naturing works as well as green projects from citizens and private companies.

In the cases of Re-naturing urbanization, Singular green infrastructure and Water interventions, solutions in this group cover vast urban areas and mitigate the effects of climate change. These include Green routes for bicycles and pedestrians to encourage sustainable mobility and reduce carbon emission. The Arboreal interventions, with the plantation of trees, will provide better air quality, pollution capture, incremented amounts of shady places, cooling the overall temperature by a few degrees during summertime and enhance local biodiversity.

Other co-benefits such as gender economic empowerment and gender engagement in suitanable urban development decisions (UN WOMEN, 2016), will be considered and the gender dimension will be analysed. Within T10.2 development, a unique list of co-benefits should be delivered using the ones previously identified (EKLIPSE, URBAN Green Up project, etc.) as well as any other that could be identified during the research processes, to tag solutions among WPs (WP6 to WP10) for developing the smart repository in T10.3 and WP3.

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3 Preliminary taxonomy of thematic areas

3.1 Overview

From the different revisions performed within section 3 (EU taxonomy, Info Kit for cities, etc.) and based on the Horizon calls and expertise of partners, the thematic areas of NetZeroCities (NZC) are defined and organised as follows:

- relevant sectors needed in the climate neutral city transition:
    - Built environment
    - Energy systems
    - Mobility and transport
    - Green industry
- enabling fields:
    - circular economy
    - nature-based solutions
    - digital solutions

In WP10, solutions will be identified, grouping them into categories as well as concepts (such as “smart cities and communities” or “positive energy districts”). Also, the solutions and groups of solutions will be linked together to form pathways that a city could follow to address a specific objective. For example, if a city’s challenge is to address climate adaptation to droughts and wanted to tackle *waste and water management for climate neutrality*, it needs include several areas at the same time. To address that challenge and technical need (waste and water management), a pathway such as Figure 21 could be applied, which integrates urban water system for power generation (through pumps as turbines), grey water heat recovery combined with treatment and reuse of water for gardens and toilets, hydraulic disposal of residential and commercial waste for co-digestion and production of biogas, that could be later used for decarbonising industries or for power and heat production (through a biogas CHP plant). Digital solutions would be needed to monitor the production and consumption, as well as water recycling and reduction of tap water use, that could inform citizens on the systems’ performance.

As co-benefits we have better air quality and health, reduction of water usage and waste, reduction of GHG emissions derived from power and heat generation and industry, among others. To design such systems, policy support is needed and dedicated regulations (such as ordinances) to push new and retrofitted buildings to include the above-mentioned solutions. The needed design environment (i.e., regulatory, policy, stakeholder engagement, etc.) will be also analysed within T10.2 including information from other WPs (WP7, WP8, WP9, among others), and considering WP6 approach on fostering a systemic and holistic perspective. The result will be the library repository (D10.2) and the smart repository (WP3+WP6-WP10 collaboration) for assisting cities in tackling different challenges, co-benefits, and needs.

Systemic approaches such as this one will be identified in T10.2 by means of linking solutions and using the levers identified by Material Economics in their tool (Figure 21).

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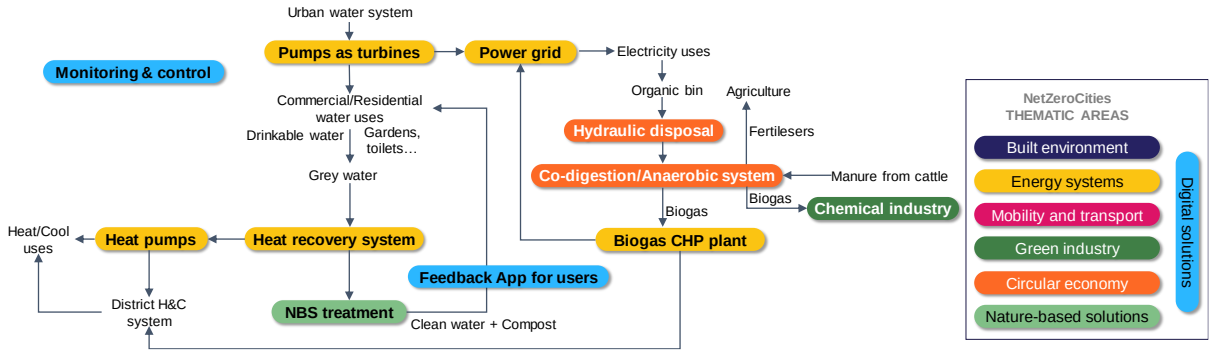

Figure 21: Example of an integrated approach tackling waste and water management in urban systems

Data and digital capabilities are special enablers as they tend to challenge traditional ways of provisioning services in closed systems. The most efficient companies today are based on platforms that are fundamentally generic and agnostic towards the application areas they are used to address. This is shown in the Figure 21 above and also recognised in the New Leipzig charter as a fourth concern, cutting across the Just, the Green and the Productive aspect. In the thematic areas below, data and digital are essential parts and are described within the scope of the area. But we recognise the transversal nature of the data spaces and platforms that are instantiated along the "computing continuum", from the Cloud with its high-performance computing capabilities to the Edge where sensors have limited resources such as power and bandwith.

In the following subsections, the thematic areas of NZC are described in detail, grouping the solutions in categories, and giving particular examples. A dedicated, concluding section addresses the transversal aspects of the digital.

3.2 Built environment

The thematic area *Built environment* addresses all solutions targeting an improvement of the building sector in climate neutrality terms, including both direct and interconnected solutions with other thematic areas.

In this case, the solutions are grouped into different categories according to their nature (technical/non-technical), field (economic, regulatory, governance, etc.), and scale (building or district), finally achieving a taxonomy that structures all those solutions identified. Regarding the more technical solutions, diverse energy efficiency and generation solutions connected to both the building and district scales are considered. Regarding the "soft" measures considered, most of times the most challenging ones, regulatory, economic, governance, procedural and engagement solutions are also on the list. Additionally, there is also an identification of key built environment concepts to be considered by a city who may take the climate neutrality path, and that can clarify the hot spots to be considered by a city strategy. Those concepts can also be connected and combined to the solutions mentioned in the other categories of this thematic area, namely:

- The energy systems area; very closely connected through active (I.e., renewable energy generation), passive (I.e., energy efficiency), and energy control solutions, both for building and district scale. **Passive solutions to renovate and reduce energy needs should be prioritized prior any renovation of the active systems.**

- The digital solutions area; as an enabler to manage, control and forecast buildings performance, with the Smart Readiness Indicator scheme as reference. Digital solutions can have a significant role in engaging buildings' users for a better building energy performance.

- The circular economy area; to assess the life cycle of building materials, fostering renovation as a key driver, integrating the urban metabolism concept as a key driver when looking at the built environment.

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- The mobility and transport area; providing from the building stock and the public space the suitable environment and infrastructure for active mobility and electric vehicles (EVs) to grow (i.e., EV charging infrastructure).
- The green industry area, thinking of it as an inherent part of the built environment, hence being applicable many of the same solutions to both.
- The Nature Based Solutions, that coexist closely with the urban space as a crucial infrastructure for climate neutrality.

Table 2 presents the main solutions identified within this thematic area.

