Comprehensive Indicator Framework

Authors: Hans-Martin Neumann, Ciarán O'Sullivan, Ghazal Etminan (AIT Austrian Institute of Technology)

Co-Authors: Gudrun Haindlmaier (AIT Austrian Institute of Technology), Nikolai Jakobi (ICLEI Europe), Nikhil Chaudhary (Climate-KIC); Apurva Singh, Eva Promes, Jette Dingemans (Metabolic); Carla Rodriguez Alonso (CARTIF); Harry Wain (Bankers without Boundaries); Rebekah Thorne, Ralf Brand (Rupprecht Consult); Sabrina Bresciani, Francesco Mureddu, Marzia Mortati (POLIMI), Jaqueline Oker-Blom (Material Economics)

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Abbreviations and acronyms

Acronym	Description
AFOLU	Agriculture, Forestry and Other Land Use
CCC AP	Climate City Contract Action Plan
EC	European Commission
EoL	End of Life
ETS	Emission Trading Scheme
EU	European Union
GHG	Green House Gas(es)
IIF	Integrated Indicator Framework
CCC IP	Climate City Contract Investment Plan
IPPU	Industrial Processes and Product Use
JRC	Joint Research Centre for the European Commission
MEL	Monitoring, Evaluation and Learning
NZC	NetZeroCities
NBS	Nature Based Solution(s)
TOC	Theory of Change
WP	Work Package

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1 Introduction

1.1 Mission Monitoring Ambition

Cities that join the European Climate-Neutral and Smart Cities Mission commit to an ambition of becoming climate-neutral by 2030. The ambition and journey are captured by a Climate City Contract, the key instrument for Mission Cities to launch and accelerate this approach. The 'main elements of the urban climate neutrality definition' are provided within the Info Kit for Cities (European Commission, 2021b), specifically in Table 2. In line with these elements, the aim of this document is to present a comprehensive integrated framework of indicators in support of the evaluation of Climate City Contracts (CCCs) and the monitoring of 2030 CCC Action Plans (APs) and Investment Plans (IPs), as they are implemented. The system should enable Mission Cities to monitor and self-assess their progress towards reaching climate neutrality by 2030.

1.2 Structure of Document

This document is structured as follows:

Section 2 "Scope of the Integrated Monitoring Evaluation and Learning Indicator Framework" introduces the logic that informs the indicator selection and defines which indicators should be considered required and which are recommended for application.

Section 3 "Monitoring of Direct Benefits" introduces the term "Direct Benefits" of CCC APs, which is another word for reductions in GHG emissions and proposes indicators for the monitoring of these direct benefits. Furthermore, it discusses how synergies with reporting systems already used by many cities (namely MyCovenant and CDP-ICLEI Track) can be achieved.

Section 4 "Monitoring of Indirect Benefits (Co-Benefits)" introduces the concept of Co-Benefits and proposes indicators for their monitoring. In the context of the CCC APs and IPs, co-benefits or indirect impacts are the additional impacts or positive effects of, and integral to, the direct benefits, i.e., GHG reductions. These indirect impacts may be expected to be achieved in the short, medium, or long-term, based on the emission domains targeted and the portfolio of solutions designed by the cities. At the same time, some climate actions could also potentially lead to negative effects or trade-offs to be avoided.

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2 Scope of Integrated Monitoring Evaluation and Learning Indicator Framework

The overall concept for the Indicator Framework, is based on the NetZeroCities impact logic (also known as the 'Theory of Change'), illustrated in the Figure below. It outlines the overall process of a Mission City's transformation and its interconnected actions directed towards intended outcomes and impacts. The starting points for this model are the key emission domains critical for climate-neutrality, as identified by the Info Kit for Cities (European Commission 2021b), as well as the Guidance and Explanations documents for the 2030 Climate Neutrality Action Plans as part of the Climate City Contracts. These emission domains cover – Energy Systems, Transport and Mobility, Waste and Circular Economy (including Industrial Processes and Product Use or IPPU), Green Infrastructure and Nature-based Solutions (including Agriculture, Forestry & Other Land Use or AFOLU).

Aligning with the Mission's intent of harnessing systemic innovation and a portfolio approach, the NZC impact logic is centred on cities acting on multiple levers of transformative change. These systemic levers are transversal areas that cut across all GHG emission domains crucial for achieving a Mission City's climate-neutrality goals and overcoming the key barriers and challenges within each of the emission domains.

Consistent with other NZC Mission Platform support, there are six levers identified for the impact logic, namely – 1) Technological innovation and infrastructure, 2) Finance and funding, 3) Social innovation, 4) Democracy and participation, 5) Governance innovation, and 6) Learning, capacities and capabilities building. Within the impact model, these systemic levers link the emission domains together as a coherent portfolio, act as entry points into larger systems-wide transformations and support the co-design and implementation of a Mission City's Action Plan or Investment Plan.

The levers amplify and enable early and later-stage outcomes and long-term impacts, as well as lend purpose, coherence, and directionality to the city's impact pathways. These transition pathways progress across short-term, medium-term and long-term timelines towards 2030 net-zero targets, including direct impacts (like sectoral GHG reduction), as well as a wide range of co-benefits and co-risks.

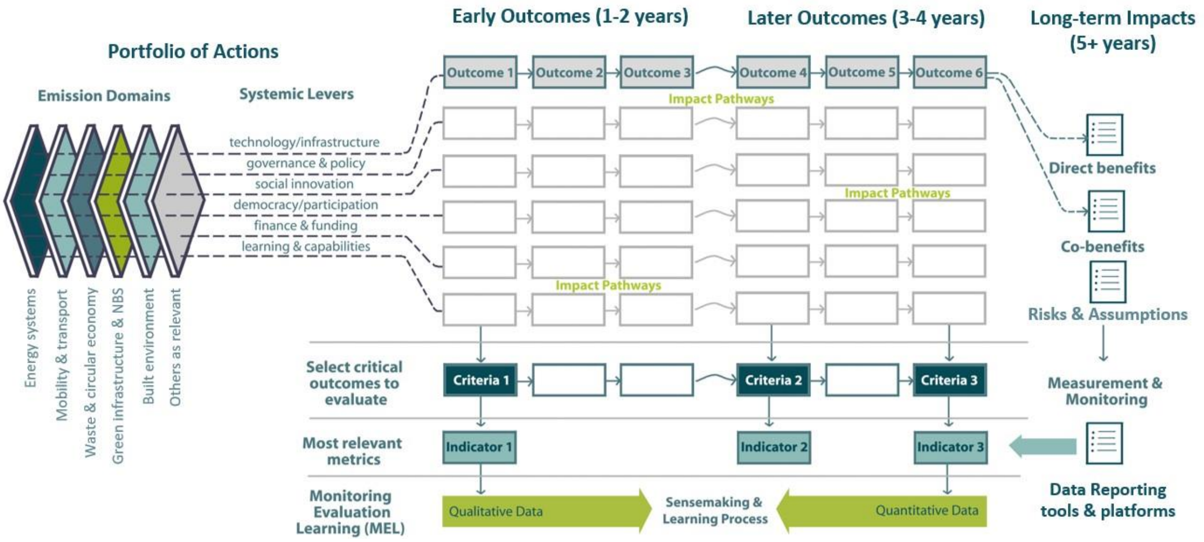

Figure 1: Impact logic to enable MEL for systemic transformation through diverse impact pathways to climate-neutrality

As illustrated in the figure above, each of the levers translate into a sequenced hierarchy of changes or outcomes, culminating into long-term impacts and co-benefits for the city's climate mission. These sequential and interconnected causal chains, also known as **Impact Pathways**, outline the fundamental mechanisms through which larger and more complex long-term systems change is

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envisioned to be influenced by the city towards climate-neutrality. By co-designing portfolios within their CCC Action Plans (AP) and Investment Plans (IP), cities will be enabled to simultaneously act on distinct but connected aspects of climate-neutrality, through multiple but synergistic interventions. Therefore, as cities act on more than one lever, the impact pathways are expected to converge and overlap, thereby necessitating coordinated actions across the portfolio and emission domains.

A Mission City's climate-neutrality journey in the impact logic begins (from left to right in the diagram) with the implementation of practical actions within the **Portfolio of Actions**, which set in motion the parallel and overlapping impact pathways. Next elements are the **Early Outcomes** (1-2 years) which create the necessary pre-conditions or achievement of 'low-hanging fruits' as a basis for subsequent, more ambitious progress, followed by the **Later Outcomes** (2-3 years) that capitalise on Early Outcomes to subsequently result in the **Long-term Impacts** of Direct or Indirect Benefits (5+ years). These intermediate outcomes and impacts are structured in the form of milestones that could be self-assessed by a city and are expected to emerge during the course of the CCC process – from design through to the real-world implementation of CCCs, deployment of planned actions, and successful operationalisation of MEL, reporting and knowledge-sharing practices. The logical connections within these impact pathways are derived from the city's assumptions and perceived risks around how changes are expected to occur. The pathways help measure the most significant outcomes that contribute to a more holistic vision of systemic transformation, based on the city's own success criteria.

The mapping and co-creation of such impact pathways can support a Mission City in identifying the most critical outcomes or impacts – also known as 'leverage points' – to continuously learn from them during the implementation. An informed selection and clear definition of these key impacts and indicators can enable a city Transition Team to find the pertinent qualitative and quantitative evidence gaps and metrics to inform their strategic planning, sensemaking, measuring and reporting of progress, as well as to set up robust MEL data collection, analysis, visualisation, and governance processes. In the following sections, the Indicator Framework is outlined in detail, along with the specific indicators within each domain and subdomain for both Direct and Indirect Benefits categories.

2.1 Definition of Required Indicators (Direct Benefits) and Recommended Indicators (Co Benefits and Process Monitoring)

The need emerged to define Required Indicators (Direct Benefits) and Recommended Indicators (Co Benefits), as well as the inclusion of both quantitative and qualitative monitoring processes. It was considered necessary to monitor GHG emissions which is a *conditio sine qua non* for urban climate neutrality. However, social, economic, and environmental drivers must also be taken into account to ensure acceptance as well as technical and financial feasibility of the transition towards climate neutrality. Such indirect indicators have been categorised as recommended but not required. They are designed to assist cities' in their climate neutrality planning processes, and thus, cities' are encouraged to make use of a selection of such indicators most applicable to their local climate neutrality target and related strategy.

In summary, the impact domains provided to monitor and evaluate the 2030 CCC AP implementation, include:

1. Required Monitoring of direct benefits (emission domains).
2. Recommended Monitoring of co benefits/ co-risks (indirect impact monitoring).

2.2 Flexibility of Indicator System

The required direct benefits indicators of the Indicator Framework will allow for national level emission data to be downscaled to the city level, as well as data acquired from a bottom-up method through local

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data sets to facilitate flexibility for cities. In other words, cities report on the total emissions per sector as a minimum requirement. The purpose of this is to allow cities, which may not have city specific data for every sector, the means to complete an emission inventory. However, it should be noted that downscaling methods imply the use of aggregate data or averages, which may not always be representative of the local context or the sectoral emission profile of a city, and therefore should be considered an approximation. The quality and reliability of a GHG inventory is directly related to the quality and reliability of input data, and therefore, it is recommended to use primary data where possible, as this facilitates robust GHG emission inventories. This in turn facilitates the basis for local governments to define data-driven policies and programmes, as well as the founding basis required to identify priority sectors and develop locally based climate neutrality actions in response.

Nonetheless, combination methods which allow for the use of both primary data and downscaled data from a national or regional level, is also considered a viable means to completing and emission inventory.

2.3 Source of Indicator Selection

Indicators were selected from tried, tested, and vetted sources where appropriate. This was to ensure that the indicator selection and design process facilitated the development of a robust indicator set that is applicable at the city level.

2.4 Scope 1, 2 and 3 emissions

The Indicator Framework covers scope 1 and scope 2 emissions while also covering indicators for scope 3 emissions for waste, i.e., waste exported for treatment outside the city. These are based on the current emissions guidelines defined under the Info Kit for Cities (European Commission 2021b).

2.5 Emission Factors

The Mission does not prescribe a methodology as cities are open to use methods that work best for them. Cities are entitled to use emission factors associated with GPC, IPCC, and CRF methodologies, as well as national or regional emission factors.

A proposed approach is also set out within section '*4.2.1 How to account for locally produced electricity in the Mission Cities' GHG inventories*', and Box 8, pg. 44, within the Info Kit for Cities (European Commission 2021b). Mission Cities are encouraged where feasible to account for local renewable energy production and at the same time allow cities to reap the significant effect of an overall decarbonizing national and European grid. This can be done by combining the following approaches:

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

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

It is important to note that no negative emission factors can be applied in the calculation of energy-related emissions, even in the case where cities are generating more zero-emissions electricity than they consume.

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2.6 Net vs Gross Emissions – Offsetting Strategies and Residual Emissions

The Mission does not prescribe a methodology for the development of Offsetting Strategies and for accounting for Residual Emissions, as cities are open to use any of the common reporting standards that work best from them.

Offsetting is only possible for emissions which are very difficult or impossible to mitigate (i.e., for residual emissions). As some form of offsetting is likely to be required by participating cities to cancel out residual emissions, Mission cities should gain a good understanding early in the process, as an integral part of developing their CCC, of the likely level of residual emissions and devise a strategy for addressing them.

The Info Kit for Cities describes the process for calculating residual emissions:

> *"The separate reporting of gross and net emissions will ensure transparency regarding residual emissions cancelled out through offsetting mechanisms. Gross emissions will include all relevant emissions in all covered sectors without taking into account GHG emission reductions from carbon sinks and credits. The net emissions are calculated by deducting from the gross emissions, GHG emissions reductions from carbon sinks and carbon credits from projects outside the city's GHG inventory boundary, and adding GHG emissions from carbon credits sold from within the city's GHG inventory boundary*."
>
> (European Commission 2021b, Pp. 25)

The separate reporting of gross and net emissions is to ensure transparency regarding residual emissions cancelled out through offsetting mechanisms. Transparency in reporting by providing the gross and net emissions is important in this context. The Mission hence follows the principle of making sufficient progress to decarbonize every sector and using integration in the urban system whenever possible to advance progress towards climate neutrality.

The development of the Indicator Set has taken account of this process and has proposed relevant indicators in response. Participating cities must separately report gross and net emissions to ensure transparency regarding residual emissions cancelled out through offsetting mechanisms.

2.7 Indicator Presentation

2.7.1 Direct Benefit and Co-Benefit Indicator Presentation – Sections 3 and 4

With respect to direct benefit and co-benefit indicators found in sections 3 and 4 of this report, each indicator set (sub domain) is supported by an introductory description of the proposed indicator set, as well as its rationale for selection. These descriptions help to emphasise the purpose of the selected indicators and why applying them would help a city to self-asses its journey towards climate neutrality. Use case examples illustrating how indicators can be applied are also provided per subdomain category.

It should further be noted that in relation to the co-benefit indicators, suggestive positive wording from sub domain co-benefit indicators have been removed (indicator titles), such as 'Reduced' Noise Pollution and 'Increased' Road Safety. This is due to the fact, that we must account for potential unintended negative effects when using indicator sets to measure outcomes. Sub-domain indicators sets have been accompanied by explanations of their relevance, with respect to the ambition of NZC, outlining why it is expected that the transition of a city towards climate neutrality will have positive effects. However, note unintended negative effects may also be possible (with respect to *Co-Benefits*).

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The tables of indicators included in relation to impact monitoring are structured under the following headings/ criteria:

- Indicator Title
- Unit of Measurement
- Required or Recommended
- Definition
- Source
- Calculation Formula
- Emission Scope for GHG related Indicators

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3 Monitoring of Direct Benefits

The purpose of monitoring direct benefits is to account for the potential direct reduction in GHG emissions as consequence of implementing CCC AP and IPs. As noted previously, the Indicator Framework incorporates both 'Required' and 'Recommended' indicators.

The following section provides the information related to indicator sets as part of the GHG domain. The Indicator Framework has sought to establish synergies with MyCovenant and CDP-ICLEI Track as far as possible. However, the GHG emissions related indicators as presented and rationalised in the following sections have also taken account of sectors as defined in the Info Kit for Cities (European Commission, 2021b), with respect to the Mission's definition of Climate Neutrality, which are as follows:

- Stationary Energy
- Transport and Mobility
- Waste and Wastewater
- Industrial Processes and Product Use
- Agriculture, Forestry, and Other Land uses

Indicators are also provided under the following additional sub domains:

- Energy
- Grid Supplied Energy
- Carbon Capture and Residual Emissions

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3.1 Greenhouse Gas Emissions (GHG)

3.1.1 Stationary Energy

Emissions from stationary energy sources come from fuel combustion and fugitive emissions released in the process of delivering, generating, and consuming energy (e.g., heat and electricity). These include emissions from the combustion of fuels in buildings and industries within the city (scope 1).

Emissions from the consumption of grid-supplied electricity, heating, steam, and cooling in the city (scope 2) may also be included here depending on the GHG accounting methodology used. Please refer to section 4.1.7 Grid Supplied Energy and Table 7 Grid Supplied Energy for more information. Note that Scope 3 emissions can be calculated but are considered optional for this sector.

3.1.1.1 Indicator Set

Table 1 Stationary Energy Indicator Set

Indicator Title	GHG emission from stationary energy	Energy use by fuel/energy type within city boundary
Unit of Measurement	t CO2 equivalent	MWh/year
Required or Recommended	Required	Recommended
Definition	Greenhouse gas emissions (mainly CO2 emissions) from the operations of buildings. (This is a simplified definition. The sources below include the layered approach to calculating this indicator.)	Real consumption data for each fuel or energy type disaggregated by sub-sector. Where data is only available for a few of the total number of fuel suppliers, determine the population (or other indicators such as industrial output, floor space, etc.) served by real data to scale-up the partial data for total city-wide consumption.
Source	GHG Protocol for Cities (2020) Also informed by: • IPCC (2006, 2019), • JRC Info kit for cities(European Commission 2021b)	GHG Protocol for Cities (2020) Also Informed by • IPCC (2006, 2019) • CCC Action plan A-1.1
Calculation Formula	Base emission information can be derived through "Amount of fuel consumption per fuel type x GHG emission per fuel type". Calculation methodology has been described in detail in GHG Protocol for Cities (GPC) pages 60 – 73.	Calculation formulae for stationary energy from GHG Protocol for Cities (GPC) pages 60 – 73.
Emission Scope for GHG Indicator	Scope 1, 2. Scope 3 can be calculated but is not mandatory.	Scope 1, 2

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3.1.1.2 Use Case Examples

GHG emission from stationary energy

For calculating GHG emissions the following formula applies:

GHG emissions = Activity data × Emission factor

The GHG Protocol [reference page 54] defines Activity data as a "quantitative measure of a level of activity that results in GHG emissions taking place during a given period of time (e.g., volume of gas used, kilometers driven, tonnes of solid waste sent to landfill, etc.)."

An emission factor is defined as "a measure of the mass of GHG emissions relative to a unit of activity. For example, estimating CO2 emissions from the use of electricity involves multiplying data on kilowatt-hours (kWh) of electricity used by the emission factor (kgCO2/kWh) for electricity, which will depend on the technology and type of fuel used to generate the electricity."

To calculate the emissions for stationary energy, a detailed guide (GHG Protocol Guidance, 2005) and a supporting calculation worksheet (GHG Protocol, 2015) is available at the GHG protocol platform.

Fuel combustion within a city boundary

When calculating the fuel combustion per sub-sector, the fuel consumption (activity data) is multiplied by the corresponding emission factors for each fuel, by gas. Depending on the selected unit of activity data the appropriate heating value metrics (Lower or Higher Heating Value) should be selected. The following equations can be applied:

Equation 1: Calculation based method for CO_2 emissions

$$E = A_{f,v} \cdot F_{c,v} \cdot F_{ox} \cdot (44/12) \quad \text{or} \quad E = A_{f,m} \cdot F_{c,m} \cdot F_{ox} \cdot (44/12) \quad \text{or} \quad E = A_{f,h} \cdot F_{c,h} \cdot F_{ox} \cdot (44/12)$$

Where,

E =	Mass emissions of CO_2 (short tons or metric tons)
$A_{f,v}$ =	Volume of fuel consumed (e.g., L, gallons, ft^3, m^3)
$A_{f,m}$ =	Mass of fuel consumed (e.g., short tons or metric tons)
$A_{f,h}$ =	Heat content of fuel consumed (GJ or million Btu)
$F_{c,v}$ =	Carbon content of fuel on a volume basis (e.g., short tons C/gallon or metric tons C/m^3)
$F_{c,m}$ =	Carbon content of fuel on a mass basis (e.g., short tons C/short ton or metric tons C/metric ton)
$F_{c,h}$ =	Carbon content of fuel on a heating value basis (e.g., short tons C/million Btu or metric tons C/GJ)
F_{ox} =	Oxidation factor to account for fraction of carbon in fuel that remains as soot or ash
(44/12) =	The ratio of the molecular weight of CO_2 to that of carbon

Note: Activity data and carbon content factors should be in the same basis (i.e., volume, mass, or energy). For gaseous fuel quantities in terms of volume, care should be taken to ensure all data are on a consistent temperature and pressure basis.

Equation 2: Calculation of heat content of fuel consumed

$$A_{f,h} = A_{f,v} H_v \quad \text{or} \quad A_{f,h} = A_{f,m} H_m$$

Where,

$A_{f,h}$ =	Heat content of fuel consumed (GJ or million Btu)
$A_{f,v}$ =	Volume of fuel consumed (e.g., L, gallons, ft^3, m^3)
$A_{f,m}$ =	Mass of fuel consumed (e.g., short tons or metric tons)
H_v =	Calorific value (i.e., heat content) of fuel on a volume basis (e.g., million Btu/ft^3 or GJ/L)
H_m =	Calorific value (i.e., heat content) of fuel on a mass basis (e.g., million Btu/short ton or GJ/metric ton)

Note: For gaseous fuel quantities in terms of volume, care should be taken to ensure all data are on a consistent temperature and pressure basis.

Figure 2: Calculation Methods for Direct Emissions from Stationary Combustion, Version 3.0. Source: GHG Protocol Guidance, 2005, Pp. 16).

The GHG protocol suggests a six-step approach for collecting the appropriate data and a supporting worksheet for calculations has been provided.

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3.1.2 Transport and Mobility

Transport vehicles and mobile equipment that produce GHG emissions by directly combusting fuel or indirectly by consuming grid-delivered electricity are part of this sector. This could be emissions from transportation occurring in the city (scope 1), emissions from grid-supplied electricity used in the city for transportation (scope 2), and emissions from transboundary journeys occurring outside of the city (scope 3). Examples of transport modes to be included are railway, water-borne transportation, aviation, off-road and on-road transportation. The purpose of these indicators is to get an overview of transport and mobility related emissions to understand which types of transport should be avoided to reduce the city's emissions. Note that Scope 3 emissions can be calculated but are considered optional for this sector.

3.1.2.1 Indicator Set

Table 2 Transport and Mobility Indicator Set

Indicator Title	GHG emission from transport	Fuel consumption for in-boundary transportation per fuel type
Unit of Measurement	t CO_2 equivalent	MJ/kg/kWh
Required or Recommended	Required	Recommended
Definition	Greenhouse gas emissions from the operations of vehicles.	Emissions per fuel type emerging from the operations of vehicles.
Source	GHG Protocol for Cities (2020), Pp. 75-87.	GHG Protocol for Cities (2020)
Calculation Formula	Calculation formulae for Transport indicators can be found in the GHG Protocol for Cities (2020).	Calculation formulae for Transport indicators from GHG Protocol for Cities (GPC) pages 75 to 87.
Emission Scope for GHG Indicator	Scope 1 and 2. Scope 3 can be calculated but is not mandatory.	Scope 1

3.1.2.2 Use Case Examples

GHG emissions from transport

To be able to calculate emissions for the transport and mobility sector the GHG Protocol for cities does not offer a single method of calculation due to variations in data availability, existing transportation models, and inventory purposes. One of the methods will be explained below:

ASIF framework

The ASIF framework uses travel activity, the mode share, energy intensity of each mode, fuel, vehicle type, and carbon content of each fuel to calculate the total emissions. Activity (A) is commonly gauged through VKT (vehicle kilometres travelled), which signifies the total distance covered by various trips in terms of both quantity and distance. Mode share (S) delineates the proportion of trips taken using diverse transportation modes (e.g., walking, biking, public transport, private cars) and vehicle categories (e.g.,

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motorcycles, cars, buses, trucks). Energy Intensity (I) by mode, often simplified as energy consumption per vehicle kilometre, is influenced by vehicle types, characteristics (e.g., occupancy or load factor, represented as passengers per kilometre or tons of cargo per kilometre), and driving conditions (e.g., typically depicted in drive cycles, a set of data points illustrating vehicle speed over time). The carbon content of the fuel, or Fuel factor (F), is primarily determined by the composition of the local fuel supply.

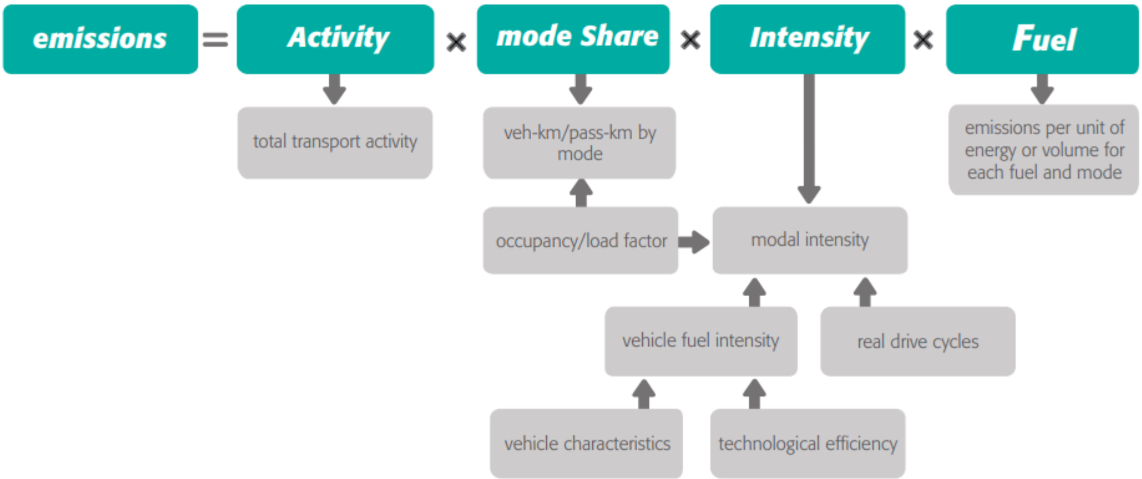

Figure 3: ASIF Framework (Source: Global Protocol for Community-Scale Greenhouse Gas Emission Inventories, pp. 78)

<u>Fuel consumption for in-boundary transportation per fuel type</u>

Fuel consumption for in-boundary transportation per fuel type forms a component of the above equation, which allows for the calculation of total emissions resulting from fuel combustion in transportation. Cities should ideally first consult any transport models developed by city transportation planners. In the absence of a transportation model, cities can use the fuel sales method as a proxy for transportation activity. The volume of fuel sold within the city boundary can be obtained from fuel dispensing facilities and/or distributors, or fuel sales tax receipts and city-wide fuel statistics.

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3.1.3 Waste and Wastewater

The Waste and Wastewater sector refer to GHG emissions generated by waste disposal and treatment through aerobic and anaerobic decomposition. These include emissions from waste and wastewater treated inside the city boundaries (scope 1) and emissions from waste and wastewater generated by the city but treated outside the city (scope 3). The three indicators outlined below include calculations as outlined by the GPC, whereby, wastewater may be a subcategory of each methodology provided.

3.1.3.1 Indicator Set

Table 3 Waste and Wastewater Indicator Set

Indicator Title	GHG emission from waste	Mass of waste processed per end-of-life treatment type within city boundary	Mass of waste processed per end-of-life treatment type outside city boundary
Unit of Measurement	t CO2 equivalent	t CO2 equivalent	t CO2 equivalent
Required or Recommended	Required	Recommended	Recommended
Definition	Greenhouse gas emissions from waste treatment, waste incineration and landfills	Depending on end-of-life treatment options available in the city boundary, the city can report mass of waste sent towards each treatment type.	If waste types or end-of-life treatments are unknown for exported waste, a singular "mixed waste exported" weight can be reported. If waste types and treatment types are known, then all data can be reported.
Source	GHG Protocol for Cities (2020) Also informed by: • IPCC (2006, 2019), • JRC Info kit for cities (European Commission 2021b)	GHG Protocol for Cities (2020)	GHG Protocol for Cities (2020)
Calculation Formula	Quantity of waste per End-of-life (EoL) treatment type x emission factors per EoL treatment. Detailed methods for different waste types are defined under GPC, pages 89 - 107	Detailed calculation and scoping methodology described in GPC, pages 89 - 107	Detailed calculation and scoping methodology described in GPC, pages 89 - 107
Emission Scope for GHG Indicator	Scope 1 & 3	Scope 1	Scope 3

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3.1.3.2 Use Case Examples

Mass of waste processed per end-of-life treatment type within city boundary

A city can use this indicator to monitor the progress of their waste sector, by building a matrix of waste types mapped against different end-of-life treatments. In addition to showing the overall changes in the emission from the waste sector, the benefit of maintaining this matrix over multiple years is to track movement of waste from low-value recovery/high-emission end of life towards high-value recovery/low-emission treatments. This can help cities also track data gaps, co-benefits such as resource efficiency, material circularity and health benefits to the public from safer collection practices.

The matrix should ideally include Municipal Solid Waste (MSW) types, Industrial waste types, Wastewater and Sludge (if not already included in other waste types). For end-of-life treatments, the matrix can include all available processes in the city such as landfill, incineration, waste-to-energy, composting, recycling, etc. IPCC provides "Waste model worksheets" (under chapter 3) with pre-filled estimates of waste divisions, which can be used when local data availability is low.

Mass of waste processed per end-of-life treatment type outside the city boundary

Cities which have information on the total waste exported for treatment can report on the total amount in weight. To improve the understanding of scope 3 emissions arising from waste management, the waste exported should be disaggregated by the following four data points:

- Waste type
- Weight of each type of waste
- Location of end-of-life treatment (country level can serve as a base information, transportation distance from source for advanced calculations)
- End-of-life treatment type at the point of treatment (if known)

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3.1.4 Industrial Processes and Product Use (IPPU)

The GHG emissions from the IPPU sector occur from industrial processes, product use, and non-energy uses of fossil fuel. These include emissions from industrial processes and product uses occurring within the city (scope 1) and outside of the city boundary (scope 3). For instance, cement production, lime production and glass production. It is however important to note that IPPU emissions reporting for cities under the mission exclude emission related to the Emissions Trading Scheme (ETS) as stated in the JRC Info Kit for Cities (European Commission 2021b). This is due to the fact that Municipalities have very limited influence over their operation and there is a specialised EU process dedicated to this. It therefore does not impact the indicators as described below but may impact the input data. Note that Scope 3 emissions can be calculated but are considered optional for this sector.

3.1.4.1 Indicator Set

Table 4 Industrial Processes and Product Use (IPPU) Indicator Set

Indicator Title	GHG emission from IPPU	Emission generation potential per unit of input/output for industrial processes within the city boundary	Emissions from non-energy product use
Unit of Measurement	t CO2 equivalent	CO2 equivalent per kg of production	t CO2 equivalent
Required or Recommended	Required	Recommended	Recommended
Definition	Greenhouse gas emissions from industrial processes and product use within city boundary.	The carbon intensity of products produced in the city. These are defined using the GHG emissions from industrial processes, which may include the production and use of mineral products (e.g. cement, lime, glass), chemicals (inorganic and organic) and metals.	Greenhouse gas emissions from industrial product use, which may include: the use of lubricants and paraffin waxes in non-energy products, FC gases used in electronic production and Fluorinate gases used as substitutes for Ozone depleting substances.
Source	IPCC (2006, 2019) Also informed by: • GHG Protocol for Cities (2020) , • JRC Infokit for Cities (European Commission 2021b)	IPCC (2006, 2019) Also informed by: • GHG Protocol for Cities (2020)	IPCC (2006, 2019) and GHG Protocol for Cities (2020)
Calculation Formula	GHG emission calculation methodology for the IPPU sector is	Detailed calculation and scoping methodology described in GPC, page	Detailed calculation methodology described in GPC, Equation 9.5.

This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

Indicator Title	GHG emission from IPPU	Emission generation potential per unit of input/output for industrial processes within the city boundary	Emissions from non-energy product use
	described in detail in the 2014 IPCC Mitigation of Climate Change, chapter 10, page 746. City-level calculation and scoping methodology described in GPC, pages 109 onward.	109 onward. Emission factors per material can be found in 2006 IPCC Guidelines for National Greenhouse Gas Inventories, volume 3.	Adapted from 2006 IPCC Guidelines for National Greenhouse Gas Inventories, chapter 3.' Emission factors can be found in the IPCC Emissions Factor Database (EFDB).
Emission Scope for GHG Indicator	Scope 1. Calculations for scope 3 (not mandatory) can also be applied if a consumption-based approach is taken which may include all imported products and their full lifecycle impacts.	Scope 1. Calculations for scope 3 (not mandatory) can also be applied if a consumption-based approach is taken which may include all imported products and their full lifecycle impacts.	Scope 1. Calculations for scope 3 (not mandatory) can also be applied if a consumption-based approach is taken which may include all imported products and their full lifecycle impacts.

3.1.4.2 Use Case Examples

Emissions from industrial processes

Emissions from industrial processes include all production activities within the city boundary (Scope 1), including production of mineral products (e.g. cement, lime, glass), chemicals (inorganic and organic) and metals.

For example, if a city has a cement plant in its territory, multiple data points need to be collected at plant level to give a full overview of the emissions components, which are then multiplied with corresponding emission factors to produce the total emissions from cement production. These will include amount of clinker produced (t), dust leaving the clinker (t), dust calcination degree (%), Organic carbon content in raw materials (%), fuel consumption of conventional fuels, alternative fuels, biomass fuels and non-kiln fuels. Cities can use multiple existing tools and inventory building software to support calculations of emissions, such as CIRIS, or the GPC calculation tools and guidance worksheets (Cement specific worksheet and guidance available here). Any change in quantities and/or emission factors will result in change in the overall emissions of the plant.

Emission generation potential per unit of input/output for industrial processes within the city boundary

Emission generation potential per unit of input/output for industrial processes within the city boundary as an indicator this measures the carbon intensity of a product produced in the city. For example, if the city's cement industry produced 10 Mt of cement in a year, and the emissions associated to the production are 9 tCO_2 equivalent, then the carbon intensity of the cement is:

Carbon intensity of the product = Total emission/total production

Which, in this example would be 9 tCO_2eq / 10 t = 0.9

Emissions from non-energy product use

Emissions from non-energy product use is a sub-section of total IPPU emissions. In many cities, this may be a minimal emission source, but for industry-heavy cities, these emissions make a notable impact.