Table 2: Built environment thematic area taxonomy

SOLUTIONS CATEGORY		Examples
Envelope	Passive EE (Energy Efficiency)	Insulation of external walls, roofs, lofts, floors; replacement of windows, doors; draught proofing; installation of solar shading systems; employment of natural ventilation techniques, passive solar heating or cooling techniques,etc.
Building automation, management, and control (link with digital solutions)	EE Heating and Cooling (link with energy systems)	Replacement of inefficient boilers with other solutions (link with energy systems); improvement of mechanical ventilation, air-conditioning, lighting, auxiliary systems; installation of heat recovery system; improvement of emission/distribution systems of technical systems (e.g. pipework insulation); installation of building controls; installation of micro cogeneration systems, etc.
	EE Ventilation and Air Conditioning (link with energy systems)	
EE Lighting/ Appliances		Replacing appliances and cooks to efficient ones (A+); smart control of appliances (link with digital solutions), etc.
Integrated Renewable Energy Sources (RES) (link with energy systems)		Biomass boilers; thermal solar systems; ground, water, air source heat pumps; photovoltaic systems, micro wind generation systems, micro-hydro systems, etc. (Classification from Energy Systems)
Integrated Energy Storage		PVs and batteries, etc. (Classification from Energy Systems)
EV charging infrastructure integration		EVs echanging electricity with the grid: uni-directional (V1G) or bi-directional (V2G) electric vehicles, etc. (Classification from Mobility and Transport)
Materials	Embedded emissions of buildings	Biobased materials are derived from renewable organic matter (biomass) of plant or animal origin: wood, hemp, straw, cellulose wadding, recycled textiles circular use of building materials (link to the circular economy)
Smart solutions	Demand management (link with digital solutions)	Demand control, smart metering, energy balancing building, energy modelling, predictive digital twins (Classification with digital solutions), etc.
District Infrastructure	Public lighting	EE LED lamps, smart lighitng systems, smart use of public lighting, etc.
	District networks (link with energy systems)	District heating, district cooling, smart grids, etc.
	Waste and water management	Vacuum waste, underground collection systems, water reuse (link with circular economy area), etc.
	City planning, control, and management	Digital twins at city level (link with digital solutions)
Governance & Planning		**Examples**
Climate neutrality Governance EU framework (and adapting national targets to local contexts)		National Energy and Climate Plans (NECP), Long-Term Strategies, Long-Term Renovation Strategies (LTRS), Circular Economy Action Plan (CEAP)
Integrated urban planning methodologies		Climate Neutral & Smart City Guidance Package, Cities4ZERO methodology, REMOURBAN model

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Integrated urban energy and climate plans	Sustainable Energy and Climate Action Plans (SECAPs)
Integrated Energy and GHGs scenario and mapping tools, modelling approach	Tool to help define a strategy, to answer operational questions (number, age, energy consumption and GHGs impact, etc. of buildings to renovate to achieve carbon neutrality).
Life Cycle Assessment (LCA)	LCA connected to building renovation, “Scope 3” of climate neutrality requisites.
Observatories at EU level	Building Stock Observatory (BSO), Energy Poverty Advisory Hub (EPAH)
Economic	**Examples**
Grants and subsidies	EC R&D Programmes, grants and subsidies from cities and local authorities
Loans	Traditional and soft loan schemes; with performance contract bill repayment model; on-tax repayment model; on-utility bill repayment model
Fiscal instruments	Income tax credits/ dedutctions; property taxation; VAT reduction
Schemes to stimulate EE	Energy Efficiency Obligation Schemes (EEOs), Energy Efficiency Feed In Tariffs (EE FITs), Third-Party Financing Company
Policy & Regulatory	**Examples**
Key regulation at EU level	Energy Efficiency Directive (EED), Energy Performance of Buildings Directive (EPBD), Renewable Energy Directive (RED), Governance Regulation (GOV)

Futhermore, some of the solutions above-mentioned, could form concepts like Nearly Zero Energy Buildings (NZEB)/ Zero Energy Buildings (ZEB), or Positive Energy Buildings (PEB) - link with energy systems area, that could form Positive Energy Districts (PEDs) / Positive Energy Neighbourhoods (PENs) - link with energy systems area. Other conceptual approaches could be considered such as:

- Energy Performance Certificate (EPC) and National EPC databases
- Energy Performance of Buildings Standards (EPB standards)
- Building Renovation Passport
- Renovation Wave
- Major/ complete renovation or step-by-step renovation;
- Renovation level (low, medium, deep)
- Smart Readiness Indicator
- Energy Poverty and Precariousness
- Embodied energy

Although, the following are not solution as such, processes, engagement & services such as: Integrated renovation processes (e.g. Turnkey retrofit), One-Stop-Shops, Active Energy Performance Contracting (like Energy Service Companies (ESCos)), Users’ engagement APPs (for consumption, gamification, training) - link with digital solutions, among others could be considered as par tof the Built Environment area.

Because of implementing these solutions in the built environment, the potential co-benefits for a city are remarkable, due to the crucial role buildings play in the urban metabolism. Energy efficient renovation of the building stock as an activity entails most of the co-benefits identified for the whole thematic area.

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The main co-benefits connected to the deployable solutions in the built environment are:

- Reduced GHG emissions and air pollution through energy-efficient renovation
- Enhanced resilience of the built environment to climate change
- Triggering private investment, generating employment, and improving the local economic performance through investments in the renovation sector
- Stimulating technological change in our homes and construction sector
- Reducing land-use through fostering renovation
- Reducing energy poverty incidence, inequality as well as enhancing health conditions and comfort in the building sector

3.3 Energy systems

The thematic area of "Energy systems" will cover solutions in the role of local energy production and Renewable Energy Sources (supply side) as well as the ones supporting system flexibility for allowing much higher shares of renewable energy in the broader energy system and infrastructures (district heating and cooling networks – DH&CN, natural gas networks, and power grids). The area will involve centralised and decentralised solutions for local electricity generation – as well as local heat and/or cold generation and sustainable fuels (connection with circular economy and green industry). Solutions will be combined and connected with:

- The digital solutions area as enabler for optimizing the energy systems and monitoring and control them
- The circular economy area, to ensure the life cycle of RES systems (increasing its reliability in time, reducing raw materials, recycling and upcycling the systems when its life cycle is over, etc.), to minimize land use and waste and use of water (that could affect other sectors such as food and urban systems), among others
- The green industry area, to decarbonise it through the integration of RES, sustainable fuels, energy efficiency, and recovering waste heat and cooling, among others.
- The buildings area to supply the uses of buildings and districts
- The mobility area to supply it with sustainable fuels (such as green H2) and RES electricity

The main scale of the systems will cover tertiary, public and residential buildings, as well as district concepts. The systems applied at the industry sector will remain in the green industry area. The taxonomy of the energy systems area will divide the solutions into a technical classification and into a more horizontal classification that will include concepts (such as positive energy districts – PEDs), challenges and co-benefits (of section 4.2) derived of the implementation of such systems, among others. Concepts such as Positive Energy District, Green neighbourhoods, Smart Cities, Local energy communities such as Citizen energy communities and renewable energy communities, among others, will be reviewed.

Table 3 presents the main solutions identified within this thematic area.

Table 3: Energy systems thematic area taxonomy

SOLUTIONS CATEGORY	Examples
Power generation	PV on buildings (BIPV, PV on roofs, etc.), solar roads, floating solar pontoons, micro-wind and micro-hydropower systems, fuel cells, etc.