This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

For example, the use of solvents manufactured using fossil fuels as feedstocks can lead to evaporative emissions of various non-methane volatile organic compounds (NMVOC), which are subsequently further oxidised in the atmosphere. Fossil fuels used as solvent are notably white spirit and kerosene (paraffin oil), which are predominantly used in the paint industry. Emission calculations for this case would be:

Emissions = solvent use (kg) x emission factor

Solvent use in cities is often measured through sale volume as a total for each industry. Emission factors for non-energy product use are often defined at a national level if detailed data from the products are not available. For European countries, the latest emission factors can be found in the EMEP-EEA air pollutant emission inventory guidebook, 2019.

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3.1.5 Agriculture, Forestry and Other Land Uses (AFOLU)

The AFOLU sector produces GHG emissions through for instance management of forests and other lands, methane produced in the digestive processes of livestock and land-use alterations that change the composition of vegetation and soil. For scope 1 this pertains to in-boundary emissions from agricultural activity and land use within the city boundary. Scope 2 is not applicable here whereas scope 3 covers out-of-boundary emissions from land-use activities outside the city.

3.1.5.1 Indicator Set

Table 5 Agriculture, Forestry and Other Land Uses (AFOLU) Indicator Set

Indicator Title	GHG emission from AFOLU	Net annual rate of change in carbon stocks per hectare of land
Unit of Measurement	t CO_2 equivalent	t CO_2/ha
Required or Recommended	Required	Recommended
Definition	IPCC guidelines divides AFOLU emission activities into three categories: Livestock, Land, Aggregate sources and non-CO_2 emissions sources on land. The cumulative of these emissions forms the sectoral emissions. It requires identifying which categories of the AFOLU sector are relevant for reporting purposes. Cities should keep in mind that when a source/sink of emissions is included in the CCC Action Plan (either for emissions reduction or emissions compensation) both positive and negative emissions should be accounted for and monitored.	IPCC divides land-use into six categories: forest land; cropland; grassland; wetlands; settlements; and other. Further refinements for each land use category may be based on national or local definitions. Using national definitions for land use categories will promote consistency with the national GHG inventory, while local definitions may be more relevant to specific policies and measures being taken at the local level.
Source	GHG Protocol for Cities (2020) Also informed by: • IPCC (2006, 2019), • JRC Infokit for Cities (European Commission 2021b)	IPCC (2006, 2019) and, GHG Protocol for Cities (2020GPC)
Calculation Formula	Detailed calculation and scoping methodology described in GPC pages 121- 137	Detailed calculation and scoping methodology described in GPC pages 121-137; Estimating carbon stock changes can also be derived from 2006 IPCC guidance, vol 4 chapter 2,the GPC Supplemental Guidance for Forest and Trees and the 2019 IPCC revision, section 4.

This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

Indicator Title	GHG emission from AFOLU	Net annual rate of change in carbon stocks per hectare of land
Emission Scope for GHG Indicator	Scope 1. Scope 3 can be included in calculations if emissions from imported agricultural and animal products are included using a consumption-based approach.	Scope 1

3.1.5.2 Use Case Examples

Net annual rate of change in carbon stocks per hectare of land

Some cities, where there are no measurable agricultural activities or relatively little wood/vegetation within the city boundary, may have no significant sources of *AFOLU* emissions. Other cities may have significant agricultural activities or significant cropland, forests, grasslands, wetlands, or urban tree canopy that result in GHG emissions or removals.

IPCC provides worksheets for calculation of carbon stock change, pre-defined emission factors for each land-use type in case local factors are not known, as well as guidance for assessment of carbon stock change resulting from each change between two different land use types. The approach chosen will depend on the starting land use and the intended end land use,

Multiple calculation methods are available based on the level of information known about the land use and change in use. For example, the basic carbon stock calculation can even be done when only the total change in area of each individual land-use category is known, but no information exists pertaining to what land-use was converted to what other land use. More advanced calculations can take into account individual land use changes from initial use state to current use state per plot of land within the scope, including details on the strata under consideration.

IPCC provides worksheets for calculation of carbon stock change, pre-defined emission factors for each land-use type in case local factors are not known, as well as guidance for assessment of carbon stock change resulting from each change between two different land use types.

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3.1.6 Energy Generation

With respect to the increase in Local Renewable Energy Production, the promotion of renewable energy sources is a high priority for sustainable development, for reasons such as the security and diversification of energy supply and for environmental protection. (ISO/DIS 37120, 2013). The share of renewable energy production in itself gives an idea of the rate of self-consumption of locally produced energy, which is an indicator of the flexibility potential of the local energy system.

Renewable energy shall include both combustible and non-combustible renewables (ISO/DIS 37120, 2013). Non-combustible renewables include geothermal, solar, wind, hydro, tide, and wave energy. For geothermal energy, the energy quantity is the enthalpy of the geothermal heat entering the process. For solar, wind, hydro, tide and wave energy, the quantities entering electricity generation are equal to the electrical energy generated. The combustible renewables include biomass (fuelwood, vegetal waste, ethanol) and animal products (animal materials/waste and sulphite lyes). Municipal waste (waste produced by the residential, commercial, and public service sectors that are collected by local authorities for disposal in a central location to produce heat and/or power) and industrial waste are not considered a renewable source for energy production.

In addition, the level of energy autonomy, provides an indication of how resilient Cities are with regards to energy generation and how reliant they are on energy imports for their energy needs. The indicator presented below intends to highlight how energy autonomous a city is. The level of energy autonomy is important because energy security, supply and price shock issues can have significant negative effects on European economic activities and public finances.

3.1.6.1 Indicator Set

Table 6 Energy Indicator Set

Indicator Title	Local RES energy production	Energy autonomy[1]
Unit of Measurement	MWh	%
Required or Recommended	Recommended	Recommended
Definition	Annual local renewable energy production. It can be inferred that this indicator will prove useful for tracking the impact of the installation and operation of renewable energy projects over time. It will allow for the analysis of the before and after situation, as following the installation and operation of renewable energy projects (or as the difference between the annual renewable energy generation related to the project compared to the BAU case). It is possible to divide the annual total energy consumption compared to a	The indicator highlights whether the local available energy is sufficient to meet the local energy demand and in turn, whether the city is energy autonomous or not.

[1] Note that this indicator is considered a Co-Benefit Indicator and not a Direct Benefit Indicator but included in this section for the purposes of clarity and as to not split the energy related indicators.

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Indicator Title	Local RES energy production	Energy autonomy[1]
	previous baseline or inventory, and then multiply by it by 100 to express the difference/result as a percentage.	
Source	Informed by Bosch, P., Jongeneel, S., Rovers, V., Neumann, H.-M., Airaksinen, M., & Huovila, A. et al. (2017) *CITYkeys list of city indicators.*	Informed by Martinopoulos G., Nikolopoulos N., Angelakoglou K., Giourka P., (2021) *D2.1 Response KPI Framework,* Integrated Solutions for Positive Energy and Resilient Cities.
Calculation Formula	Annual local renewable energy production is calculated by acquiring the total renewable energy generation within the city in a given year. Relevant unit conversions are 1 J = 1 Ws; 1 kWh= 3,600,000 J; and 1 TOE = 41.868 GJ, 11,630 kWh, or 11.63 MWh (ITU-T L.1430: 2013)	Local available energy/ total consumption x 100/1

3.1.6.2 Use Case Examples

<u>Local renewable energy production</u>

A benefit of this indicator is that it will allow for comparison of renewable energy production overtime. For instance, the current rate of local renewable production is 50MWh/50,000kWh and a new large turbine is installed capable of generating 5MWh/5,000kWh, the percentage increase calculation would be done as follows:

5,000kWh (installation of new wind turbine) / 50,000kWh (existing renewable energy production) = .10 * 100 = 10%

Or 10% increase in local renewable energy production compared to the baseline/ BAU case of 50,000kWh.

<u>Energy Autonomy</u>

Energy Autonomy is considered a co-benefit.

Taking a hypothetical case, if a city's gross available energy is 100MW, yet the local energy demand is 150MW, the calculation would be as follows:

150MW – 100MW = 50MW

50MW / 150MW = 0. 33333333333 * 100 = 33%.

Therefore, the City's Energy Autonomy is 66%, as 33% will need to be imported or acquired by other means.

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3.1.7 Grid Supplied Energy

This indicator set has been designed to capture all GHG emissions that result from the use and consumption of grid supplied energy within the city boundary. In other words, the purpose of these indicators is to get an overview of the consumption of energy that is generated outside the city boundary but used within the city boundary.

In some cases, grid supplied energy can be considered a part of stationary energy as scope 2. However, what is proposed here is to allow for clarity and transparency of accounting. Therefore, this indicator set proposes to account for grid supplied energy emissions that are consumed within the city boundary, whereby the energy itself has been generated elsewhere, outside of the city boundary. For a detailed understanding of the relationship between stationary energy and grid supplied energy, readers can view IPCC 014 Energy Systems figure 7.1, GPC pages 60-61 as well as Deliverable D2.5 annex B 5 (Singh, A. et al, 2023).

It should be noted that should a city's emission inventory methodology calculate the emissions from grid supplied energy as part of a stationary energy calculation, the below grid supplied energy indicator may not be appropriate to use, in order to avoid double counting.

3.1.7.1 Indicator Set

Table 7 Grid Supplied Energy Indicator Set

Indicator Title	GHG emission from grid supplied energy	Grid specific emission factor	Transmission and distribution loss factor for grid supplied energy
Unit of Measurement	t CO2 equivalent	tCO2 eq/MWh	%
Required or Recommended	Required[2]	Recommended	Recommended
Definition	GHG emissions occurring as a consequence of the use of grid-supplied electricity, heat, steam and/or cooling within the city boundary	Mass GHG emissions per unit of grid-supplied energy	Average loss rate of the grid and amount of energy transmitted. These include losses from generation (upstream activities and combustion) of electricity, steam, heating, and cooling that is consumed (i.e., lost) in a Transmission and Distribution (T&D) system reported by end user. Localised Grid Loss Factors are usually provided by local utility or government publications.
Source	GHG Protocol for Cities (2020)	GHG Protocol for Cities (2020)	GHG Protocol for Cities (2020) Also informed by:

[2] Note that some GHG accounting methodologies account for the generation of energy for grid-distributed electricity, steam, heating, and cooling, within the stationary energy domain. If this is the case for a particular city, this indicator may not be applicable for the purposes of avoiding double counting.

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Indicator Title	GHG emission from grid supplied energy	Grid specific emission factor	Transmission and distribution loss factor for grid supplied energy
	Also informed by: • IPCC (2006, 2019), • JRC Infokit for Cities (European Commission 2021b)	Also informed by: • IPCC (2006, 2019),	• IPCC (2006, 2019),
Calculation Formula	Detailed calculation and scoping methodology described in GPC pages 56 – 75.	Detailed calculation and scoping methodology described in GPC pages 56 – 75.	Transmission & Distribution Losses (%) = (Energy Input at Power Plants (kWh) – Billed Energy to Consumer (kWh)) / Energy Input (kWh) x 100 Detailed scoping methodology described in GPC standard 56-75 for various sectors and more specific calculations in the GPC scope 3 guidance, incl. pages 44-45. Transmission and distribution losses vary by location, see The World Bank's World Development Indicators (WDI) for an indication of national transmission and distribution losses as a percent of output, see: http://data.worldbank.org/indicator/EG.ELC.LOSS.ZS
Emission Scope for GHG Indicator	Scope 2	Scope 2	Scope 3

3.1.7.2 Use Case Examples

Grid supplied energy from the grid

GHG emission (tCO2) = Electricity consumption (MWh) x GHG emission factor (tCO2/MWh)

It is possible to use emission factors associated with GPC, IPCC, and CRF methodologies, as well as national emission factors. However, as described earlier in section 2.6 of this report, it is preferred to use a local grid factor based on the specific energy mix at city level over annual national grid factors. The Infokit for Cities (section 4.2.1) (European Commission 2021b) further elaborates on possible approaches for data collection and calculations.

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<u>Distribution and Transmission losses</u>

A full description of fuel- and energy-related activities not Included in Scope 1 or Scope 2 is described by the GHG protocol for scope 3 emissions. A full use case and a calculation of the emissions from transmission and distribution losses is provided on page 44-45.

CO2 e emissions from energy (generation of electricity, steam, heating, and cooling that is consumed (i.e., lost) in a T&D system) = sum across suppliers, regions, or countries:

∑ (electricity consumed (kWh) × electricity life cycle emission factor ((kg CO2e)/kWh) × T&D loss rate (%)) + (steam consumed (kWh) × steam life cycle emission factor ((kg CO2e)/kWh) × T&D loss rate (%)) + (heating consumed (kWh) × heating life cycle emission factor ((kg CO2e)/kWh) × T&D loss rate (%)) + (cooling consumed (kWh) × cooling life cycle emission factor ((kg CO2e)/kWh) × T&D loss rate (%))

Multiplying total consumption for each grid-supplied energy type (activity data for scope 2) by their corresponding loss factor yields the activity data for transmission and distribution (T&D) losses. This figure is then multiplied by the grid average emissions factors.

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3.1.8 Carbon Removal and Residual Emissions

While cities will be required to reduce all sources of GHG emissions to the extent feasible, it is acknowledged that depending on local circumstances there may be certain emission sources (e.g., specific industrial processes) which cannot be fully mitigated by 2030 due to technological or financial constraints. Subsequently, compensating for any 'residual emissions' will be possible, to an extent, to account for those emissions sources which cannot be fully eliminated (Info Kit for Cities, European Commission 2021b).

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

3.1.8.1 Indicator Set

Table 8 Carbon Capture and Residual Emissions Indicator Set

Indicator Title	Amount of permanent sequestration of GHG within city boundary	Negative emissions through natural sinks
Unit of Measurement	t CO2 equivalent	t CO2 equivalent
Required or Recommended	Required	Required
Definition	This indicator supports the reporting of carbon sequestration through "Technological sinks", such as Biomass for Energy with Carbon Capture and Storage (BECCS) and Direct Air Carbon Capture and Storage (DACCS) technologies. This indicator can only be reported for Carbon Capture Project (CCP) applications which result in permanent sequestration of the CO2 (i.e., injected into geological structures)	"Natural sinks" refer to the planting of trees or other conversion of land use. Cities are allowed to account for negative emissions through the enlargement or enhancement of natural sinks within the territory to address residual emissions (accounting for all changes in the carbon stock). Carbon sinks should be accounted for as part of the 'AFOLU' sector of the GHG inventory and can be independently monitored as a progress indicator to show negative emissions.
Source	Infokit for Cities (European Commission 2021b)	Infokit for Cities (European Commission 2021b)
Calculation Formula	Direct reporting from Carbon Credit Projects (CCP) based on C40 guidance: C40 and NYC Mayor's Office of Sustainability, Defining Carbon Neutrality for Cities and Managing Residual Emissions. Cities' perspective, C40, 2019. Available here.	Refer to AFOLU indicators section

This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

Indicator Title	Amount of permanent sequestration of GHG within city boundary	Negative emissions through natural sinks
Emission Scope for GHG Indicator	Scope 1	Scope 1

3.1.8.2 Use Case Examples

Research based on a case study in Helsinki, Finland (Ariluoma, et al, 2021) applied planting tools to assess the current and potential life cycle CSS of the case area. The results reveal that trees and the mixing of biochar into growing medium can increase the CSS in urban areas considerably. The CSS potential of the case area is 520 kg CO_2 per resident for 50 years. The added biochar accounts for 65 % of the capacity and the biomass of trees accounts for 35 %. At the city scale, it would lead to 330 000 t CO2 being stored for 50 years. The findings suggest that green planning could contribute more strongly to climate change mitigation by encouraging the use of biochar and the planting of trees, in addition to ensuring favourable growing conditions.

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4 Monitoring of Co-Benefits and/or Co-Risks

In the context of the CCC APs and IPs, co-benefits or indirect impacts are the additional impacts or positive effects of, and integral to, the direct impacts, i.e., GHG reductions. Co-benefits should be reflective of expected short, medium, or long-term impacts, based on the emission domains targeted and the portfolio of solutions designed by the cities. At the same time, some climate actions could also lead to negative effects or trade-offs to be avoided, in other words 'co-risks'.

Clearly identifying co-benefits is of paramount importance in garnering political support for the transition of a city to climate neutrality by 2030. Demonstrating that the move toward climate neutrality is not only beneficial for the environment but also yields positive outcomes, such as enhancing the quality of life, fostering innovation, and generating new job opportunities, will make both voters and politicians more inclined to endorse an ambitious climate agenda. Conversely, political support is at risk if the shift to climate neutrality results in undesirable consequences, like job losses, a high cost of living, or a surge in public debt. Therefore, to ensure the ongoing legitimacy of achieving climate neutrality by 2030, it is imperative to meticulously and transparently monitor and evaluate co-benefits and associated risks using appropriate key performance indicators (KPIs).

Co-benefits could be identified based on how closely they are related to the outcome of an action or solution. For instance, improved air quality through renewable energy usage (reduction in nitrous oxide, particulate matter concentrations) would be a primary co-benefit. Therefore, having a clear and comprehensive understanding of potential co-benefits and how they are interconnected will help cities in identifying a broad range of indirect impacts and trade-offs for their specific actions or interventions.

Outlining the targeted co-benefits within their impact pathways can support cities in assessing the most critical evidence gaps while generating learning from and evaluating in real-time, their portfolio implementation. Moreover, monitoring of indirect impacts or co-benefits within the CCC AP and IP may entail consideration of some outcomes that are critical yet hard to measure and evaluate, for example, social indicators for measuring inclusion. These 'Recommended' indicators can support cities in designing and implementing a range of monitoring and evaluation methods to integrate quantitative and qualitative data within a coherent MEL process.

The following sections outline the co-benefits identified by NetZeroCities and the key indicators that could be deployed by a city for MEL purposes within impact categories. These are – Public Health & Environmental Impact; Social Inclusion, Democracy and Cultural Impact; Digitalisation and Smart Urban Technology; Economy; Finance and Investment; Resource Efficiency; and Biodiversity.

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4.1 Public Health and Environment

4.1.1 Air Quality

Air quality relates to the ambient levels of air pollutants that are known to have a negative impact on human health and the natural environment. These include nitrogen oxides (NO_x), particulate matter (PM), carbon monoxide (CO), ozone (O_3), and sulphur dioxide (SO_2), which can contribute to health problems such as asthma, strokes, and cardiovascular disease when absorbed through the lungs. Many air pollutants are generated through the combustion of fossil fuels and are related to GHG emissions. As such, achieving climate neutrality using measures that reduce urban air pollution, for example, increasing the number of trees and reducing motorised transport, can significantly contribute to cleaner air. This, in turn, should improve citizen health and contribute to reduced healthcare costs.

Many air pollutants are already required to be measured in European cities, in line with EU Directive 2008/50/EC. Particulate matter and nitrogen dioxide are of particular relevance in urban contexts as they are associated with high levels of traffic and industrial activity. The indicator set should therefore capture the ambient levels of nitrogen dioxide and particulate mattes less than 10 and 2.5 microns in diameter (PM_{10} and $PM_{2.5}$ respectively). These are usually measured in µg per cubic metre. Data is available from the EEA here: https://discomap.eea.europa.eu/App/AirQualityStatistics/index.html.

4.1.1.1 Indicator Set

Table 9 Air Quality Indicator Set

Indicator Title	PM2.5 concentration levels	PM10 concentration levels	NO2 concentration levels
Unit of Measurement	µg/ m3	# of days	µg/ m3
Required or Recommended	Recommended	Recommended	Recommended
Definition	This indicator corresponds to the highest annual mean of PM2.5 concentration recorded in a particular year at stations in urban and suburban background locations.	This indicator corresponds to the highest number of days in a year where the PM10 concentration level recorded at stations in urban and suburban background locations has exceeded the WHO recommendation of 45 µg/ m^3. It refers to the number of days on the monitoring station that measured the most days in excess of the WHO recommendation of 45 µg/m^3.	This indicator corresponds to the highest value of the annual mean of nitrogen dioxide (NO_2) concentrations recorded in a particular year at stations with the highest traffic location levels.
Source	European Commission (2022), *Green City Accord, Clean and Healthy Cities for Europe, GCA Mandatory Indicators Guidebook*, Version of 29 April 2022	European Commission (2022), *Green City Accord, Clean and Healthy Cities for Europe, GCA Mandatory Indicators Guidebook*, Version of 29 April 2022	European Commission (2022), *Green City Accord, Clean and Healthy Cities for Europe, GCA Mandatory Indicators Guidebook*, Version of 29 April 2022

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Indicator Title	PM2.5 concentration levels	PM10 concentration levels	NO2 concentration levels
Calculation Formula	This indicator corresponds to the highest annual mean of PM2.5 concentration recorded in a particular year at stations in urban and suburban background locations. Data can be obtained: 1) From air quality monitoring reports in different stations on a municipal or regional level and 2) Based on measurements made in urban and suburban background locations established for this purpose. When a city is not able to report this value due to the non-existence of monitoring stations within city boundaries, they may report PM2.5 values from the closest regional/national station where concentration values are available.	This air quality management indicator, corresponds to the highest number of days in a year where the PM10 concentration level recorded at stations in urban and suburban background locations has exceeded the WHO recommendation of 45 µg/ m3. It refers to the number of days on the monitoring station that measured the most days in exceedance of the WHO recommendation of 45 µg/m³. Data can be obtained from: 1) Air quality monitoring reports in different stations on a municipal or regional level; and 2) Based on measurements made in urban and suburban background locations established for this purpose.	This indicator corresponds to the highest value of the annual mean of nitrogen dioxide (NO2) concentrations recorded in a particular year at stations with the highest traffic locations. Data can be obtained: - From air quality monitoring reports in different stations on a municipal and regional level; and - Based on measurements made in urban and suburban background locations established for this purpose.

4.1.1.2 Use Case Examples

PM2.5,

The minimum requirements set by the EU and WHO are:

- EU limit value: 25 µg/ m^3
- WHO New Air Quality Guidelines: 5 µg/ m^3

Using air quality monitoring stations the annual mean of PM2.5 would be calculated.

PM10

The PM10 daily observed concentration indicator, allows cities to monitor if they meet the EUAAQ Directive (EU Directive 2008/50/EC*)* or the WHO New Air Quality Guidelines (2021). The minimum requirements set by the EU and WHO for observed daily concentrations are:

- EU limit value: 50 µg/ m^3
- WHO New Air Quality Guidelines: 45 µg/ m^3 24-hour mean

The minimum requirements set by the EU and WHO are:

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- EU limit value: is: 40 µg/m^3
- WHO New Air Quality Guidelines: 10 µg/ m^3

Using air quality monitoring stations, the number of days in a year where the PM10 concentration level recorded in urban and suburban background locations has exceeded the WHO recommendation of 45 µg/ m3, can be recorded.

<u>NO2,</u>

The minimum requirements set by the EU and WHO are:

- EU limit value: is: 40 µg/m3
- WHO New Air Quality Guidelines: 10 µg/ m3

Using air quality monitoring stations, the annual mean of nitrogen dioxide (NO2) concentrations can be recorded.

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4.1.2 Noise Pollution

Urban noise pollution refers to excessive noise levels in urban areas, typically caused by transportation, construction, and industrial activities. Excessive noise can have negative impacts on human health, including hearing loss, sleep disturbance, stress, and cardiovascular problems, and can also impact wildlife and ecological systems by disrupting animal behaviour and communication.

Lower levels of urban noise pollution can be achieved through emissions-reducing actions such as shifting from internal combustion engine to electric vehicles and reducing motorised transport overall. This would be expected to improve the overall quality of life for residents, through reducing negative health impacts, improving sleep quality, and enhancing the natural environment. It may also contribute to improved economic activity and increased social interaction in urban areas. Significantly, it is expected that noise pollution would decrease in a climate neutral city due to such sifts from combustion engines to electrically powered vehicles and machinery within the transport, industrial and construction sectors.

Noise pollution varies throughout the urban area and should be measured at a variety of locations. Noise mapping using common assessment methods is required in EU Member States under EU Directive 2002/49/EC. Noise pollution can be assessed by measuring the proportion of population exposed to excessive noise levels, e.g. noise above 55 decibels (dB). Noise pollution is usually assessed considering the time of the day, given the greater impact of night-time noise on human wellbeing. Data is available from the EEA here: https://www.eea.europa.eu/data-and-maps/data/data-on-noise-exposure-8. These indicators are considered useful because they are designed to directly monitor the impact of noise pollution on human health, such as those measuring the amount of a city's population impacted night-time noise as well as the general amount of noise over a certain threshold.

4.1.2.1 Indicator Set

Table 10 Nosie Pollution Indicator Set

Indicator Title	Population exposed to night-time noise (Lnight) >= 50 dB	Population exposed to average day-evening-night noise levels (Lden) ≥ 55 dB.
Unit of Measurement	%	%
Required or Recommended	Recommended	Recommended
Definition	The indicator 'Population exposed to night-time noise (Lnight) ≥ 55 dB refers to an annual average period of exposure to noise at night.	The indicator 'Population exposed to average day-evening-night noise levels (Lden) ≥ 55 dB' represents the average noise level to which a citizen is exposed throughout the day, evening, and night over the period of one year.
Source	Green City Accord; European Commission (2021c), *Evaluating the Impact of Nature-based Solutions*: Appendix of Methods.	Green City Accord; European Commission (2021c), *Evaluating the Impact of Nature-based Solutions*: Appendix of Methods.
Calculation Formula	(no. inhabitants exposed to noise > 50 db (A) / Total number of inhabitants) x 100 = % population affected by noise.	Lden= 10log10 1/24 (12 × 10Lday/10 + 4 × 10Levening+5/10 + 8 × 10 Lnight+10/10) $L_{den} = 10\log_{10}\frac{1}{24}\left(12 \times 10^{\frac{L_{day}}{10}} + 4 \times 10^{\frac{L_{evening}+5}{10}} + 8 \times 10^{\frac{L_{night}+10}{10}}\right)$

This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

Indicator Title	Population exposed to night-time noise (Lnight) >= 50 dB	Population exposed to average day-evening-night noise levels (Lden) ≥ 55 dB.
		In which L_{day}, L_{night} and $L_{evening}$ are the A-weighted long-term Averages. Simulated LDEN (numerical predictions): NMPB2008 or CNOSSOS-EU (see reference pdf document from UN/Ifsttar/LAE/BG). Measurement unit: Decibels with A ponderation: “dB(A)”

4.1.2.2 Use Case Examples

Use Case Example

These indicators can be calculated on an object, neighborhood or city scale. The data requirements relative to the indicator set are as follows:

- Measured LDEN (in situ measurements): acoustic acquisition (in dB(A)) on hourly periods (with typically 1 sec sampling rate), gathered on 3 periods (Day, Evening, Night) and next aggregated on 24h (see definition above).
- Simulated LDEN (numerical predictions): acoustic simulation (in dB(A)) on hourly periods (depending on input data, e.g., road traffic characterization, built-up implementation through GIS, etc.), gathered on 3 periods (Day, Evening, Night) and next aggregated on 24h (see definition above).
- Georeferenced data for built-up area: data from OPEN STREET MAP (OSM)
- Road traffic counts: data from district, city or regional agencies.
- Number of inhabitants exposed to noise, and total number of inhabitants.

It should be noted that, regardless of the calculation used, the noise level should be measured (or modelled) at the object receiving the noise. In urban areas, “night” hours are defined differently depending on jurisdiction but typically involve a specific time range, e.g., 22:00-07:00, rather than the meteorological definition of night as the period between dusk and dawn.

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4.1.3 Road Safety

Urban traffic safety refers to the degree to which people are protected from crash harm while travelling on and around roads in urban areas. Of particular relevance in urban areas is the safety of people outside vehicles (also referred to as vulnerable road users) because they make up a large proportion of people travelling in urban areas, and they are more likely to be injured or killed in crashes with vehicles compared to people inside vehicles. This group includes people walking, cycling, and increasingly, people using scooters and other forms of micro-mobility. The consequences of traffic crashes can be severe, including property damage, injury, and death, and they contribute to wider societal issues such as higher health care costs, reduced productivity, and preference for carbon-intensive transport modes (e.g. SUVs) over low-carbon ones (e.g. cycling).

Certain measures to reduce urban GHG emissions with the aim of achieving climate neutrality are likely to improve urban traffic safety as well. Reducing motorised transport and lowering speed limits, especially in areas with high pedestrian and cyclist activity, would be expected to also reduce crash risk, as well as the severity of crashes that do occur. There are, however, some potential negative effects on traffic safety from some measures to reduce carbon emissions. For example, there is the potential for electrification of vehicles to increase collision risk, as electric vehicle engines are quieter, reducing the cues that can alert other road users to the presence of a vehicle. In addition, increasing numbers of people travelling by active modes, such as walking and cycling, may be associated with a higher (absolute) number of injuries and deaths among these road users. However, an increasing presence of people walking, and cycling is also likely to increase driver awareness and safe behaviour around these users, meaning the *relative* rate of injuries and deaths among pedestrians and cyclists (by number of trips or distance travelled) should go down. Given the risk of negative side effects on traffic safety, it is important both that urban traffic safety is assessed and that emissions reductions measures that do not increase risk for people outside vehicles are prioritised.

Urban traffic safety is usually measured by the number of fatalities, injuries, and crashes on urban roads. Crash severity is an important factor because more severe crashes, such as those causing death or serious injury, produce more harm. It is also important to assess crashes for people outside of vehicles in urban settings, as there are more of these users and these crashes tend to produce more harm, and crashes can discourage the use of sustainable transport modes.

4.1.3.1 Indicator Set

Table 11 Road Safety Indicator Set

Indicator Title	Road Deaths	Traffic Safety Active Modes
Unit of Measurement	# of deaths / 100,000 inhabitants	# of deaths / 1000,000,000 trips
Required or Recommended	Recommended	Recommended
Definition	Number of deaths within 30 days after the traffic accident as a corollary of the event per annum caused by urban transport per 100,000 inhabitants of the urban area.	Fatalities of active modes users in traffic accidents in the city in relation to their exposure to traffic; This indicator corresponds to the number of deaths within 30 days after the traffic accident as a corollary of the event per annum caused by active modes of transport, per billion trips per annum (exposure)
Source	Rupprecht Consult et al. (2020) *Technical support related to sustainable urban mobility indicators (SUMI).*	Rupprecht Consult et al (2020), *Technical support related to sustainable urban mobility indicators (SUMI).*

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Indicator Title	Road Deaths	Traffic Safety Active Modes
Calculation Formula	FR = $\frac{\sum_i K_i * 100\,000}{Cap}$ Where: FR = Fatality rate [# per 100,000 urban area population per year] Ki = Number of persons killed in transport mode i [# per year] Cap = Capita or number of inhabitants in the urban area [#] i = Transport mode	RF = $\frac{\sum_i K_i * 1000}{Exp_i}$ Where: RFi = Risk factor for transport mode i [# per billion trips per year] Ki = Number of persons killed within 30 days after the traffic accident as a corollary of the event in transport mode i [# simple average over the last 3 years for which data is available] Expi = Exposure, defined as number of trips (in million) [# per year] i = Transport mode (pedestrian, bicycle) [type]

4.1.3.2 Use Case Examples

For instance, take a city with a population of 300,000, in which the following numbers of people died in 2022:

Transport mode	**Number of traffic fatalities**
Pedestrian	4
Bicycle (including regular bicycle, e-bike, etc.)	8
Moped	3
Motorcycles	5
Cars	8
LGV (<3.5 tons)	2
HGV - Trucks (≥3.5 tons)	1
Bus	0
Tram / Lightrail	0
Other	0
Unknown	0

The overall fatality rate would be calculated as follows:

((4+8+3+5+8+2+1+0+0+0+0)*100000)/300000 = 10.33 deaths / 100000 inhabitants.

Note the same calculation can be used to calculate the fatality rate for each mode, for example, in the above example, the fatality rate for pedestrians would be:

(4*100000)/300000 = 1.33 deaths / 100000 inhabitants.

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4.1.4 Urban Heat Island (UHI) Effect, Temperature Increase and Heatwave Incidence

Several measures a city will undertake to become climate neutral are likely to have positive impacts on the local climate and reduce, for example, the local heat island effect. For example, urban greening can capture carbon emissions and at that the same time improve local microclimate. Therefore, the reduction of the urban heat island effect can be considered a potential co-benefit of the transition of a city to climate neutrality.

The Urban Heat Island (UHI) effect denotes an urban area that is significantly warmer than its rural or undeveloped surrounding areas. Urban areas in Europe and worldwide are increasingly experiencing the pressures arising from climate change and are projected to face aggravated climate-related impacts in the future.

As described within Bosch, P. et al. (2017), the UHI effect is expressed and evaluated as temperature ºC. It is caused by the absorption of sunlight by (stony) materials, reduced evaporation and the emission of heat caused by human activities. It is greatest after sunset and reported to reach up to 9ºC in some cities. Because of it, citizens living in urban areas experience more heat stress than those living in the countryside.

Additionally, the mean of daily maximum and minimum temperature are good indicators to give an idea of the high temperature effects of climate change in urban comfort and human health.

Finally, a heatwave is a period of consecutive days with hot temperatures where both length and peak temperature are important. It is defined as 3 or more days where either the Excess Heat Factor (EHF) is positive, the mean of daily maximum temperature (TX) excesses the 90^{th} percentile or the mean of daily minimum temperature (TN) does not reach the 90^{th} percentile. It can be measured through the number of individual heatwaves that occur each summer.

The Excess Heat Factor (EHF) is a measure of heatwave intensity, incorporating two ingredients. The first ingredient is a measure of how hot a three-day period is with respect to an annual temperature threshold at each particular location. If the daily mean temperature averaged over the three-day period is higher than the climatological 95^{th} percentile for daily mean temperature, then the three-day period and each day within in it are deemed to be in heatwave conditions. The second ingredient is a measure of how hot the three-day period is with respect to the recent past (specifically the previous 30 days). This takes into account the idea that people acclimatise (at least to some extent) to their local climate, with respect to its temperature variation across latitude and throughout the year but may not be prepared for a sudden rise in temperature above that of the recent past.