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Hybrid solutions		Hybrid solutions (PV+HP, FPC + HPs, etc.), hybrid PV thermal panels (PVT), micro fuel cells co-generation units (H2 based, methane/natural gas based, etc.), oxide fuel cells, etc.
Storage solutions	Thermal	Phase change materials for storage, Seasonal storage (pits, dwells,etc.)
	Electric	Li-on batteries, condensers, etc.
	Chemical	Metal hydrides, H2 pressure vessels, biogas holders, etc.
	Others	Reservoir energy storage, compressed air, etc.
Sustainable fuels		H2 electrolysers, biomass plants (coming from a sustainable use of biomass such as forest waste), biogas boilers, etc.
Infrastructure		From 3G to 5G district heating and cooling networks (DH&CN) (generation to substations), renovation of 1G and 2G DH&CN, micro grids, etc.
Heat recovery		Sewage heat recovery system, Heat from DH return pipeline for low temperature usage, etc.
RES heating and cooling		Heat Pumps, Free cooling, solar thermal collectors, etc.
Reduction of pollution to air, water, and ecosystems (DNSH)		Use of natural refrigerants (CO2, Ammonia) and new refrigerants (F-GAS regulation compliance), Efficient Filters for biomass (reduction of particles in exhaust gases), Desalination technologies (for use for energy systems), Carbon capture, eco-design of systems (link with circular economy), etc.
Energy efficiency measures		Energy efficiency measures for energy technologies
Solutions for service provision		**Examples**
Management and optimization (link with digital solutions)		Demand response mechanisms modelling in the energy domain, data-driven energy system, energy system optimization (MPC, advanced controllers, etc.), P2P services in the energy domain
Policy and regulation		**Examples**
Energy social structure		Cooperatives, local energy communities, etc.
Replication support		Support cities in identifying (and overcoming) barriers Capacity building and training in energy solutions
Energy policy and planning support		Energy policy planning definition (strategies, incentives, regulations, etc.), Integral model chains for energy system analysis, long term scenarios for identifying energy strategies (carbon taxes, etc.), etc.
Economic instruments		**Examples**
Business models and exploitation of energy systems		Business Models for energy communities, ESCO business models, etc.
Funds and incentives		Funds for deploying energy communities in cities, funds for renovation of old boilers into RES systems, etc.
Taxes		Increase taxes in a specific fossil fuel, etc.

The co-benefits and challenges that can be obtained/addressed by applying a single or a group of solutions will be analysed. For example, by means of the deployment of renewable energy communities, not only emissions of a city can be reduced but also social co-benefits can be obtained, such as being able to access to scholarships (e.g., Crevillent energy community in Spain), increasing health (direct by reduction of particle matters, or indirect by means of investing in recreation spaces) or reducing energy poverty thanks to bills reduction. How the implementation of the solutions can be done in a successful way, will be also analysed within T10.2 by means of defining the most typical barriers and the most suitable environment (i.e., the desired context in terms of regulatory, funding – WP7, etc. Terms that are needed to apply a technology in a successful way) so it is easier for a city to identify their missing gaps and barriers. Some direct co-benefits can be summarized as follows:

- Increase access to clean, affordable, and secure energy

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- Increase low carbon energy production (the threshold of the EU Taxonomy, i.e., <100 g CO_2eq/kWh[8], should be followed)
- Reduce energy poverty (through energy communities' implementation, reduction of energy bills, etc.)
- Reduce land use (through agrovoltaics, use existing infrastructures to locate PV panels, among others)
- Increase upcycling and reduce primary raw materials (for example, lithium or catalysers), linked to circular economy
- More social cohesion and job access (indirect, through energy communities)
- Increased technological readiness
- Lower future maintenance costs (by improving the reliability with digital solutions)
- Increased property value
- Better air quality and health (indirect, through the reduction of particle matters)
- Enhanced stability of the urban infrastructure (district heating networks, power grids, etc.)
- Improved participation, interaction, and awareness among citizens (link with digital solutions)
- Healthier and more active lifestyles (indirect, through investing benefits from energy communities in recreational activities)

Furthermore, integrated, and systemic pathways will be also identified by linking solutions together to address a specific objective or need of a city.

3.4 Mobility and transport

In the mobility and transport thematic area, it is important to take a systems perspective in defining the taxonomy. A mobility or transport system (international, national, or local) is a large socio-technical entity. The state of the transport system is a result of the measures and actions carried out by the producers, operators, and users of the system. Producers and operators are organisations or companies, which can be categorised according to their main duties, such as: policy formulation, infrastructure construction and maintenance, production and operation of services for the transport system, and production of transport-related technologies and services (e.g., vehicle manufacturing and fuels). Individual people, actually the whole population, are the users of the passenger transport system. In freight transport, users are companies and organisations in the fields of industry, transport service provision and commerce. Basically, the ultimate purpose of the transport system is to serve the needs and expectations of the end users, who in turn shape the system by their own behaviour and actions. The system is thus both socially constructed and society shaping. Solutions and measures have evident linkages with:

- Digital solutions, which act as an enabler for many new mobility service solutions, such as e-vehicle or e-scooter sharing and charging solutions.
- Circular economy, in various considerations of reducing raw materials and minimising land use and waste (e.g., in transport and urban infrastructure construction and upgrading), and in recycling of the batteries and materials of e-vehicles and infrastructures, among others.

[8] According to: Final report of the Technical Expert Group on Sustainable Finance, March 2020

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- Green industry, to decarbonise transport industries through the electrification of urban road transport and logistics, integration of RES, sustainable fuels, and increasing energy efficiency, among others.
- Energy systems, for example in provision of RES electricity, in the management of supply and demand of e-vehicle charging, and in the provision and distribution of other sustainable fuels
- Built environment and nature-based solutions, in planning, allocation and use of urban space for transport versus other urban uses (parks, green belts, residential and commercial areas etc.).

Traditionally, solutions and measures shaping the transport system can be placed in five broad categories. These are regulatory instruments, economic instruments, land-use measures, infrastructure measures and information provision. Below we have modified and extended this traditional categorisation to serve the development and deployment of the transport systems of climate neutral cities, in which new technological and service solutions are particularly emphasised.

Table 4 presents the main solutions identified within this thematic area.

Table 4: Mobility and Transport thematic area taxonomy

SOLUTIONS CATEGORY	Examples
Vehicle solutions	e-cars, e-buses, e-scooters, Cooperative, connected and automated mobility (CCAM)
Infrastructure solutions	Charging stations, hubs, networks, Intermodal mobility hubs, C-ITS for urban areas, bike lanes, pedestrian lanes, reserved lanes (e.g. car sharing vehicles), parking spaces
Service solutions	Drone transport for goods & passengers, Urban freight delivery, Car-sharing, Bike-sharing, carpooling, shared e-scooters, Collective passenger transport, other smart mobility services, multi-modal services, Mobility as a Service (MaaS) offerings, Micromobility services
BioFuel and clean fuel solutions	Clean fuels e.g. 2nd generation biofuels, LNG, CNG, synthetic fuels, hydrogen, etc. With less fossil energy and more renewable energy
Digital solutions	Digital twins for mobility and environment, AI for mobile machinery, Mobility apps, Traffic Management for efficiency gains, Multimodality apps.
Planning & Regulation	**Examples**
Transport and urban planning	Promotion of active mobility (walking and cycling), Sustainable urban mobility planning (SUMP), Policy measures for sustainable mobility, Recovery of public space
Restrictions	Urban vehicle access restrictions, low-emission zones, parking management
Economic instruments	**Examples**
Pricing	Road pricing, parking fees, public transport fees, congestion charging
Green finance for sustainable mobility	Green bonds, green equity, EIB
R&D funding	Research programmes for new smart mobility services, eVehicles, active modes, etc.
Research & Development (Decision-making support)	**Examples**
Modelling approaches	Network efficiency and emissions in urban areas, System dynamics modelling for policy options. AI and Digital Twins
Evaluation frameworks	CIVITAS impact and process evaluation framework, SUMI indicator set, Road safety evaluation tools
Impact Assessment approaches	Mobility assessment framework (incl. conceptual model for mobility)

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Foresight approaches for sustainable mobility	Scenarios, roadmaps, horizon scanning
Other approaches	Planning tools for cleaner transport, Gender diversity considerations in urban mobility (exploratory walks, sentiment of security)
Information provision, Capacity building	**Examples**
Mobility management	marketing, information, communication, education, training, company mobility plans
Co-creation and Collaboration	**Examples**
Public participation and citizen engagement in urban mobility	Temporary urban interventions, collaborative mapping, stakeholder mapping, focus groups,
Co-creation in mobility	Urban living labs, co-design workshops,
Institutional cooperation, business modelling, PPP	Public-private partnership
Testing solutions and city/firm match making	Living labs and demos of solutions for scale-up

As discussed above, the transport system is a complex socio-technical entity, which means that linkages between the elements of the system are complex. Consequently, impacts of a certain solution may be manifold and synergetic or conflicting and hence not so easy to capture entirely.

Technological and service solutions, e.g., EVs, charging stations or car and bike sharing systems, bring potentially also socio-economic benefits such as new jobs to the transport industry and service businesses, which may increase the competitiveness of the sectors. New service solutions may on the one hand reduce the urban land take by reducing the need for parking spaces and vehicle lanes, but on the other hand, increased transport automation in the future may also induce new trips and increase urban congestion and energy consumption. There are, however, also conflicts with protection and restoration of biodiversity and ecosystems. For example, batteries, components, etc. require a lot of resources; climate change impacts of electricity depend on how it is produced, etc. Cultivation of plants for biofuels production may have conflicts with other uses of fields, e.g., food production. Nearly all the solutions in this first category are linked with each other somehow.

In the context of *Planning and Regulation,* the Sustainable Urban Mobility Planning concept provides an established and proved framework, endorsed by the European Commission. The promotion of active transport modes (biking and walking) can bring individual and public health co-benefits as well as have positive implications to local air quality together with vehicle access restrictions.

Further examples of horizontal challenges directly linked with the mobility and transport thematic area are socio-economic issues such as, transport poverty, equity, and vulnerability. Often urban transport system users do not have the ability, skills, or competence; or they cannot afford to use new technologies and service solutions.

3.5 Green industry

Green industry based on resource efficiency, use of renewables and circularity of the processes is one of the pillars that need to be addressed. For cities, however, many times this is out of scope. It is understood that companies should walk autonomously, and their efforts are not integrated as part of cities' strategy. However, companies cannot be considered isolated from the local context in which they operate. They bring to the territory wealth (taxes, employment, etc.) and probably also synergies and symbiosis in many solutions. It must also be pointed out that the term `*Green Industry*´ is very generic and not only gathers process industries (steel, machinery, automotive, pulp & paper, etc.), but also service companies (logistics, software, engineering, etc.), and even retail service companies (cities' shops, supermarkets, restaurants, …). The needs in each case will be different and the proposed solutions as well.

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It should be considered that industry decarbonisation is looking at not only direct emissions but also indirect emissions from a life cycle perspective. By doing so the scope is broader and more difficult but at the same time more synergies appear with city level solutions.

Furthermore, many of presented solutions will be connected with:

- the digital solutions area as enabler for optimizing the energy and environmental systems and their monitoring
- the circular economy area, to ensure that from a life cycle perspective GHG are considered and reduced as much as possible, as well as the use of raw materials, water, etc.
- the energy systems area, from the perspective of integration of RES, sustainable fuels, energy efficiency, and recovering waste heat and cooling, among others.
- the built environment area to reduce building energy demand and consumption,
- the mobility area, not only from the point of view of logistics, automotive and component industries, but also considering the impact associated to employee's mobility as well as from an urban strategy point of view.

Table 5 illustrates the main solutions for this thematic area.

Table 5: Green Industry thematic area taxonomy

SOLUTIONS CATEGORY		Examples
Energy Efficiency	Heat Recovery & Valorisation	Heat recovery systems (heat upgrade technologies such as heat pumps, heat transformers, etc.), heat recovery from Data Centers, heat recovery from industrial sites for District Heating, etc.
	Smart Energy Management	Digital Twin (link with energy systems) in industries
	Monitoring Systems	ISO certification, control systems for industries energy management, energy audits
	Renewal of equipment	Efficiency in ovens, engines, compressors, etc.
	NZEB	Building envelope and systems improvement (link with built environment area)
Renewable Generation (link with energy systems)	Biomass	Cogeneration, boilers, etc.
	PV	PVs on roof, solar canopies, large scale PV power plants, etc.
	Solar Thermal	Solar thermal integration for industries, solar concentration technologies, etc.
	Geothermal	
	Heat Pumps	Heat electrification, High temperature HP
	Waste valorisation (energy)	Link with circular economy
Integrated Systems	Green Hydrogen technologies	Power-to-gas and gas-to-power technologies such as Fuel cells, electrolysers, etc applied in industries (green H2 integration in chemical, steel, etc. Industries)
	Storage	Batteries, H2 storage, compressed air storage, etc.
	Energy Communities	Link with energy systems area
CO_2 emission reduction	Capture, Storage & Utilisation	Use of CO2 for industrial processes (for instance for concrete production)
	Compensation (link with nature – based solutions)	CO2 certificates? Tree planting, support to renewable energy generation projects,

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Other Resource Efficiency	Water (link with circular economy)	Reduction and reuse of water streams in an industry, reuse etc.
	Greener raw materials (link with circular economy)	Reduction of raw materials quantity and embedded GHG
	Circularity (link with circular economy)	Recycle and reuse of waste to include them again in the manufacturing process
Air Quality improvement	Use of biochemicals	Reduction of dissolvents. New organic dissolvents, varnishes, paints and coatings.
	Filters	Air filtration systems
Transport & Mobility (Link with Transport & Mobility thematic area)	Fleet decarbonisation	Transformation of the fleet into EVs, hydrogen, use of biofuels
	Route optimisation	IA applied to optimisation
	Last Mile Delivery	
Planning & Regulation		
Decarbonisation Strategy & Planning		Decarbonisation Plans for industry

As part of the urban environment the co-benefits of the application of solutions on Green Industry thematic area are very broad. For example, using heat recovery from industrial processes for a district heating system will help decarbonize the thermal energy system, or just by decarbonizing companies' fleet the impacts and benefits at urban level go from a clear reduction of the use of fossil fuels to cleaner environment and health improvement. Direct co-benefits linked with the Green Industry can be listed as follows:

- Higher autonomy on clean, affordable, and secure energy
- Increase low carbon energy production (<100 g CO_2eq/kWh[9])
- Increase upcycling and reduce primary raw materials (link to circular economy)
- More social cohesion and job access. If linking companies competitivity to territory and this is done through the transition process this will help in keeping employment, social cohesion, etc.
- increased technological readiness at sector's level.
- lower future maintenance costs
- better air quality and health (reduction of pollutants, CO_2, etc.)
- enhanced stability of the urban infrastructure (district heating networks, power grids, etc.)

The urban approach to green industry identifies benefits that may not be at the core of the decision processes in the companies. However, they are very important not only at environmental level but also at social and economic level where they act as a main engine for general wealth in a wide sense.

3.6 Circular economy

This thematic area will include solutions to promote circular economy around **key city resources**. The circular approach implies that, instead of throwing resources 'away' (for example municipal solid waste (MSW) to landfill or incineration), new distributed management systems, nutrient flows, or reverse logistics are implemented to make the return, sorting, and reuse of products possible. Under this **circular approach**, materials are non-harmful, locally sourced and from renewable feedstocks where appropriate, and can be composted, recycled, and reused.