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4.1.4.1 Indicator Set

Table 12 Urban Heat Island (UHI) Effect, Temperature Increase and Heatwave Incidence Indicator Set

Indicator Title	Urban Heat Island (UHI) effect	Mean value of daily maximum temperature (TXX)	Mean value of daily minimum temperature (TNN)	Heatwave (HW) incidence
Unit of Measurement	°C UHImax	ºC TX_x	ºC TN_N	# of HW in summer
Required or Recommended	Recommended	Recommended	Recommended	Recommended
Definition	Maximum difference in air temperature within the city compared to the countryside during the summer months	Mean of daily maximum temperatures (TX) observed during specific time period, to detect temperature increment	Mean of daily minimum temperatures (TN) observed during specific time period, to detect temperature increment at night	Period of consecutive days with hot temperatures where both length and peak temperature are important
Source	Bosch, P., Jongeneel, S., Rovers, V., Neumann, H.-M., Airaksinen, M., & Huovila, A. et al. (2017) *CITYkeys list of city indicators.*	European Union (2021c) *Evaluating the Impact of Nature-based Solutions -* Appendix of Methods	European Union (2021c) *Evaluating the Impact of Nature-based Solutions -* Appendix of Methods	European Union (2021c) *Evaluating the Impact of Nature-based Solutions -* Appendix of Methods
Calculation Formula	At least one meteorological (temperature) measurement station within the built environment and other station in the outside (that functions as reference station), to then look for the largest temperature difference (hourly average) during the summer months.	Measure the maximum temperature (TX) at day of a period, and then calculate the mean of those temperatures, to be compared with that of a past period	Measure the minimum temperature (TN) at day of a period, and then calculate the mean of those temperatures, to be compared with that of a past period	Measure the number of heatwaves over a period (summer); heatwave define as 3 or more days with one of the following cases: • Excess Heat Factor (EHF) positive • TX excesses the 90th percentile • TN does not reach the 90th percentile

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4.1.4.2 Use Case Examples

Urban Heat Island (UHI) effect

For calculating the *Urban Heat Island (UHI) effect* indicator, at least data from two meteorological measurement station is needed, as they need to be compared: one should be located in the built environment and the other one in the countryside, this last to acts as reference stations. Then, mainly during the summer months, it will be looked for the largest temperature difference in comparison between the values (for example, at hourly average) of both stations.

An example of this calculation in a certain city could be with the following data:

STATION	1st July - hours												
	0	**1**	**2**	**...**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**...**
CITY (Centre)	15	14	14	...	22	24	26	27	28	29	29	28	...
COUNTRYSIDE (Ref)C	13	13	12	...	20	21	23	24	26	27	27	26	...
Difference [ºC]	2	1	2	...	2	**3**	**3**	**3**	2	2	1	2	...

STATION	July (days)												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**...**
Largest temperature difference (in each day) [ºC]	3	2.5	2.2	3.1	2.5	2.8	**3.3**	2.5	1.8	2.6	3.2	3.5	...

Then, with the total series of the largest temperature difference per day over the summer, it can be obtained the indicator value:

Urban Heat Island (UHI) effect = 3.3 ºC UHImax for the summer of 2022

Mean Value of Daily Maximum and Minimum Temperature

The *mean value of daily maximum and minimum temperature* indicators are calculated with daily maximum and minimum data temperature over a certain period. This period can be, for example a month in the year, for which the mean of daily maximum and minimum temperature is calculated, and then compared with that same data of a past period.

An example of this calculation in a certain city for the month of October 2022:

	October (days)												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**...**
Maximum Temperature	22	22	21	21	21	20	19	19	19	20	20	19	...
Minimum Temperature	10	10	9	9	8	7	9	10	11	12	11	9	...

Then, the mean value for the maximum and minimum temperatures are calculated:

Mean value of daily maximum temperature: TX_X = 19.5 ºC

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Mean value of daily minimum temperature: TN_N = 9.8 ºC

This data is meant to be compared then with series of historical data, and it will probably be observed the progressive increasing of both maximum and minimum temperatures over time. For example:

	Oct 2022	**Oct 2012**	**Oct 2002**	**Oct 1992**	**Oct 1982**	**Oct 1972**	**...**
Mean value of daily maximum temperature: TX_X	19.5 ºC	19.2 ºC	18.5 ºC	17.8 ºC	16.3 ºC	16.1 ºC	...
Mean value of daily minimum temperature: TN_N	9.8 ºC	8.5 ºC	8.2 ºC	7.8 ºC	6.5 ºC	6.2 ºC	...

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4.1.5 Physical and Mental Wellbeing

This indicator set should assess the physical and mental wellbeing of citizens and how this is encouraged through activities. This indicator should offer insight into self-perceived wellbeing of citizens. Not only is it important to ensure wellbeing of citizens in the process of transforming cities into net zero cities, but the wellbeing will also ensure sustainability of this transformation. It will ensure that the transformation will last. Additionally, while in certain fields the positive association between exposure to green space and the self-perceived general mental health has been proven, the evidence from natural experiments is lacking. Those studies could offer evidence for causality of the association.

This indicator set is a combination of self-assessment questionnaires and the quantity of activities related to physical or mental wellbeing. On the one hand indicators can rely on self-perceived wellbeing. The physical and mental wellbeing should be measured partially through self-assessment and questionnaires to gather perceptions of the general population within the City.

4.1.5.1 Indicator Set

Table 13 Physical and Mental Wellbeing Indicator Set

Indicator Title	Wellbeing of citizens (questionnaire)
Unit of Measurement	Likert Scale
Required or Recommended	Recommended
Definition	The change in perceived wellbeing during the lifetime of the Climate-Neutral and Smart City Mission
Source	Urban Audit, based on Brazier et al. (1992) *Validating the SF-36 health survey questionnaire: a new outcome measure for primary care,* BMJ; 305,160.
Calculation Formula	A survey is used by sampling, asking questions asking participants about the amount they felt certain feelings. European Union (2021c) Evaluating the Impact of Nature-based Solutions - Appendix of Methods pg. 989)

4.1.5.2 Use Case Examples

A strength of this indicator is that it is obtained by applying a validated and widely used questionnaire to assess mental health status. This questionnaire has been translated into many languages and re-validated. A limitation is that the indicator is self-reported, although validation studies have demonstrated that the questionnaire has acceptable predictive value.

The SF-36 consists of eight scaled scores, which are the weighted sums of the questions in their section. Each scale is directly transformed into a 0-100 scale on the assumption that each question carries equal weight. The eight sections are:

- vitality
- physical functioning
- bodily pain
- general health perceptions
- physical role functioning
- emotional role functioning
- social role functioning

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- mental health or emotional wellbeing

A proposal would be that municipalities can set up data collection in the form of online and paper questionnaires to be collected at scheduled intervals.

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4.1.6 Liveability, Attractiveness and Aesthetics of the Built Environment

This indicator set reflects the overall quality of the urban environment and how it influences quality of life for its residents and visitors. A highly liveable and aesthetically attractive city has buildings and public spaces that are both appealing and easy to access. Features that contribute to an attractive and liveable urban environment include high quality public spaces, including public squares, streets, and parks, and a high density of green spaces. These provide opportunities for people to spend time outdoors and among greenery, to rest, to socialise, and to hold events. They also encourage healthier lifestyles by promoting physical and social activity, and can encourage tourism and stimulate economic activity, as well as improving quality of life for residents. Note that liveability often has a much broader meaning than is relevant here: elements of liveability that are not directly related to the physical urban environment, such as employment opportunities, are considered in other indicator sets.

Working toward climate neutrality can generally be expected to improve urban liveability and built environment attractiveness given the role of green spaces, and in particular, trees, in absorbing carbon and reducing carbon emissions. Furthermore, parks and effectively designed public spaces can contribute to resilience against climate change and natural hazards, for example, by soaking up excess water during bouts of heavy rain and providing cool spaces and shade during heat waves. It is considered that Climate Neutrality requires better urban planning, which consequently will result in a more aesthetic and attractive city.

As such, the indicator needs to measure the amount of green space in the urban area, and ideally also take into consideration the quality of public spaces (including green spaces).

4.1.6.1 Indicator Set

Table 14 Liveability, Attractiveness and Aesthetics of the Built Environment Indicator Set

Indicator Title	Green spaces	Quality of public spaces
Unit of Measurement	hectares / 100 000 inhabitants	# (rating from 0 to 10 of overall satisfaction with green and non-green public spaces)
Required or Recommended	Recommended	Recommended
Definition	The amount of green area in a city per 100 000 population	This indicator corresponds to residents' self-reported satisfaction with public spaces in their city. This indicator has been designed to analyse results from the European Commission's Urban Audit, a perception survey on quality of life in European cities which is being conducted by Eurostat based on telephone interviews on a regular basis. The parameter is an averaged score of survey responses about a respondent's satisfaction with green and non-green public spaces.
Source	Bosch, P., Jongeneel, S., Rovers, V., Neumann, H.-M., Airaksinen, M., & Huovila, A. et al. (2017) *CITYkeys list of city indicators.*	Rupprecht Consult et al (2020) *Technical support related to sustainable urban mobility indicators (SUMI).*

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Indicator Title	Green spaces	Quality of public spaces
Calculation Formula	(Total amount of green space in hectares * 100000) / Total inhabitants	$\overline{SAT} = \frac{\sum_m \overline{ASPECT_m}}{m}$ *m being the number of aspects (dimensions)* $\overline{ASPECT_m} = \sum_h \overline{AGREE_{h,m}}$ *h being the four replies of the agreement scale:* *(strongly agree, somewhat agree, somewhat disagree, strongly disagree)* $\overline{AGREE_{h,m}} = \frac{\#times\ agreement\ h\ was\ used\ in\ sample\ for\ aspect\ m}{\#people\ sample\ of\ aspect\ m - \#\frac{DK}{NA}\ answers\ in\ sample\ m} x C_h$ $C_{h=strongly\ agree} = 10;\ C_{h=somewhat\ agree} = 6.66;\ C_{h=somewhat\ disagree} = 3.33$ $C_{h=strongly\ disagree} = 0$

4.1.6.2 Use Case Examples

Green Spaces:

For a city of 170,000 people with a total of 65 hectares of green space, the green spaces indicator would be calculated as follows:

- (65 * 100000) / 170000 = 38.24 hectares / 100 000 inhabitants.

Quality of Public Spaces:

If a survey were taken of 500 people in the same city, with the following results:

Aspect	Question	*Surveyed Persons*	*(DK/NA)*	*Satisfied*	*Rather satisfied*	*Rather unsatisfied*	*Not at all satisfied*
Public spaces	Q1.6	**500**	**0**	**100**	**150**	**200**	**50**
Green spaces	Q1.7	**500**	**50**	**150**	**125**	**125**	**50**

The Quality of public spaces indicator would be calculated by first calculating the rating for each space type, as follows:

Public (non-green) spaces

- Satisfied = (100 / (500 – 0)) * 10 = 2
- Rather satisfied = (150 / (500 – 0)) * 6.66 = 1.998
- Rather unsatisfied = (200 / (500 – 0)) * 3.33 = 1.332
- Not at all satisfied = (50 / (500 – 0)) * 0 = 0
- Subtotal (public spaces) = 2 + 1.998 + 3.33 + 0 = 5.33

Green spaces

- Satisfied = (150 / (500 – 50)) * 10 = 3.33
- Rather satisfied = (125 / (500 – 50)) * 6.66 = 1.85
- Rather unsatisfied = (125 / (500 – 50)) * 3.33 = 0.925
- Not at all satisfied = (50 / (500 – 50)) * 0 = 0
- Subtotal (green spaces) = 3.33 + 1.85 + 0.925 +0 = 6.11

Then calculating the mean of the two ratings for an overall rate:

- Overall satisfaction (quality of public spaces) = (5.33 + 6.11) / 2 = 5.71

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4.1.7 Equitable and Affordable Access to Housing

An official or legal definition for affordable housing or what it constitutes does not exist in many countries. According to Rosenfeld, Affordable Access to Housing means that no more than 30% of one's median-income should be spent on median-housing. It can be considered whether energy bills for heating and the functioning of appliances need to be included (Rosenfeld, 2017).

With respect to Fuel Poverty, affordable housing may not only regard housing itself but also the affordability of the most basic levels of energy. The CITYkeys indicator definition states that households are considered as energy poor if their energy bill consumes 10% or more of the household income (Bosch, P., et al. (2017), Pp. 264).

Affordability of housing is best applied to new dwellings built, since renovation projects generally do not effect the indicator score. Yet it should be kept in mind that some newly built areas may be more expensive, which in turn effects diversity. Defining this indicator is difficult and has to be contextualized. The contextualization also requires several calculations. (Bosch,P., et al. (2017), Pp. 141).

4.1.7.1 Indicator Set

Table 15 Equitable and Affordable Access to Housing Indicator Set

Indicator Title	Affordability of Housing	Fuel poverty
Unit of Measurement	% of households	% of households
Required or Recommended	Recommended	Recommended
Definition	The percentage of households the housing and energy cost of which account for 30% or less of their disposable housing income	The percentage of households unable to afford the most basic levels of energy
Source	Rosenfeld (2017), *Interpreting the term 'affordable housing' in the Housing Partnership.*	Bosch, P., Jongeneel, S., Rovers, V., Neumann, H.-M., Airaksinen, M., & Huovila, A. et al. (2017) *CITYkeys list of city indicators.*
Calculation Formula	Calculate the median-income of the median-housing costs of all households and then calculate the percentage of it.	For simplicity the 10% variant and not the more complicated Low Income High Costs (LIHC) variant is proposed here. The fuel poverty ratio of a single household under this method is defined as: Fuel Poverty Ratio = Modelled fuel costs (i.e. modelled consumption * price)/income. Where this ratio has a value greater than 0.1, the household is considered to be fuel poor. In the next calculation step the number of households living in fuel poverty is

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Indicator Title	Affordability of Housing	Fuel poverty
		compared with the total number of households in the city. Note: The energy costs include all building related energy, i.e. for heating/cooling, warm water and electricity.

4.1.7.2 Use Case Examples

Affordability of Housing
To calculate this the yearly income needs to be sorted:
4.000, 4.000, 4.000, 4.500, 4.500, 4.500, 4.500, 4.500, 4.500, 4.500, 5.500, 5.500
The amount in the middle needs to be taken to assess the median income, in this case: 4.500 Euro.

The same needs to be done to the rent plus added energy costs:
900, 900, 900, 900, 925, 948, 948, 950, 950, 955, 955, 956.
The median rent is therefore 948 Euro.

The next step is to divide 948/4500= 0.21 = 21%

This number is assessed for every household of the area in question. The amount of households with a percentage above 30% are then divided by the total number of households.

Fuel Poverty
With respect to Fuel Poverty, the data needed for the calculation are: Household income; Energy consumption (dependent on dwelling characteristics and the lifestyle of householders) and Prices of energy. The cost of energy is modelled rather than based on actual spending. It is calculated by combining the fuel requirements of the household with corresponding fuel prices.

For instance, if fuel cost for a household for a given year were €3,000 and for that same year, the household income was €30,000, then calculation would be as follows:

3,000/ 30,000 = 0.1 * 100 = 10%

In this hypothetical scenario, the household would be considered energy poor as it has met the 10% threshold.

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4.2 Social Inclusion, Innovation, Democracy and Cultural Impact

4.2.1 Citizen and Communities' Participation

Open public participation includes opportunities for citizens, but also nongovernmental organizations and businesses, to contribute and comment on rules and laws. It measures the publics opportunity to respond to issues and challenges, which should enhance the democratic legitimacy and strengthens the connection between the population and the government. An increased amount of participation strengthens the citizens feeling of belonging into the community.

This indicator is easily measures through an absolute number, yet the clear definition of open participation can vary. The city administration can usually offer data and the data should also be publicly available.

4.2.1.1 Indicator Set

Table 16 Social Inclusion, Innovation, Democracy and Cultural Impact Indicator Set

Indicator Title	Openness of public participation processes
Unit of Measurement	% of processes
Required or Recommended	Recommended
Definition	The proportion of public participation processes in a given municipality per residents per year (expressed as %)
Source	Informed by Bosch, P., Jongeneel, S., Rovers, V., Neumann, H.-M., Airaksinen, M., & Huovila, A. et al. (2017) *CITYkeys list of city indicators.*
Calculation Formula	Calculation: (Total amount of open public participation processes/City population) *100

4.2.1.2 Use Case Examples

For instance, if a City has a population of 500,000 for the year 2022 and within 2022 the City held 500 public participation processes or events, then the calculation would be made as follows:

500 (public participation processes) / 500,000 (city population) = 0.001 * 100 = 0.1%

The strength of this indicator is an absolute measure of the amount public participation processes, which in turn can be compared across Cities. It should be noted that definitions and interpretations of what constitutes open public participation processes is subjective.

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4.2.2 City Capacities for Participation/Engagement

This indicator set intends to evaluate certain processes of policy making. It includes not just the number of policies regarding climate neutrality, but also the involvement and engagement of the community and citizens. The indicator set can reflect how the government approaches awareness raising in a society and the influence this has on agreeing with or accepting certain solutions. This acceptance can lead to easier and more sustainable implementation. Without the support of citizens, the transformation into a net zero city, will not lead to a sustainable or equitable outcome for citizens.

This indicator set should evaluate the governments readiness for co-creation and participation of citizens, while also including the eagerness of citizens to get engaged. It should measure how inclusive a government is to address contemporary challenges in collaboration with citizens. The involvement of citizens needs to be in different forms and matters to ensure inclusion of different societal groups. Not just the citizens engagement but also the involvement of public authority in Design Scenarios is evaluated to measure the quality of participation.

The data for this indicator set is partially very straightforward, by evaluating the numbers of citizens involved or the amount of policies in climate neutrality quantitatively. Yet gathering the information can be very time consuming and the records might not be a true representation of the situation. Therefore, while little data might be needed sometimes, it is difficult to understand it in the social context.

4.2.2.1 Indicator Set

Table 17 City Capacities for Participation/Engagement Indicator Set

Indicator Title	Policy support for promoting climate neutrality	Citizen involvement in co-creation/co-design of climate neutrality actions
Unit of Measurement	Number	Number
Required or Recommended	Recommended	Recommended
Definition	Number of policies set up to promote climate neutrality	Number of people involved in participatory process set up during the design and implementation of the climate city contract action plan process.
Source	Adapted from PHUSICOS (Grant Agreement no. 776681) in: European Union (2021c) *Evaluating the Impact of Nature-based Solutions* - Appendix of Methods pg. 843	PHUSICOS (Grant Agreement no. 776681) In: European Union (2021c) *Evaluating the Impact of Nature-based Solutions* - Appendix of Methods pg.852)
Calculation Formula	Number of policies that the city has set up to promote climate neutrality, deduced by publicly available city council resolutions from the baseline year.	Total number of people involved during meetings for the co-creation or co-design of projects on social innovation and climate neutrality.