[9] According to: Final report of the Technical Expert Group on Sustainable Finance, March 2020

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The European Commission is currently translating the environmental objective of the transition to a circular economy into criteria upon which the **sustainability of an investment** is evaluated. Therefore, it develops criteria to measure substantial contributions to the transition to a circular economy, as well as for significant harm (**DNSH criteria**). The transition to a circular economy affects all aspects of a supply chain and all phases necessary for the implementation of a solution (or set of solutions) in a city: planning, design, making, accessing, operating, and maintaining (Circular Economy in Cities: Project guide. Ellen MacArthur Foundation 2019).

For the circular economy area, **technical solutions** have been grouped depending on the type of resource: materials-waste, water, energy, or food. An additional category related to methodological solutions for circularity or Water-Energy-Food nexus analysis have been included (see Table 6). The seven key sectors / industries identified in the EU Circular Economy Action Plan are considered in this taxonomy as categories or sub-categories: Electronics and ICT, batteries and vehicles, packaging, plastics, textiles construction and building and food. The circular economy taxonomy is completed with a second level of **non-technical solutions** related to instruments, policy and governance:

Table 6 presents the main solutions identified within this thematic area.

Table 6: Circular economy thematic area taxonomy

SOLUTIONS CATEGORY		Examples
Waste	Municipal solid waste (MSW)	MSW management and collection, MSW treatment (urban biodegradable waste for compost and biogas production), Smart waste (sensoring and pay-as-you-throw)
	Textiles*	Circular textiles - urban recovery & processing techniques, waste to feedstock optimization
	Electronic and ICT*	Microelectronics waste management, New processes & strategies for the recovery of Critical Raw Materials
	Packaging*	Reducing demand for (over)packaging/packaging waste, improved circular design and strategies that fully replace the need for packaging
	Plastics*	Regulations, such as the ban on certain single-use plastic products, phasing out certain types of plastics, setting waste reduction targets and recycling contents for key products. In addition, expanding the use of bio-based and compostable materials to re-place today's plastics is also part of the strategy.
	Construction and building*	Optimal management of waste at the end of building life cycle, Re-using local building waste, Urban mining model to assess circular construction opportunities and optimize resource use and exchange
	Batteries and vehicles*	Circular economy approaches to reduce environmental pressures of the growing demand for key materials (such as lithium, cobalt nickel and manganese) as well as the EU's import dependence for such raw materials.
	Others	Valorization of Waste from the paper Industry, Recycling of glass fibers of aerogenerator blades, Reduction of raw materials, waste and integration of secondary materials
Water	Buildings*	Grey water treatment (including NBS) and reuse

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	Urban water cycle infrastructure	Rain water harvesting by water buffer systems or NBS for water reuse or aquifer infiltration, micro-hydropower generation, water leaks detection
	WWTP	Wastewater treatment (including NBS) and reuse
Energy	Energy efficiency	Improvement of energy efficiency by active and passive solutions (buildings), Recycling of energy flows (industry)
	Energy generation-RES	Renewable energy and local energy solutions, Energy/ production of biofuel based on black liquor from the paper industry, Energy/ production of DME based on CO2 recycling, Guarantee the energy production in buildings
Food*		Circularity food cities, Encompasses the full value chain of producing food for human consumption
Conceptual		Circularity indicators, Analysis of City/(Building) circularity, BOB database, online register with building and infrastructure material/parts/products for reuse/circular use, Urban metabolism mapping - identifying product streams and material inputs (in addition to waste), Water-Energy-Food nexus assessments, Circular job assessments including potential employment and re-skilling pathway, business models for circular economy
Non-technical solutions: Instruments, Policy and Governance		**Examples**
Policy		Development of waste-strategies (policy advice), Supporting municipalities to monitor resource flows in line with impact targets and measurement processes, Regulatory aspects
Capacity building		Capacity building and engagement with municipalities to identify and co-create circular solutions and roadmaps, Sustainable procurement innovation for the managing of key resource streams and waste
Social engagement		Social engagement for co-creation of circular solutions in current housing value chain, etc.

** Key sectors identified in the EU Circular Economy Action Plan.*

As it can be seen in Table 6, the classification of Circular economy solutions includes links with the other NetZeroCities thematic areas as follows (Figure 22).

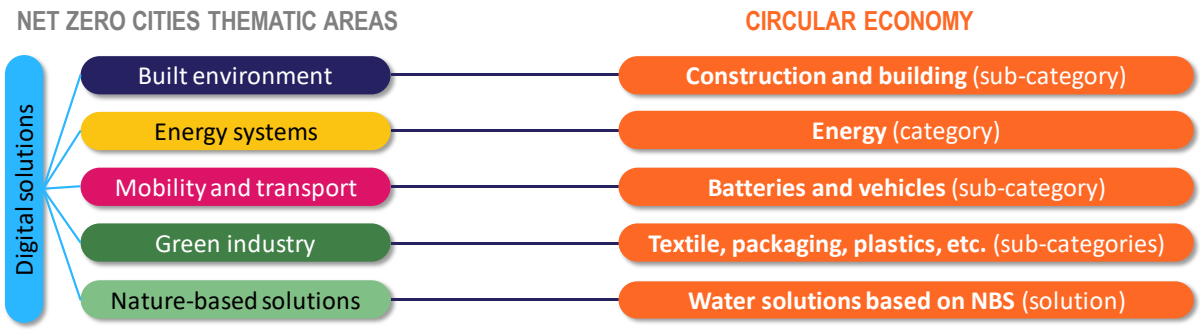

Figure 22: Circular economy links with NetZeroCities

We can summarize the following **horizontal challenges and co-benefits**:

- Climate change: adaptation and mitigation solutions

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- Health: air quality and well being
- Green Economy
- Social cohesion
- Resource efficiency
- Land use
- Biodiversity

Finally, integrated and systemic pathways will be also identified by linking solutions together to address a specific objective.

3.7 Nature-based solutions

The thematic area of “Nature Based Solutions”, defined in section 2.1, addresses the problems related to the growing number of people living in our cities through actions for promoting sustainability in urban areas.

Nature Based Solutions area is linked with the other thematic areas in the following aspects:

- **Built environment.** Ecosystem services provided by the appropriate design of NBS in buildings and streets can improve the effect of built environment and housing solutions so that both types can provide effective synergies. That is the case, for instance, of green façades, green roofs, green covering settlers or bio-filters. These solutions can also provide support to improve energy efficiency and that is also related with the **Energy system** area.
- **Mobility and transport**. The planned implementation of a green infrastructure network is related to green and sustainable mobility. Green corridors or green routes are a mobility alternative to motor vehicles, providing an attractive and healthy area not only for recreational purposes, but also as a route for mobility (walking, cycling, etc).
- **Green industry**. One of the clearest links to this area is the compensatory measures for GHG emissions, through the implementation of carbon sinks or urban forests. However, there are other nature-based solutions that can also be related to green industry, such as air biofilters or green screens.
- **Circular economy**. Blue infrastructure is the group of NBS that is most closely related to the circular economy due to its contribution to wastewater management. In addition, composting techniques and the use of compost from waste within green infrastructure are also related to this thematic area.

Table 7 presents the main solutions identified within this thematic area.