4.2.2.2 Use Case Examples

Policy support for promoting Climate neutrality

The indicator will be equal to the whole number of policies that the city has adopted to promote Climate Neutrality, deduced by publicly available city council resolutions from the baseline year.

This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

Citizen involvement in co-creation/co-design of climate neutrality actions

This indicator will be equal to the whole number of people involved in participatory process set up during the design and implementation of the climate city contract action plan process. Municipalities maintain records of the number of citizens involved in face-to-face meetings or other activities. Evaluation of citizen engagement should take into account not only direct/face-to-face interactions between citizens and decision-makers,but should also account for online (internet- or app/smartphone-based) engagement. Software providers and/or platform hosts can provide metrics related to the number of unique visitors for use in calculating digital citizen engagement.

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4.2.3 Social Innovation

Social innovation is widely acknowledged to play an important role in the transformation towards climate-neutrality. Social innovation enables collaborative and people-centred practices and solutions to complex challenges as it activates the ecosystem by fostering partnerships and co-creation toward lowering GHG emissions. An innovation is therefore social when it is socially accepted and diffused in society or certain sub-areas and ultimately becomes institutionalised as new social practice (Howaldt and Hochgerner, 2018). However, as social innovation is not only a result, but also a change process, it is crucial to be able to assess and deeply understand the progress made on the path to climate neutrality, analyse achievements and enable learning for all local stakeholders as well as for other cities. Therefore, a comprehensive list of evaluation questions and indicators on social innovation have been described in NZC Deliverable 2.7 (POLIMI), based on several evaluation frameworks (such as RESINDEX: Regional Social Innovation Index (Sinnergiak 2013); SIMRA: Innovative methods to assess social innovation and its impacts in marginalised rural areas (Secco et al. 2020); EU POLIS: Integrated NBS-based Urban Planning Methodology for Enhancing the Health and Well-Being of Citizens (EU-Polis 2021); NBS: Evaluating the Impact of Nature-based Solutions - Appendix of Methods) as well as by mapping 30 different social innovation urban projects for climate neutrality, described in NZC Deliverable 9.1. The following set of indicators are a selection of key social innovation outcome indicators for impact monitoring. Each indicator is related to specific social innovation actions as described in NZC Deliverable 9.3 and related publications (Bresciani et al. 2023). A comprehensive catalogue of social innovation indicators from which cities can select the most suitable measures for specific readiness levels and projects, is provided in Appendix B.

4.2.3.1 Indicator Set

Table 18 Social Innovation Indicator Set 1

Indicator Title	Skills and Capacity Building – Social Innovation Experts	Skills and Capacity Building - Social Innovation skills development activities
Unit of Measurement	# Number	# Number
Required or Recommended	Recommended	Recommended
Definition	Total Number of people participating to the city' transition team/task force, with expertise on social innovation for climate sustainability, including public administration employees and other professionals with skills related to social innovation or co-creation (i.e., public officials who participated to social innovation for climate neutrality training, professionals from university centers focusing on social innovation, professionals from social innovations consultancies, etc.)	Total number of people involved in capacity building activities (i.e., workshops/awareness campaigns for increasing awareness of social innovation for climate neutrality to the public administration, citizens, urban stakeholders, etc.)
Source	Mureddu, F., Bresciani, S. & Rizzo, F. (2022). *Report on Indicators & assessment methods for social innovation action plans*. NetZeroCities D2.7.	Mureddu, F., Bresciani, S. & Rizzo, F. (2022). *Report on Indicators & assessment methods for social innovation action plans*. NetZeroCities D2.7.
Calculation Formula	The total number of experts in social innovation in the transition team: this information could be acquired by assessing the number of experts of	Total number of people involved in capacity building activities – this information could be acquired from registration lists.

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Indicator Title	Skills and Capacity Building – Social Innovation Experts	Skills and Capacity Building - Social Innovation skills development activities
	social innovation in the transition team and by evaluating a y' tendering and procurement framework.	

Table 19 Social Innovation Indicator Set 2

Indicator Title	Empowerment and Inclusion – Inclusion and Collaboration	Funding for Social Innovation initiatives for climate neutrality
Unit of Measurement	# Number	# Number (euros)
Required or Recommended	Recommended	Recommended
Definition	How many new social enterprises or social innovations (networks/partnerships) have been established in the city to tackle climate neutrality thanks to the co-creation platforms established by the public administration?	Total Amount of funding dedicated to the city's Social Innovation initiatives (for training, for social innovation business seeding, for platforms, etc.) per category: philanthropy, crowdfunding, social bonds, cross-sector partnerships, change in ownership, platform for attracting investors, in-kind donations, hours of volunteering, others.
Source	Mureddu, F., Bresciani, S. & Rizzo, F. (2022). Report on Indicators & assessment methods for social innovation action plans. NetZeroCities D2.7.	Mureddu, F., Bresciani, S. & Rizzo, F. (2022). Report on Indicators & assessment methods for social innovation action plans. NetZeroCities D2.7.
Calculation Formula	The information can be obtained from the cities' initiatives registry.	Information could be extracted from a City's Yearly Budget.

4.2.3.2 Use Case Examples

The evaluation of Social Innovation based on activities, outputs and outcomes has been applied to evaluate 11 cases (Spain, Finland, Netherlands, Italy, Switzerland, Austria, Tunisia, etc.) within the EU-funded project SIMRA (Social Innovation in Marginalized Rural Area, GA No 677622 D.5.2 and D5.3). A similar approach can be adapted to cities: municipalities collect data by tracking participation in initiatives and through experts' opinions.

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4.2.4 Social Justice

Social Justice addresses how benefits and negative impacts are distributed amongst the citizens of a society equally. Meaning no individual or group of people is benefited or negatively impacted through certain rules and policies more than others. Since identifying what is good and bad is difficult, it is often determined by the unemployment rate or the inequity of incomes. This starts with the lack of making a living wage, to an inequity in pay amongst certain community members. The underlying idea is that all citizens of the same society are treated equally (Miler (1999) p. 3-5).

In this case the gini coefficient is used. It calculates a countries deviation from a completely equal distribution of income ranging from 0 (perfect equality) to 100 (complete inequality). It is based on the cumulation of the population in ratio to the cumulative income (eurostat.at).

The Gini index, or Gini co-efficient, measures income distribution across a population. Developed by Italian statistician Corrado Gini in 1912, it often serves as a gauge of economic inequality, measuring income distribution or, less commonly, wealth distribution among a population.

4.2.4.1 Indicator Set

Table 20 Social Justice Indicator Set

Indicator Title	GINI coefficient
Unit of Measurement	#
Required or Recommended	Recommended
Definition	The Gini coefficient measures the inequality among values of a frequency distribution, such as levels of income. A Gini coefficient of 0 reflects perfect equality, where all income or wealth values are the same, while a Gini coefficient of 1 (or 100%) reflects maximam inequality among values.
Source	Informed by Eurostat (2022), *Living conditions in Europe - income distribution and income inequality.*
Calculation Formula	Gini Coefficient = A / (A+B) Where A = area where 'A' is the area above the Lorenz Curve and 'B' is the area below. A Lorenz curve is a graphical representation of the distribution of income or wealth within a population. A Lorenz curve graph demonstrates percentiles of the population against cumulative income or wealth of people at or below that percentile.

4.2.4.2 Use Case Examples

Eurostat (2022) have published an online article based on Data extracted in November 2022. The article is titled, '*Living conditions in Europe - income distribution and income inequality'.* With respect to the Gini Coefficient, it provides a section on '*Income inequality as measured by Gini coefficient above the EU average in 11 Member States*'. It describes therein that the Gini coefficient gives the extent to which the distribution of income within a country deviates from a perfectly equal distribution. A Gini value of 100 % means that only one person receives all the income in the country, while a Gini value of 0 % means that income is distributed equally across the population. In 2021, the Gini coefficient for the EU was 30.1 %. In 2021, the highest levels of inequality in terms of disposable income in the EU were

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experienced in Bulgaria (39.7 %), Latvia (35.7 %), Lithuania (35.4 %) and Romania (34.3 %). On the other hand, among the EU Member States, income was most equally distributed in Slovenia (23.0 %) and Slovakia (20.9 %, 2020 data).

The Gini Coefficient can be applied to Cities as it is an important tool for analyzing income or wealth distribution, however, it should not be mistaken for an absolute measurement of income or wealth. It should be noted that,

1. The Gini Coefficient is a statistical measure that calculates inequality.
2. It measures inequality by measuring the distribution of income across the City (in this case).
3. Although the Gini coefficient measures wealth inequality, it doesn't measure or factor in overall wealth.

A high-income City and a low-income City can have the same Gini co-efficient, as long as incomes are distributed similarly within each.

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4.2.5 Social Cohesion, Gender, Equality, Equity

Definitions of "vulnerable" and "under-represented" groups in society vary somewhat, but in general the following groups can be considered vulnerable to discrimination and/or under-represented:

- Women and girls
- Children
- Refugees
- Internally displaced persons
- Stateless persons
- National minorities
- Indigenous peoples
- Migrant workers
- Disabled persons
- Elderly persons
- HIV positive persons and those suffering from AIDS
- Roma/Gypsies/Sinti
- Lesbian, gay, bisexual, transgender, queer, and differently gendered people (LGBTQ+)

Particular effort is necessary to ensure that these groups receive equal representation and opportunity to become involved in climate neutrality projects. Specifically engaging vulnerable and/or under-represented groups in climate neutrality projects enhances social cohesion and diversity whilst tapping into underdeveloped social capital.

4.2.5.1 Indicator Set

Table 21 Social Cohesion, Gender, Equality, Equity Indicator Set

Indicator Title	Inclusion of different social groups
Unit of Measurement	Likert (number)
Required or Recommended	Recommended
Definition	"The extent to which the NZC project has led to the increased participation by groups of people who are typically not well represented in the society." (NBS Appendix of methods pg. 920).
Source	European Union (2021c), *Evaluating the Impact of Nature-based Solutions - Appendix of Methods*. Pp.920. Also informed by: Bosch, P., Jongeneel, S., Rovers, V., Neumann, H.-M., Airaksinen, M., & Huovila, A. et al. (2017) *CITYkeys list of city indicators.*
Calculation Formula	5-point Likert scale (calculation of the mean)

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4.2.5.2 Use Case Examples

Inclusion of different social groups

Definitions of “vulnerable” and “under-represented” groups in society vary somewhat, but in general the following groups can be considered vulnerable to discrimination and/or under-represented:

- Women and girls
- Children
- Refugees
- Internally displaced persons
- Stateless persons
- National minorities
- Indigenous peoples
- Migrant workers
- Disabled persons
- Elderly persons
- HIV positive persons and those suffering from AIDS
- Roma/Gypsies/Sinti
- Lesbian, gay, bisexual, transgender, queer, and differently gendered people (LGBTQ+)

Particular effort is necessary to ensure that these groups receive equal representation and opportunity to become involved in NBS projects. Specifically engaging vulnerable and/or under-represented groups in NBs projects enhances social cohesion and diversity whilst tapping into underdeveloped social capital.

The participation of vulnerable or traditionally underrepresented groups in Climate Neutrality related projects or specific measures can be qualitatively assessed using a five-point Likert scale:

Not at all – 1 — 2 — 3 — 4 — 5 — Excellent

1. Not at all: the project has not increased participation of groups not well represented in society.
2. Poor: the project has achieved little when it comes to participation of groups not well represented in society.
3. Fair: the project has somewhat increased the participation of groups not well represented in society.
4. Good: the project has significantly increased the participation of groups not well represented in society.
5. Excellent: Participation of groups not well represented in society has clearly been hugely improved due to the project.

Information used to evaluate the performance of a particular NBS project with regard to the participation of vulnerable or traditionally under-represented groups can be obtained from project documentation and/or interviews with the project leaders and stakeholders (including representatives of the groups targeted).

The indicators have been used in the EU-funded project CONNECTING Nature in 11 European cities. (for more details: Grant Agreement No 730222 - Dumitru, A, et al. (2019) Deliverable 1.1). A questionnaire with the validated scales is administered to citizens through online media and in-persona data collection.

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4.2.6 Functioning of Democratic Institutions

The percentage of the eligible voting population that voted in the last municipal election is an indicator of the public's level of participation and degree of interest in local government (ISO/DIS 37120, 2013).

The vast majority of analysts, consider a high voter turnout to be preferable to a low turnout because it means that the government will more likely reflect the interests of a larger share of the population. Low voter turnout implies that the democratic system may not be reflecting the interests of all citizens.

However, it should be noted that this indicator will only reveal the level of participation within the democratic institution, not the level of satisfaction of the population. In some cases, high rates of participation will mean that the population is not satisfied with its local government's leadership and actions.

4.2.6.1 Indicator Set

Table 22 Functioning of Democratic Institutions Indicator Set

Indicator Title	Voter participation
Unit of Measurement	% of people
Required or Recommended	Recommended
Definition	% of people that voted in the last municipal election as share of total population eligible to vote.
Source	Bosch, P., Jongeneel, S., Rovers, V., Neumann, H.-M., Airaksinen, M., & Huovila, A. et al. (2017) *CITYkeys list of city indicators.*
Calculation Formula	The voter participation in the last municipal election shall be calculated as the number of persons that voted in the last municipal election (numerator) divided by the city population eligible to vote (denominator). The result shall then be multiplied by 100 and expressed as a percentage: (People who voted/total voting population) *100

4.2.6.2 Use Case Examples

For instance, if a city has a population of 1,000,000 and 300,000 people voted in a local election, the calculation would be carried out as follows:

300,000/ 1,000,000 = 0.30 * 100 = 30%

Or in other words, there was a 30% voter participation in the election.

It should be noted that in countries where voting is mandatory, the percent of votes (ballots) that are not blank or spoiled shall be reported. This will indicate the share of positive voter participation.

There is a distinction between eligible to vote and registered to vote. In some countries people have to register (actively) in order to be allowed to vote. In all other countries, eligible and registered voters are one and the same. This should also be noted.

The strength of this is an absolute indicator which reflects the level of political participation. Its weaknesses is that determining the underlying influences of declining voter turnout rates can be difficult. A low turnout may be due to disillusionment or indifference, or even complacent satisfaction with the way the City is being governed. Conversely, a high turnout rate may reflect compulsory voting laws (as in Australia and Belgium) or coercion.

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4.2.7 Behavioural Change Towards Low Carbon Lifestyle and Practice

The behavioural change towards a low carbon lifestyle represents the awareness an acceptance citizens have for more sustainable changes. This relates to all sectors from energy to transport and expenditure, yet the decrease in energy consumption is the most important.

These indicator sets should indicate behavioural change towards energy consumption, mobility and household expenditure, as well as an overall understanding of environmental behaviour in a society. They can thereby give an understanding whether the measures implemented, work and are accepted by the community.

The data of these indicators are easy to understand since they are easily collectable and measurable. Yet the implication of the numbers still must be contextualized.

4.2.7.1 Indicator Set

Table 23 Behavioural Change Towards Low Carbon Lifestyle and Practice Indicator Set

Indicator Title	Energy consumption per household	Modal share of green transport modes (biking, walking and public transport)
Unit of Measurement	kWh	%
Required or Recommended	Recommended	Recommended
Definition	A measured trend of the energy a household consumes in Kwh. Comparisons can be made on a quaterly or yearly basis.	An increase in the shares of walking, biking and public transport indicates that the mobility behaviour of the local population has changed and that the preference for climate friendly mobility options has risen. The transport modes walking, biking and public transport are summarized as green transport modes because they cause no (walking and biking) greenhouse gas emissions, or at least significantly less (public transport) greenhouse gas emissions than the transport modes private motor cars or motorbikes. The indicator can be defined as the average number of trips per day that an inhabitant of the city does walking, biking or going by public transport, expressed as a percentage of the average total number of trips per inhabitant and day.
Source	N/A	NA
Calculation Formula	A formula is provided below, however, we have assumed that all mission cities will have access to microcensus data on the energy consumption of households. Alternatively, this information could be obtained through metred data, energy	$MS_{green} = \frac{T_w + T_b + T_{train} + T_{bus} + T_{tram}}{T_{total}} x\ 100$ $Where:$ $T_w = Walking\ trips\ per\ capita\ and\ day$ $T_b = Bike\ trips\ per\ capita\ and\ day$

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Indicator Title	Energy consumption per household	Modal share of green transport modes (biking, walking and public transport)
	bills or energy companies directly: Multiply the power in kW by the hours household devices are used per day, per week or per month. However, this information could acquired through metred data.	T_{train} = *Train trips per capita and day* T_{bus} *Bus trips per capita and day* T_{tram} = *Tram trips per capita and day* T_{total} = *Total trips per capita and day*

4.2.7.2 Use Case Examples

<u>Modal Share</u>

In 2019, the inhabitants of Happy City did on the average 3.2 trips per day. 40% of all trips were done with private motor cars and bikes, 15% of the trips were done with public transport, 10% were walking trips and another 10% were done by bike. The remaining 25% were multi modal trips, of which 15% included the use of cars and motorbikes, while 10% included green transport modes (walking, biking and public transport) only.

To calculate the share of green transport modes in the baseline year, the public officer in charge made the following calculation: Modal share of public transport (15%) + Modal share of walking (10%) + Modal share of biking (10%) + multimodal transport trips involving green transport modes only (10%) = Share of green transport modes (45%).

In 2024, Happy City reports for the first time on their progress to the NetZero Cities Platform. While preparing the report, the officer in charge finds out that the share of public transport has risen from 15% to 17%, and the share of biking from 10% to 13%. The share of green transport modes is now 50%, thus Happy City reports and increase of 5% compared with the baseline year.

In 2026, Happy City reports for the second time against the baseline. Now, walking and green multimodal trips have risen by 5% each. The share of green transport modes is now at 60%, and Happy City reports an increase of 5% against the baseline.

<u>Energy Consumption per Household</u>
It is assumed that all mission cities will have access to microcensus data on the energy consumption of households. Alternatively, this information could be obtained through metred data, energy bills or energy companies directly:

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4.3 Digitalisation and Smart Urban Technology

The transition of a city to climate neutrality not only holds the promise of addressing climate change but also offers significant potential to foster the introduction and market uptake of digital technology and smart city solutions. This dual approach can yield multiple benefits for urban environments and their inhabitants.

This transition is likely to support the rollout of low-carbon technology, which is essential for decarbonizing energy and transportation systems. Many of these technologies are rooted in the digital realm, where innovation plays a crucial role. For example, the deployment of smart meters can significantly enhance the energy efficiency of buildings. These devices enable real-time monitoring of energy consumption, allowing for the identification of energy-saving opportunities. Furthermore, digital technology can empower building energy management systems to not only reduce the energy demand of buildings through better control but also optimize the utilization of locally generated renewable energy sources.

The pursuit of climate neutrality goes hand in hand with sustainable economic growth and the creation of green jobs. This emphasis on sustainability can stimulate investments in digital technologies and smart city solutions. Initiatives such as renewable energy infrastructure, electric vehicle charging networks, and energy-efficient building systems all require advanced digital tools and IoT technology. The prospect of a growing green economy can attract private sector investments in digitization, as it aligns with the sustainability objectives of cities.

In essence, the journey towards climate neutrality not only addresses environmental concerns but also provides a fertile ground for the growth of digitization and the uptake of digital smart city solutions. The interplay between these two goals not only fosters sustainability but also enhances the quality of life and economic prospects in urban environments.

4.3.1 Green ICT and Smart Metering

The OECD (2020) defines smart cities as “cities that leverage digitalisation and engage stakeholders to improve people’s well-being and build more inclusive, sustainable and resilient societies”. Such considerations should also be taken into account and seen as important to establishing a climate neutral city. Nonetheless, it should be noted that there is no guarantee that all smart city initiatives automatically improve everyone’s well-being. In some instances, digitalisation may bring about challenges and threats, including privacy risks, regulatory challenges and widening inequalities.

With respect to smart metering, data-collection networks and infrastructure allow cities to build networks between local government departments and relevant external agencies or private sector partners to collate datasets on energy and water among other important city services. Ultimately, smart city measurement enhances accountability and helps citizens monitor how governments deliver on their commitments.

For instance, smart energy meters can help optimise energy consumption, thereby decreasing GHG emissions and helping people save money on their energy bills at the same time. Cities would benefit enormously from aggregated and anonymised energy data on monthly consumption per building. They could use it to support the energy transition and optimise consumption. Digital innovation is a means to fundamentally render urban services more efficient. In consideration of same, the indicator set below aims to calculate the level of smart metering within cities with respect to energy and water, as well as the related impact of same.

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4.3.1.1 Indicator Set

Table 24 Green ICT and Smart Metering Indicator Set

Indicator Title	% of households and buildings with reduced energy consumption as a consequence of installing smart energy metres	% of households and buildings with reduced water consumption as a consequence of installing smart water meters	% of municipal buildings equipped with building energy management systems
Unit of Measurement	% of households	% of households	% of public buildings
Required or Recommended	Recommended	Recommended	Recommended
Definition	A smart meter is an electronic device that records information—such as consumption of electric energy and communicates the information to the consumer and relative suppliers. This indicator intends to monitor the impact of/and related behavioural change in energy consumption following the installation of a smart energy meter in a household or building. Subsequently it also useful for gauging the possibility of carrying out analysis and offering better and more efficient city services in real-time.	A smart meter is an electronic device that records information—such as consumption of water and communicates the information to the consumer and relative suppliers. This indicator intends to monitor the impact of/and related behavioural change in water consumption following the installation of a smart water meter in a household or building. Subsequently it also useful for gauging the possibility of carrying out analysis and offering better and more efficient city services in real-time.	The indicator counts the number of municipal buildings equipped with building energy management systems. Public buildings are defined as non-residential buildings (e.g. office buildings, schools, fire stations etc). that are owned by the city. Building energy management systems (BEMS) are defined as "integrated building automation and energy management systems, utilizing IT or ICT, intelligent and interoperable digital communication technologies promoting a holistic approach to controls and providing adaptive operational optimization." (Yang et al. 2017)
Source	Informed by OECD (2020) *Measuring Smart Cities' Performance, Do Smart Cities Benefit Everyone*. Aggregate data could be provided by energy and utility suppliers.	Informed by OECD (2020) *Measuring Smart Cities' Performance, Do Smart Cities Benefit Everyone.* Aggregate data could be provided by water and utility suppliers.	Yang, T., Clements-Croome, D., Marson, M., 2017. Building Energy Management Systems. In: Abraham, M.A. (Ed.), *Encyclopedia of Sustainable Technologies*. Elsevier, pp.291–309.

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Indicator Title	% of households and buildings with reduced energy consumption as a consequence of installing smart energy metres	% of households and buildings with reduced water consumption as a consequence of installing smart water meters	% of municipal buildings equipped with building energy management systems
Calculation Formula	Total no. households and buildings with reduced energy consumption following the installation of smart energy meters in year B (comparison year) divided by total number households and buildings prior to the installation of smart energy metres during year A (baseline year) multiplied by 100.	Total no. households and buildings with reduced water consumption following the installation of smart energy meters in year B (comparison year) divided by total number households and buildings prior to the installation of smart water metres during year A (baseline year) multiplied by 100.	Total no.of municipal buildings equipped with building energy management systems divided by total number of municipal buildings prior to the installation of building energy management system during year A (baseline year) multiplied by 100.

4.3.1.2 Use Case Examples

<u>% of households and buildings with reduced energy consumption as a consequence of installing smart energy metres</u>

The purpose of this monitoring is to demonstrate the energy performance of the implementation area. For instance, in a hypothetical case, if 10,000 households and buildings installed smart energy meters in 2024, and of those households and buildings following a recording of their energy consumption over a year's time, 7,500 reduced their overall energy consumption, the calculation would be as follows:

7,500 (households and buildings with reduced energy consumption)/ 10,000 (total no. households and buildings that installed smart energy metres) = 0.75

0.75 x 100 = 75 or 75%

Therefore 75% of households or buildings that installed smart energy metres reduced their overall energy consumption.

<u>% of households and buildings with reduced water consumption as a consequence of installing smart water meters</u>

The purpose of this monitoring is to demonstrate the efficiency of water consumption of the implementation area. For instance, in a hypothetical case, if 10,000 households and buildings installed smart water meters in 2024, and of those households and buildings following a recording of their water consumption over a year's time, 7,500 reduced their overall water consumption, the calculation would be as follows:

7,500 (households and buildings with reduced water consumption)/ 10,000 (total no. households and buildings that installed smart water metres) = 0.75

0.75 x 100 = 75 or 75%

This project has received funding from the H2020 Research and Innovation Programme under the grant agreement n°101036519.

Therefore 75% of households or buildings that installed smart water metres reduced their overall energy consumption.

% of municipal buildings equipped with building energy management systems

In an effort to promote energy efficiency and sustainability, a NetZeroCities Mission City aims to track and improve the energy management of its municipal buildings. They have adopted the "Percentage of Municipal Buildings Equipped with Building Energy Management Systems" as an important indicator to measure progress. This indicator will help assess the extent to which municipal buildings are adopting energy-saving technologies.

Data Collection

- Baseline Year (Year A): The city identifies a baseline year, e.g., 2018, to assess the starting point of energy management in municipal buildings. They count the total number of municipal buildings as of this year.
- Year of Assessment**: For the current year, the city assesses the number of municipal buildings that have been equipped with BEMS.

Calculation Formula

The formula for calculating the Percentage of Municipal Buildings Equipped with Building Energy Management Systems is as follows:

- Percentage of Buildings with BEMS = (Number of Municipal Buildings with BEMS / Number of Municipal Buildings in the Baseline Year) * 100
- Number of Municipal Buildings with BEMS: Count of municipal buildings that have been equipped with BEMS during the year of assessment.
- Total Number of Municipal Buildings in the Baseline Year: The total count of municipal buildings as of the baseline year (Year A).

Results

For example, in the baseline year (Year A), there were 100 municipal buildings in the city. In the current year, 2023, 25 of these buildings have been equipped with BEMS. Using the formula:

- Percentage of Buildings with BEMS = (25/100) *100 = 25%.

This means that 25% of municipal buildings have adopted energy management systems. By tracking this indicator, the city can assess its progress in adopting energy-efficient technologies in its public buildings. An increasing percentage indicates a positive trend toward improved energy management and sustainability.

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4.3.2 EGovernment

According to the OECD (2020) smart city measurement enhances accountability and helps citizens monitor how governments deliver on their commitments. Digital technologies can improve citizen engagement through e-government services and civic technology to facilitate access to information, take better and informed decisions, and express opinions through online platforms, petitions and voting. The OECD (2019) note that across OECD Member countries, the use of digital government services has tripled since 2006, with around 36% of OECD citizens submitting forms via public authorities' websites in 2016. While ESPON (2017) highlights that across the European Union, the digitalisation of services has somewhat or even substantially reduced operating costs for 85% of cities. Furthermore, according to ESPON (2017), the results of a survey including 136 responses from all the EU Member States highlights that,

- 91% of city services have improved as a result of digitalisation.
- 39% of cities saw a substantial increase in uptake of specific services as a result of digitalisation.
- 68% use the data gathered from the use of digitalised service to improve services or in decision making processes.
- 1 in 3 Cities have a seen a substantial reduction in operating costs.
- The digitalisation of services has resulted in a reduction of staffing for 3 in 5 cities.

In short, the potential benefits of digitalisation of for a city include:

- Modernisation of the city's services.
- Increase internal efficiency.
- Improve citizen experience.
- Facilitate the access to information provided to the citizens.
- Increase transparency.
- Expanding the coverage of existing services.
- Provide new services that would not be feasible otherwise.

Therefore, the relevant indicator provided below aims to account for the number of additional city services provided online as a consequence of the development and implementation of a CCC AP, which in turn should improve and shape a cities EGovernment model.

With respect to better Business to Government (B2G) data sharing, Eurocities (2021) describes the process as a collaboration in which a company or other private organisation makes available its data (or insights) to the public sector (local, regional, national or EU) for a public interest purpose. Sharing data in this way can bring many benefits, which include:

- data on traffic flows can give insights into mobility challenges and the economic development of cities.
- data from sensors in cities can provide insights to predict tourist inflows or estimate pollution, and provide real time information and data on transportation and cargo.

It should be noted that such data collaboration exercises should take place in a secure, privacy-preserving, sustainable and ethical way.

With respect to the above, the B2G indicator presented is intended to capture number of business to government data sets shared as a consequence of the development and implementation of a CCC AP, which in turn should improve and shape a cities EGovernment model.

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4.3.2.1 Indicator Set

Table 25 EGovernment Indicator Set

Indicator Title	% of city services available online	Improvement in online government services
Unit of Measurement	% of total services	Likert Scale
Required or Recommended	Recommended	Recommended
Definition	The percentage of city services available online as a consequence of the CCC AP development and implementation.	The extent to which access to online services provided by the city was improved by the project.
Source	Informed by OECD (2020) and ESPON (2017).	Bosch, P., Jongeneel, S., Rovers, V., Neumann, H.-M., Airaksinen, M., & Huovila, A. et al. (2017) *CITYkeys list of city indicators.*
Calculation Formula	Total # number city services available online in year B (comparison year) divided by total number of online services prior to the development and implementation of a CCC AP during year A (baseline year) multiplied by 100.	Likert scale: No improvement – 1 — 2 — 3 — 4 — 5 — Very much improved. 1. Not at all: access to online services was not at all improved. 2. Poor: there was little improvement of access to online services, such as a basic municipal web site. 3. Somewhat: there was some improvement of access to online services, such as the possibility to schedule appointments online 4. Good: a sufficient improvement of access to online services, such as reporting minor issues to the police (i.e. passport loss, stolen goods). 5. Excellent: access to online services were extensively improved, including open data platforms.

4.3.2.2 Use Case Examples

<u>% of city services available online</u>

With respect to the % of city services online indicator this is intended as means to capture the impact the development and implementation CCC Action Plans will have with respect to a city's online services, dataset development and use.

Calculating the number of newly available services and datasets during the development and implementation of CCC APs is a means to capture progress towards Climate Neutrality, Smart Cities and Digitalisation. The more services become available the better and more accurate the measures within CCC APs will be.

Examples of additional online services could include:

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- Council meetings whereby members of the public would be free to join, observe and participate.
- Demonstration and public participation sessions relating to new city plans and programmes.
- Submission of planning and development applications.
- Public review of planning and development applications within the city.
- Making appoints for administrative services such as change of address procedures, a new passport, etc.

Improvement in online government services

With respect to the improvement in online government services indicator, this would be measured using a Likert scale, as defined above. The drawback with such an approach is that results can be subjective.

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4.3.3 Access to Information

As alluded to above, the internet has proven to be an important enabler, not only for sharing information, but also for online services. Cities now also provide municipal services online. For instance, such as the possibility of making planning and development applications, and related consultation of documents and public submission opportunities. This is in addition to more administrative type services such as making an appointment for a new passport or reporting stolen property. Furthermore, improved data sets which are open for public use help inform decision making, policy development, and related action strategies.

With respect to the above, the indicators presented below attempt to capture both the number of open data sets published as a consequence of the CCC AP development process and its implementation, as well as the extent of the improvement in providing online government services.

4.3.3.1 Indicator Set

Table 26 Access to Information Indicator Set

Indicator Title	Business-to-government (B2G) data sharing
Unit of Measurement	# of Private Datasets Shared with the City/Local Authority.
Required or Recommended	Recommended
Definition	The number of business to government data sets shared as a consequence of the CCC AP development and implementation.
Source	Informed by EuroCities (2021).
Calculation Formula	Total # number of new datasets in absolute terms shared by businesses to the city/local authority as a consequence of the Climate Neutrality Action Plan development and implementation process.

4.3.3.2 Use Case Examples

It is likely that Cities will rely on a number of datasets in developing their action plans, as quality data allows for informed decision-making processes. With respect to the open dataset indicator, it is intended as means to capture the impact the development and implementation a CCC Action Plan will have with respect to dataset development and use. It is likely that cities will rely on a number of datasets in developing their action plans, as quality data allows for informed decision-making processes. Calculating the number of newly available datasets during the development and implementation of CCC APs is a means to capture progress towards Climate Neutrality. The more datasets become available the more accurate the measures within CCC APs will be.

Examples of Business to Government datasets shared could include:

- Number of passengers per mode of transport in a given month/year, including private means of transport, such as taxi trips and bookings, private bike and scooter share schemes, etc.
- Energy usage and trend data from energy companies and providers.
- Waste related data which monitors how a full waste bins our which can then inform waste collection routes, increase efficiency and reduce CO_2.
- Mobile operator data which could inform for example evacuation operations and increase effectiveness.

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4.3.4 Urban Data Platforms and Data Spaces

An Urban [Data] Platform': is *"(…) a logical city data architecture that brings together and integrates data flows within and across city systems in a way that exploits modern technologies (sensors, cloud services, mobile devices, analytics, social media etc). An urban platform provides the building blocks to enable cities to rapidly shift from fragmented operations to include predictive effective operations, and novel ways of engaging and serving city stakeholders; It has the potential to transform, in a way that is tangible and measurable, outcomes at local level (e.g. increase energy efficiency, reduce traffic congestion and emissions, create (digital) innovation ecosystems, efficient city operations for administrations and services".* (BSI 2017).

Various urban data platforms can play a critical role in collecting and disseminating information to improve city services and enhance the quality of life for residents. Such platforms and data spaces may therefore play an important role with respect to achieving climate neutrality within a city. In consideration of the above, the following indicators have been provided.

4.3.4.1 Indicator Set

Table 27 Urban Data Platforms and Data Spaces Indicator Set

<table>
<tr><th>Indicator Title</th><td>Usage of Urban Data Platforms</td><td>User Satisfaction with Urban Data Platforms</td></tr>
<tr><th>Unit of Measurement</th><td># Users / Day</td><td>User Satisfaction Score (Likert Scale)</td></tr>
<tr><th>Required or Recommended</th><td>Recommended</td><td>Recommended</td></tr>
<tr><th rowspan="2">Definition</th><td>This indicator assesses in a quantitative manner how intensely the urban data platforms operated by the city are used.</td><td>This indicator assesses in a qualitative manner how satisfied the end users are with the digital services provided by the city's urban data platforms.