Table 7: Nature-based solutions thematic area taxonomy

SOLUTIONS CATEGORY	Sub-category	Examples
CLIMATE RESILIENCE	Climate Mitigation	Urban carbon sink Green roof
	Climate Adaptation	Rain gardens Floodable park
WATER MANAGEMENT	Water scarcity	Green resting areas Hard drainage pavements
	Water quality	Natural wastewater treatment Green filter area
	Circular economy	Green resting areas

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		Natural wastewater treatment
NATURAL AND CLIMATE HAZARDS	Coastal Resilience	Dune restoration Beach regeneration Oyster reefs
	Flooding	SUDs Floodable park
GREEN SPACE MANAGEMENT		Urban orchards Green resting areas
BIODIVERSITY ENHANCEMENT		Pollinator's modules Floating islands
AIR QUALITY	Primary pollutants. Paticulate matter.	Urban garden bio-filter Vertical mobile garden
	Primary pollutants. Nitrogen oxides.	Green noise barriers Green resting areas
	Secondary pollutants. Ozone.	Green filter area
PLACE REGENERATION	Managing urban growth	Rain gardens Green resting areas
	Redevelopment areas	Shade trees Green façade with climbing plants
	Urban retrofitting	Planting and renewal urban trees Grassed swales and water retention ponds
KNOWLEDGE AND SOCIAL CAPACTIY BUILDING FOR SUSTAINABLE URBAN TRANSFORMATION		Non-technical actions Community composting Urban orchards Edible forest Small-scale urban livestock
PARTICIPATORY PLANNING AND GOVERNANCE	Green integrated management	Green noise barriers Urban orchards
	Environmental awareness	Pollinator's modules Community composting
	City identity	Parklets Green resting areas
SOCIAL JUSTICE AND SOCIAL COHESION	Distribution	Rain gardens Procedure
	Parklets	Recognition Green resting areas
	Capability	Urban catchment forestry
HEALTH AND WELLBEING	Human health	Green noise barriers Green resting areas
	Physical activity	Urban orchards Cycle and pedestrian green pavement
	Mental health and wellbeing	Urban orchards Pollinator's modules
NEW ECONOMIC OPPORTUNITIES AND GREEN JOBS	Providing information to disseminate NBS industry	Rain gardens Parklets
	Fostering multi-skateholder cooperation	Small-scale urban livestock Community composting
	Developing legislation and policies that promote NBS implementation	Community composting Small-scale urban livestock
	Implementing apropiate planning procedures	Urban orchards Green resting areas
	Setting several financial incentives for	Parklets

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	the implementation of NBS	Hard drainage-flood prevention Unearth water courses SUDs
Planning & Regulation		**Examples**
RUP (Renaturing Urban Plan)		City Targets, City NBS Adopted Scenarios, City Impact, Monitoring Program and Action Plan, Roles and Responsibilities, Process and reforms
Economic instruments		**Examples**
Public bodies		Public organisations, Bank loans, Green bonds
Private firms		Private organisations, Bank loans / equity (real estate development); Institutional investors (pension funds).
Citizens/communities		Donation & reward crowd-funding, Lease (greening as a service), Subsidies / tax breaks for households, Access to bank loans? Mortgage incentives (like Energy label)
Conceptual frameworks		**Examples**
Evaluation frameworks		EKLIPSE Impact evaluation framework for NBS, Evaluating the impact of Nature-based Solutions: a handbook for practitioners
NbS Standards and catalogues		IUCN Global Standard for NbS URBAN GreenUP catalogue

The main classification of the NBS is made using the list of challenges in the Handbook (Evaluating the impact of Nature-based Solutions: a handbook for practitioners), which is based on the classification made by the EKLIPSE methodology. The contribution of NBS to addres these Challenges are assumed to be potential co-benefits within the NZC project. This classification allows a standardised method for the NBS's MEL and facilitates measuring and shows how NBS projects fare against the identified indicators in delivering the multiple environmental, economic, and societal benefits to promote Climate Resilience in Urban Areas.

These co-benefits are:

- Climate Resilience: NBS are capable of providing resilience to the impacts of climate change trough the provision of ecosystem services, and by enhancing social awareness and actions to combat climate change. This concept is the result of the revision of the Climate Mitigation and Adaptation concept taken from EKLIPSE methodology.

- Water management: NBS are able to address issues associated with anthropogenic impacts on the water cycle. Includes: water availability for extraction, groundwater and surface water levels, water scarcity and water quality.

- Natural and Climate Hazards: Risk is a combination of hazard (negative) consequences. NBS employed for disaster risk reduction are expected to reduce risk level and deliver social, human and environmental benefits. This concept is the result of the revision of the Coastal resilience concept taken from EKLIPSE methodology.

- Green space management: this co-benefit refers to the planish, establishment and maintenance of green and blue infrastructure in urban areas. These infrastructures are a type of NBS that refers to the strategically managed network of natural and semi-natural ecosystems within urban boundaries and provides a range of ecological and socio-economic benefits as reducing air and noise pollution and concerns regarding public wellbeing.

- Air quality: NBS based on the creation, enhancement, or restoration of ecosystems in human-dominated environments play a relevant role in removing air pollutants and carbon dioxide, reducing the air temperature (which slows down the creation of secondary pollutants) and

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increasing oxygen concentration, contributing to a beneficial atmospheric composition for human life.

- Biodiversity enhancement: The NBS and moreover the connection of different NBS along cities creates the suitable conditions to enhance the animal biodiversity, mainly for small insects and birds. The link between climate change and biodiversity loss involves a feedback loop whereby climate change accelerates loss of natural capital, which is in turn a key driver of climate change. This concept it the result of the revision of Green Space Management from EKLIPSE methodology, and considered as a separated area.

- Place regeneration: NBS hold the potential to contribute to the aim of ensuring successful achievement of sustainable place regeneration by way of enhancing the green space and people-nature connection, using fewer environmental resources, enhancing place resilience to natural disasters, fostering collective participation and social cohesion, and improving individual wellbeing.

- Knowledge and Social Capacity Building for Sustainable Urban Transformation: NBS contribute to achieving sustainable urban transformation. The development of knowledge and social capacities through educational initiatives can contribute to the complex enterprise of accumulating resources for sustainable urban places. This challenge area is a new addition to the original ten challenges described in the EKLIPSE Expert Working Group impact evaluation framework.

- Participatory planning and governance: NBS design and implementation require a holistic and transdisciplinary planning approach that conciliates different types of knowledge. Furthermore, NBS must focus on the interests and perceptions of citizens, examining the changes in policy narratives when incorporating the ecosystem services framework in planning.

- Social justice and social cohesion: This concept aim at comprising the environmental justice and social cohesion supported by NBS in urban areas, through a multi-dimensional approach.

- Health and Well-being: NBS can contribute to a wide range of positive psychological and physiological benefits, improving overall human health.

- New economic opportunities and green jobs: The design, implementation and maintenance of NBS generates new business and job opportunities associated with the green sector.

These co-benefits are divided into impacts that help to face the different challenges. These are very important and very different from each other. This difference is evident in the NBS used for each purpose, as in the case of mitigation, the urban carbon sink is an important measure but requires a long time dimension, and in the case of an adaptation, such as the floodable park, it is a short-term, one-off time dimension.

In order to achieve a synergistic effect from the implementation of NBS in a city, actions must be integrated and designed in a planned way, taking into account several characteristic aspects of the city. To support re-naturing journey of the cities, URBAN GreenUP developed a systematic strategy to reach high level of impacts through the use of NBS. It aims to provide an integrated methodology to support the Urban Planning of NBS at the local city level, as a powerful strategy to contribute to increase sustainability, addressing a range of societal challenges.

The main components of a RUP are shown in the Figure 23:

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Figure 23: Components of URBAN GreenUP methodology (Source: URBAN GreenUP)

3.8 Digital solutions

Data and the digital systems are both specific solutions and more general capabilities. With the fourth industrial revolution it has become clear that data and digital capabilities are an extremely important and powerful factor in how we organise our societies, and how we best reach our climate goals.

Data is understood as information that has been the basis for any kind of advanced governance and government. It is as old as civilisation itself. But with the advent of connected computing, sensing and actuation capabilities, and of the virtualisation of processes, we have new ways to provision of evidence-based and more proactive actions towards our goals (Figure 24).

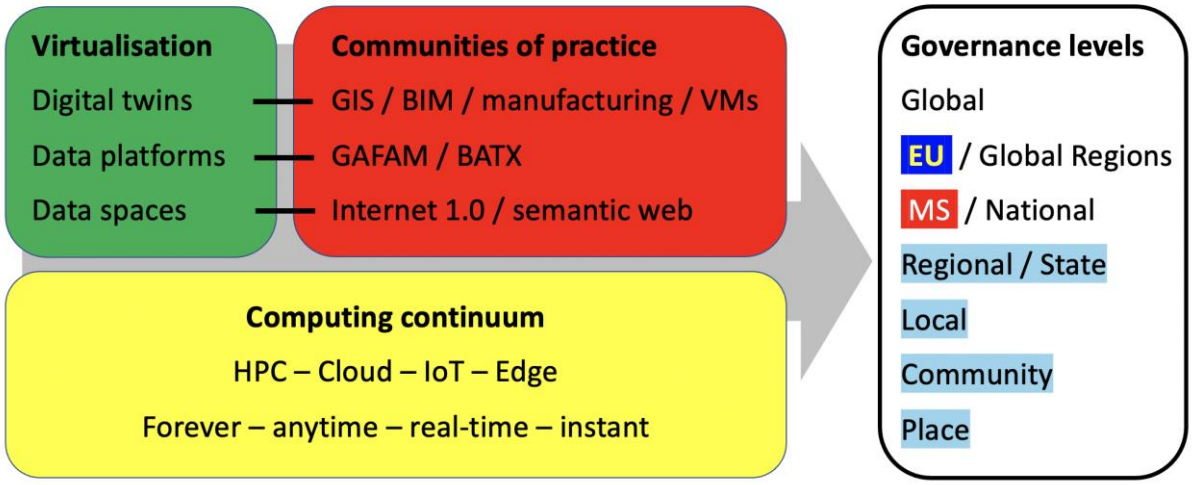

Figure 24: Virtualisation as the fundamental process underlying digital solutions. There are different levels of virtualisation, instantiated along the computing continuum with related communities of practice, governed at different levels (Brynskov, 2021).

Data has become a prerequisite for solution provisioning, sometimes in closed data flows but more increasingly based on data ecosystems spanning public, closed and personal pieces of data, and

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sometimes the solutions run on dedicated hardware on the computing continuum, sometimes on generalised platforms.

As with the previous solution categories, we divide the digital into more specific “solutions” and more general “capabilities”. This is followed by a concluding section on the importance of interoperability.

Table 8: Digital solutions thematic area taxonomy

CORE CAPABILITIES	Examples
City IT Core	E-administration platform
	Urban Data Platform
	City Database(s)
	Geospatial Information System
Smart Core Services	Business Intelligence Tools
	Balanced Score Cards
	API management
	Extract-Transform-Load Tools
External Services	Connectivity (2-3-4-5G, LPWan, broadband)
	IoT Device Management
	Cloud Services
	Databases
SOLUTIONS	**Examples**
Smart Solutions	Facility Management (including energy efficiency)
	Waste Management
	Environmental Monitoring
	Lighting Management
PLANNING & REGULATION	**Examples**
Local Digital Twin (forecasting and simulation)	Crowd Management
	Traffic Forecasting
	Weather Forecasting
	Energy load-balancing
AI Registry	Approved algorithms for automated decision making
Personal Data Management	Measures against unlawful profiling and to ensure data ownership

Given the broad scope of data and digital systems, even within carbon optimisation, the examples given are only examples. But the overall picture is clear: If a city wants to manage its carbon footprint efficiently and effectively pursue a net zero target, digital capabilities are essential – but naturally not by themselves sufficient – enablers towards that goal (Figure 25).

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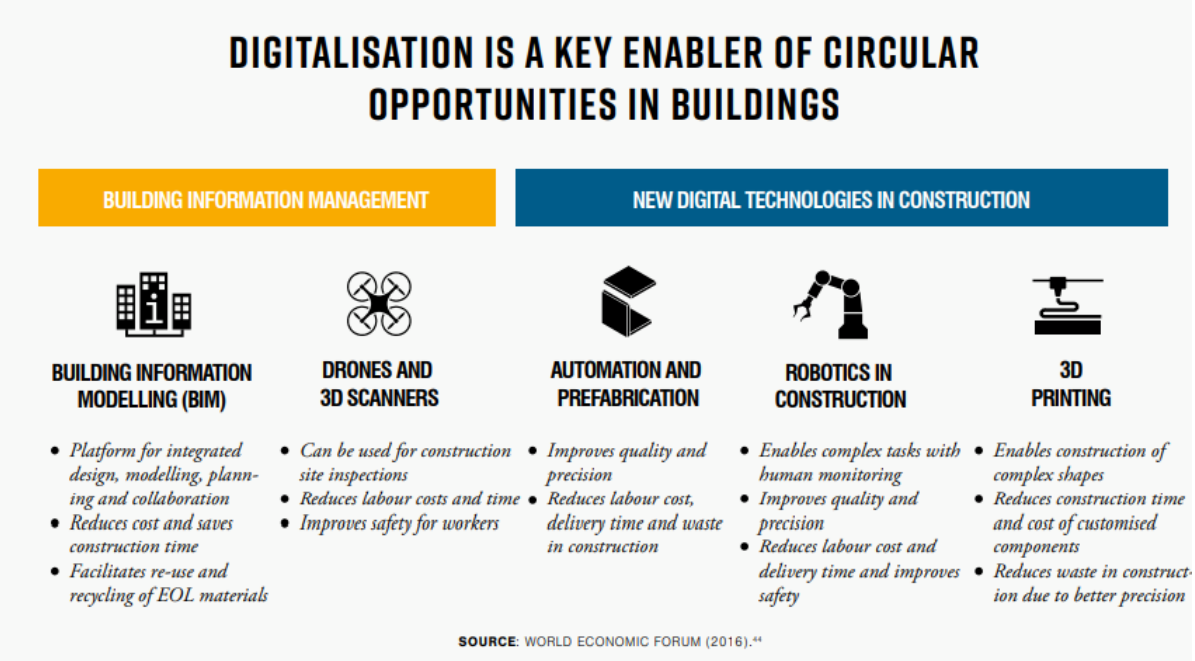

Figure 25: Digitalisation as a key (Source: Material Economics the circular economy – a powerful force for climate mitigation (2018))

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4 Cross-sectoral integration, connectivity and interoperability

Section 4 defined Thematic areas grouping climate-neutral cities solutions into categories. As shown in the description of each of the thematic area, there are many interconnections. Indeed, urban solutions typically integrate several sectors. For the moment, these overlaps and links are described separately for each thematic area. These links will be made more visible as the work in WP10 advances, as T10.2 will continue defining the thematic areas and related solutions. T10.2 will thus continue to expand the categories and solutions to address all the cross-cutting issues pointed out in some areas (such as capacity building, planning, policy, economic instruments, etc.). The possibility to harmonise the solution categories of the thematic areas will be also analysed in order to develop a matrix more clearly visualising the cross-sectoral links.

The following transversal topics have been identified (with links to other WPs in NZC):

- Digital solutions and circular economy as enabling fields for the solutions identified in the different sectors.
- Social innovation (inputs from WP9): How co-creation processes can be taken into account for the design and operation of the solutions, or any other social innovation process.
- Stakeholders' collaboration and citizen engagement (inputs from WP8): which stakeholders should be considered as well as how to engage them for the design and operation of the solutions.
- Financial mechanisms and Business models (inputs from WP7): How to finance the solutions' implementation and how to operate the solutions.
- Consideration of a regulation, policy and governance (WP13 and T10.2).
- Education and capacity building in the different areas at different levels in the city (capacitate municipalities, citizens, companies, etc.).
- Replication of solutions (WP5): support cities in identifying (and overcoming) barriers.

Among the thematic areas analysed, the cross-sectoral aspects of Digital solutions deserve special attention, as all solutions within this thematic area are applied in other thematic areas, thus further supporting the climate-neutrality goal. Beyond the individual digital solutions and capabilities, connectivity and interoperability are worth highlighting here.

As mentioned throughout this document, the fourth industrial revolution has changed the conditions for how a society optimally organises its net zero efforts.

A key reference will be the EIF4SCC Framework which is designed exactly to take these various types of interoperability into account: cultural, legal, organisational, semantic and technical (Figure 26).

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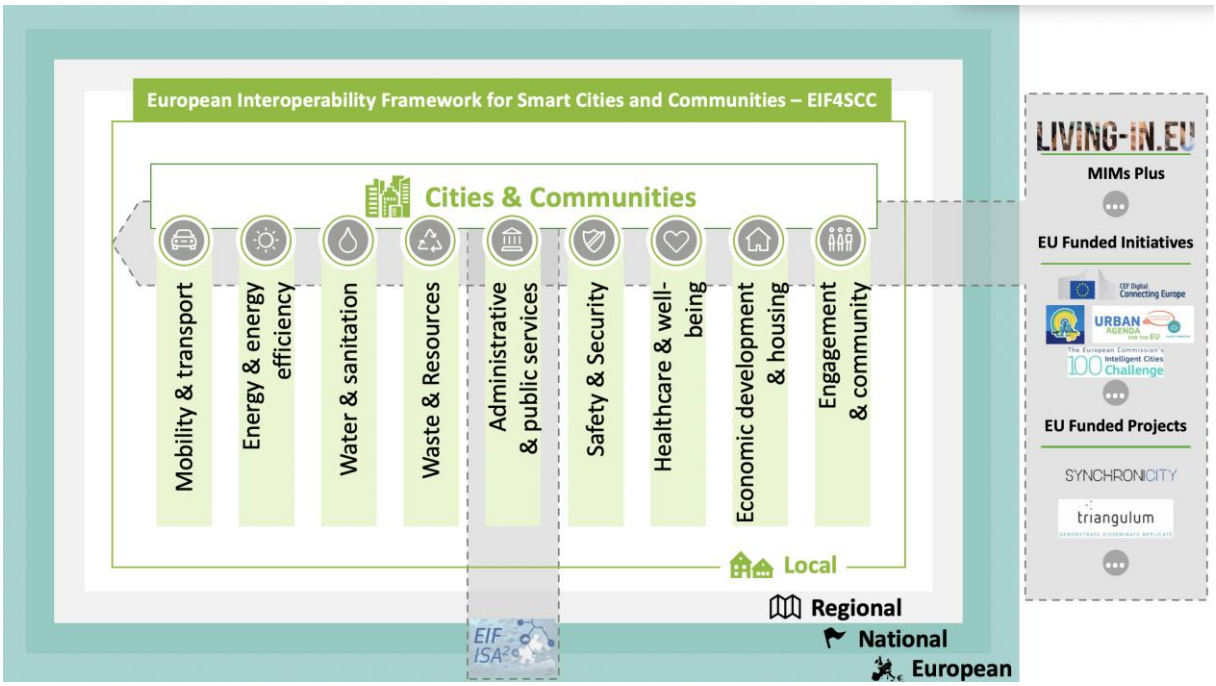

Figure 26: The proposed European Interoperability Framework for Smart Cities and Communities (EIF4SCC) addresses both vertical and horizontal concerns, grounded at the local level

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5 Conclusions

As one of the first jointly published Net Zero Cities project efforts, this deliverable described a taxonomy classifying climate-neutral cities' solutions and concepts in selected thematic areas (the city sectors Built environment, Energy systems, Mobility and transport, Green industry; and enabling fields, Circular economy, Nature-based solutions, Digital solutions).

This classification will provide a common starting point for future project activities in different Work Packages (WPs): WP10 which will develop a catalogue with state-of-the-art solutions (T10.2) and design expert services (T10.3) for deploying climate neutral city actions, and WP6 to WP10 which will work on tagging different solutions and case studies to create a smart repository within WP3 platform. Furthermore, WP2 will defineimpact metrics and evaluation methodologies that will be considered in T10.2 for evaluating some of the WP10 solutions. WP3 will create a portal accessible to all cities and stakeholders that will include the catalogue from T10.2 for inspiring cities in different climate neutral solutions. Furthermore, cities with access to the platform will have different questionnaires to guide them on the diffferent solutions available to supply their needs (e.g. tackle climate neutrality at the same time they do not harm/reduce the water usage of the city). WP3 will be designing a platform to deliver the actual services described to cities.

As can be expected, climate-neutral city solutions are often cross-sectoral. When classifying solutions into thematic areas, many overlaps and synergies have been identified. For example, Green industry strongly relates to all the other analysed city sectors (Built environment, Energy systems, Mobility and transport). Sub-optimisation is a key risk factor in any urban green-digital transformation due to sectoral silos inherent in city organisations and the challenges related to orchestration of cross-sectoral collaboration. WP10 will try to map those interlikanges in detail within T10.2, but a first attempt has been defined within this document. Also, WP3 on platform development will work on cross-sectoral integration of solutions, services and data flows across sectors and different WPs of the project into a one-stop-shop platform.

Mapping of co-benefits, synergies and impacts has started for the different thematic actions, covering climate resilience, environment (water, land, and ecosystems), food supply and production, socio-economic and health co-benefits and ensuring a cross-sectoral integration. These links are, however, complex and will need to be analysed more deeply in T10.2. on "Analysis of solutions, co-benefits and barriers to adoption", and the other relevant project WPs. It is worth noticing also that many solutions in an enabling field (Digital solutions, Circular economy) are horizontal in the way that they can be applied in most of the city sectors (Built environment, Energy systems, Mobility and transport). A useful question to address in the future project activities is then the level of maturity and potential added value of the enabling solutions in different sectoral use cases.

The EU taxonomy regulation, presented in this report, sets basic conditions for urban solutions to qualify as environmentally sustainable, explaining that they should substantively contribute to one of the six main environmental objectives (climate change mitigation, climate change adaptation, sustainable use and protection of water and marine resources, transition to a circular economy, pollution prevention and control, protection and restoration of biodiversity and ecosystems) without doing significant harm to the other five environmental objectives (DNSH principle). This EU taxonomy has naturally been also the starting point for the Net Zero Cities taxonomy presented in this report. However, the experience collected from the field shows that the application of the DNSH principle is still not simple in practice (e.g. carbon capture, biomass). As the application of the EU taxonomy will often be a prerequisite for attracting funding for green urban projects, the application of the DNSH principle will deserve more specific attention in the following WP10 activities when selecting solutions and services for transition to climate-neutrality, with support from WP2 on Monitoring, Evaluation & Learning.

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