User satisfaction should be captured by an online survey of end users. In this survey, a Likert scale of 5 steps shall be used, reach::

5 – Very satisfied with the services
4 – Somewhat satisfied
3 – Neutral
2 – Somewhat unsatisfied
1 – Very unsatisfied</td></tr>
<tr><td colspan="2">An Urban [Data] Platform': is "(…) a logical city data architecture that brings together and integrates data flows within and across city systems in a way that exploits modern technologies (sensors, cloud services, mobile devices, analytics, social media etc). An urban platform provides the building blocks to enable cities to rapidly shift from fragmented operations to include predictive effective operations, and novel ways of engaging and serving city stakeholders; It has the potential to transform, in a way that is tangible and measurable, outcomes at local level (e.g. increase energy efficiency, reduce traffic congestion and emissions, create (digital) innovation ecosystems, efficient city operations for administrations and services". (BSI 2017).</td></tr>
<tr><th>Source</th><td>Informed by:</td><td>Informed by:</td></tr>
</table>

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Indicator Title	Usage of Urban Data Platforms	User Satisfaction with Urban Data Platforms
	British Standards Insititute (BSI) (2017): *Rethinking the city:* *using the power of data to address urban challenges and societal change. A guide for city leaders*. Version 2.1a. London: BSI	British Standards Insititute (BSI) (2017): *Rethinking the city:* *using the power of data to address urban challenges and societal change. A guide for city leaders*. Version 2.1a. London: BSI
Calculation Formula	Average Users of Urban Data Platforms per Day = Average Users per Data Platform 1 + Average Users per Data Platform 2 + ... + Average Users per Data Platform N	User Satisfaction Score = [(Satisfaction Score for Data Platform 1 * Average Users per Data Platform 1) + (Satisfaction Score for Data Platform 2 * Average Users per Data Platform 2) + ... + (Satisfaction Score for Data Platform N * Average Users per Data Platform N)] / Total Average Users Where: - "Satisfaction Score for Data Platform 1" represents the average Likert scale score (1 to 5) for Data Platform 1 based on the user survey. - "Average Users per Data Platform 1" represents the average number of users per day for Data Platform 1 (calculated using the formula from the previous response). - Repeat the same structure for Data Platform 2, Data Platform 3, and any additional data platforms. - "Total Average Users" represents the sum of the average users per day for all data platforms in the city.

4.3.4.2 Use Case Examples

<u>Usage of Urban Data Platforms</u>

In a NetZeroCities Mission City, various urban data platforms play a critical role in collecting and disseminating information to improve city services and enhance the quality of life for residents. City officials want to understand the daily engagement and utilization of these data platforms to make informed decisions.

Data Platforms

- Data Platform 1: Smart Transportation System
- Data Platform 2: Public Health Information Hub
- Data Platform 3: Energy Consumption Tracker

Average Users per Data Platform

- Data Platform 1: 1,500 users
- Data Platform 2: 2,000 users

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- Data Platform 3: 1,200 users

Using the Formula

- Average Users of Urban Data Platforms per Day = 1,500 + 2,000 + 1,200
- Average Users of Urban Data Platforms per Day = 4,700 users

In this use case, the simplified formula allows city officials to determine the daily engagement of users with urban data platforms. The "N" signifies that you can include any other relevant data platforms, and the formula remains flexible to accommodate additional platforms as needed. This information is crucial for assessing the overall engagement with urban services, optimizing resource allocation, and enhancing the city's data-driven decision-making processes.

<u>User Satisfaction with Urban Data Platforms</u>

In NetZeroCities Mission City, the city administration has invested in various data platforms to enhance citizen services, ranging from public transportation to healthcare information. To gauge the effectiveness of these platforms, they decide to assess user satisfaction using a Likert scale in an online survey. The aim is to calculate an overall satisfaction score while considering the number of users for each platform.

Data Platforms

- Data Platform 1: Smart Transportation System
- Data Platform 2: Public Health Information Hub
- Data Platform 3: Energy Consumption Tracker

Satisfaction Survey Results:

- Data Platform 1: Average satisfaction score of 4.2 (on a Likert scale of 1 to 5)
- Data Platform 2: Average satisfaction score of 4.5
- Data Platform 3: Average satisfaction score of 3.8
- Data Platform N: (Average satisfaction score for any other relevant data platform)

Average Users per Data Platform (calculated as in the above use case):

- Data Platform 1: 1,500 users
- Data Platform 2: 2,000 users
- Data Platform 3: 1,200 users
- Data Platform N: (Average Users per any other relevant data platform)

Using the Formula

- Total Average Users = 1,500 + 2,000 + 1,200 + (Average Users per any other relevant data platform)
- User Satisfaction Score = [(4.2 * 1,500) + (4.5 * 2,000) + (3.8 * 1,200) + (Average Satisfaction Score for any other relevant data platform * Average Users for that platform)] / Total Average Users

Results

- After collecting satisfaction survey data and calculating the weighted satisfaction scores using the formula, the city administration finds that the User Satisfaction Score is 4.25 (on a scale of 1 to 5). This indicates that, on average, users are "somewhat satisfied" with the services provided by the urban data platforms in the city.
- The User Satisfaction Score provides valuable insights into the overall perception of citizens regarding the digital services offered by the city's data platforms. This information can guide improvements, resource allocation, and policy decisions to enhance user satisfaction and the quality of urban services.

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4.4 Economy

4.4.1 Investment in R&I

The Climate Neutral and Smart Cities Mission is currently one of the largest European research and innovation initiatives. It can be assumed that it will stimulate additional investment in research and innovation (R&I) from the private sector, as urban climate neutrality provides big market opportunities. On the other hand, this additional investment in R&I would grow the innovative and industrial capacity of cities. An increase in local R&I investment can therefore considered a potential co-benefit of the transition towards climate neutrality.

As described by Eurostat (2021) one of the key aims of the EU during the last few decades has been to encourage increasing levels of research investment, in order to provide a stimulus to the EU's competitiveness. In May 2021, the European Commission adopted a Communication on a Global Approach to Research and Innovation — Europe's strategy for international cooperation in a changing world (COM(2021) 252 final). This Communication underlines the EU's desire to play a leading role in supporting international research and innovation partnerships, while delivering innovative solutions that support green and digital solutions in line with the sustainable development goals. It engages the EU to promote resilience, prosperity, competitiveness, economic and social well-being.

4.4.1.1 Indicator Set

Table 28 Research Intensity Indicator Set

Indicator Title	Research intensity
Unit of Measurement	%
Required or Recommended	Recommended
Definition	This indicator corresponds to the R&D expenditure as percentage of city's GDP.
Source	Eurostat (2021), *R&D expenditure*.
Calculation Formula	Gross domestic spending on R&D is defined as the total expenditure (current and capital) on R&D carried out by all resident companies, research institutes, university, the government sector, and the private non-profit sector. in a City.

4.4.1.2 Use Case Examples

R&D expenditure is a basic measure that covers intramural expenditure, in other words, all expenditures for R&D that are performed within a statistical unit or sector of the economy. This can be applied at the City Level.

The main analysis of R&D statistics is by four institutional sectors of performance. These four sectors are:

- the business enterprise sector,
- the government sector,
- the higher education sector and,
- the private non-profit sector.

Gross domestic expenditure on R&D (GERD) is composed of expenditure in each of these four sectors. Expenditure data covers the research performed on the City territory, regardless of the source of funds; data are usually expressed in relation to GDP and this ratio is often referred to as R&D intensity.

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Taking a simple hypothetical case, if the GDP of a City was €1,000,000.00 and expenditure in R&D activities per sector was as follows:

- the business enterprise sector - €2,000
- the government sector - €1,500
- the higher education sector - €1,000
- the private non-profit sector - €500

Then the percentage calculation per sector would be as follows:

- the business enterprise sector – 2000/1,000,000 = 0.002 x 100 = 0.2%
- the government sector - 1,500/1,000,000 = 0.0015 x 100 = 0.15%
- the higher education sector - 1,000/1,000,000 = 0.001 x 100 = 0.1%
- the private non-profit sector – 500/1,000,000 = 0.0005 x 100 = 0.05%

The total expenditure calculation in R&D would be as follows:

- Total – 5,000/1,000,000 = 0.005 x 100 = 0.5%

To understand how this data may be useful in practicality Eurostat (2021) describes that the EU's R&D intensity changed between 2011 and 2021 in each of the four sectors of performance: the Business enterprise sector, the Government sector, the Higher education sector and the Private non-profit sector. Throughout this period, the majority of R&D expenditure was performed in the business enterprise sector, and its R&D expenditure rose from 1.27 % of GDP in 2011 to 1.5 % by 2021, an overall increase of 18.11 %. The second largest sector performing R&D was the higher education sector, whose R&D intensity increased by 0.02 percentage points between 2011 and 2021, with some fluctuations during this period and reaching 0.49 % of GDP in 2021. The R&D intensities of the two other sectors changed little over the period under consideration: in 2021 the R&D intensity of the government sector was 0.27 % of GDP compared with 0.26 % in 2011; and for the private non-profit sector it was 0.01 % of GDP in 2021, half of what was recorded in 2011.

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4.4.2 Number of Skilled Jobs and Rate of Employment

The creation of additional local jobs is a co-benefit created in a city during its transition towards net-zero emissions, because it can be expected that the massive investment needed to upgrade buildings and urban infrastructures will create a significant number of new jobs.

A shift to more public transportation could create more job opportunities within the transportation sector in the city. In addition, increased renovations have a positive effect on employment in the local construction sector. Jobs are created through the procurement of services or deployment of technologies, and this has additional direct and indirect benefits to the economy. Retrofitting hundreds of buildings requires significant increases in the number of people employed to do that work, with salaries and the multiplier benefits of their spending in the wider economy.

'Greening the economy' can boost job creation in areas directly connected to the environment such as conservation, waste, water and air quality. UNEP 2008 defines a green job as “work in environmental service activities that contribute substantially to preserving or restoring environmental quality. Specifically, but not exclusively, this includes jobs that help to protect ecosystems and biodiversity; reduce energy, materials, and water consumption through high efficiency strategies; de-carbonize the economy; and minimize or altogether avoid generation of all forms of waste and pollution.” Therefore, it is considered that a green job is relevant to the Climate Neutral ambition.

The youth unemployment rate is a key indicator for quantifying and analyzing the current labour market trends for young people (ISO/DIS 37120, 2013). Unemployed or underemployed youth are less able to contribute effectively to community and national development and have fewer opportunities to exercise their rights as citizens. They have less to spend as consumers, less to invest as savers and often have no “voice” to bring about change in their lives and communities. Widespread youth unemployment and underemployment also prevents companies and countries from innovating and developing competitive advantages based on human capital investment, thus undermining future prospects. Knowing the costs of non-action, many governments around the world do prioritize the issue of youth employment and attempt to develop pro-active policies and programmes. It is considered that a reduction of youth unemployment as consequence of Climate Neutrality Action, would be a co-benefit in in this regard.

4.4.2.1 Indicator Set

Table 29 Number of Skilled Jobs and Rate of Employment Indicator Set

Indicator Title	Green jobs	Youth unemployment rate
Unit of Measurement	% of jobs	% of people
Required or Recommended	Recommended	Recommended
Definition	Share of jobs related to environmental service activities that contribute substantially to preserving or restoring environmental quality	Percentage of youth labour force unemployed. Unemployed youth shall refer to individuals above the legal working age and under 24 years of age who are without work, actively seeking work in a recent past period (past four weeks), and currently available for work. Youth who did not look for work but have a future labour market stake (arrangements for a future job start) are counted as unemployed (International Labour Organization).

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Indicator Title	Green jobs	Youth unemployment rate
Source	N/A	IBosch, P., Jongeneel, S., Rovers, V., Neumann, H.-M., Airaksinen, M., & Huovila, A. et al. (2017) CITYkeys list of city indicators.
Calculation Formula	(Number of green jobs/Total number of jobs) * 100	Youth unemployment rate shall be calculated as the total number of unemployed youth (numerator) divided by the youth labour force (denominator). The result shall be multiplied by 100 and expressed as a percentage.

4.4.2.2 Use Case Examples

Green Jobs

A green job is any job that genuinely contributes to a more sustainable world (i.e. related to measuring, avoiding, reducing, limiting or removing environmental damages as well as the preservation of natural resources). The employing company or organization can either be in a 'green' sector (e.g. solar energy), or in a conventional sector, but making genuine and substantial efforts to green its operations.

For example, if a renewables company invested in wind and solar technology deployment hired 400 people in City with a population of 500,000, the calculation would be as follows:

400/ 500,000 = 0.0008 x 100 = 0.08%

Or in other words there would be a 0.08% increase in green jobs within the City due to the renewables company's recent hires.

Youth Unemployment

As an example, if the total number of unemployed youths is 5,000 and the population of the City 500,000, then the calculation would be as follows:

5,000/500,000 = 0.01 x 100 = 1%

Or in other words, the youth unemployment rate is 1%.

It should be noted that discouraged workers or hidden unemployed shall not be counted as unemployed or as part of the labour force. Not actively seeking work shall refer to people who have not taken active steps to seek work (i.e. job searches, interviews, informational meetings etc.) during a specified recent period (usually the past four weeks). Youth labour force shall refer to all persons above the legal working age and under 24 years of age, who are either employed or unemployed over a specified reference period.(ISO/DIS 37120, 2013).

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4.4.3 Economic Thriving

Urban climate neutrality is an excellent opportunity to gradually transform the local economy into a modern, resource-efficient and competitive economy, in other words to initiate a "Local Green Deal", to stimulate sustainable economic growth.

Gross domestic product, abbreviated as GDP, is a basic measure of a city's overall economic production. As an aggregate measure of production, GDP is equal to the sum of the gross value added of all resident institutional units (i.e. industries) engaged in production, plus any taxes, and minus any subsidies, on products not included in the value of their outputs. Gross value added is the difference between output and intermediate consumption. GDP is also equal to:

- the sum of the final uses of goods and services (all uses except intermediate consumption) measured in purchasers' prices, minus the value of imports of goods and services;
- the sum of primary incomes distributed by resident producer units.

4.4.3.1 Indicator Set

Table 30 Economic Thriving Indicator Set

Indicator Title	Gross Domestic Product
Unit of Measurement	€/cap
Required or Recommended	Recommended
Definition	City's gross domestic product per capita.
Source	Bosch, P., Jongeneel, S., Rovers, V., Neumann, H.-M., Airaksinen, M., & Huovila, A. et al. (2017) *CITYkeys list of city indicators.*
Calculation Formula	The total of consumer spending, plus business investment, and government spending, plus net exports (which is total exports minus total imports) / the population of the City.

4.4.3.2 Use Case Examples

The expenditure approach is the most commonly used GDP formula, which is based on the money spent by various groups that participate in the economy.

GDP = C + G + I + NX

- C = consumption or all private consumer spending within a country's economy, including, durable goods (items with a lifespan greater than three years), non-durable goods (food & clothing), and services.
- G = total government expenditures, including salaries of government employees, road construction/repair, public schools, and military expenditure.
- I = sum of a country's investments spent on capital equipment, inventories, and housing.
- NX = net exports or a country's total exports less total imports.

For instance, if a City with a population of 500,000 had the following expenditure, as per the formula outlined above, where:

- C - €10 billion or €10,000,000,000.00

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- G - €5 billion or €5,000,000,000.00
- I - €12 billion or €12,000,000,000.00
- NX - total exports of €15 billion or 15,000,000,000.00 – total imports of €5 billion or €5,000,000,000.00 = €10 billion or 10,000,000,000.00

The total is calculated at €42 billion or 42,000,000,000.00.

This is then divided by the population of the city of 500,000 or 1,500,000,000.00 to get the per capita figure,

€42,000,000,000 / 500,000 = 84,000

In other words, the GDP per capita would be €84,000 in this case.

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4.4.4 Adoption of Key Technologies

The transition towards climate neutrality will require a city-wide roll-out of certain key technologies at large scale. For example, it will be necessary to replace gas boilers as a source for domestic heat by heat pumps, or, instead, to connect homes to district heating systems, and these district heating systems must be decarbonized. Local renewable energy systems, like solar panels, and small-scale wind and water turbines, need to be deployed at scale, and vehicles with internal combustion engines must be replaced by electric vehicles or by vehicles using green hydrogen or other climate-friendly fuels as a source of energy.

As the large-scale adoption of these technologies is a precondition for reducing GHG emissions by 80%, it is important that cities identify the technologies key for their local transition pathways, define objectives for their deployment, and document these objectives in their CCC Action Plan. The below indicators will allow cities to track the progress towards meeting this objective.

4.4.4.1 Indicator Set

Table 31 Adoption of Key Technologies Indicator Set

Indicator Title	Adoption of key climate neutral technologies
Unit of Measurement	%
Required or Recommended	Recommended
Definition	This indicator measures the progress a city makes in the adoption of key climate neutral technologies. It is expressed as a percentage of the roll-out objective for the year of 2030, i.e. the year in which climate neutrality should be achieved. The key technologies and the respective targets must be specified in the CCC Action Plan of the City. The progress in each key technology should be reported separately.
Source	N/A
Calculation Formula	$AR_{kt} = \frac{A_{ry} - A_{by}}{A_{2030} - A_{by}}$ $Where:$ $AR_{kt} = Rate\ of\ adotopion\ of\ the\ key\ technology\ KT\ in\ the\ reporting\ years$ $A_{by} = Adoption\ (\#\ of\ solutions\ deployed) in\ the\ baseline\ year\ (usually\ 2019)$ $A_{ry} = Adoption\ (\#\ of\ solutions\ deployed) in\ the\ reporting\ year$ $A_{2030} = Adoption\ target\ (\#\ of\ solutions\ to\ be\ deployed)\ for\ 2030.$

4.4.4.2 Use Case Examples

Happy City has identified district heating as a key technology for achieving climate neutrality According to Happy City's CCC Action Plan, 80% of the households should be connected to the district heating system by 2030.

In 2024, Happy City needs to report their progress for the first time. The public officer calculates the adoption rate of key technologies in the following way: Happy City has 100,000 households. In the baseline year 2019, 50,000 of them were already connected to the district heating system. Between 2019 and 2024, another 10,000 households were connected. The indicator is calculated by subtracting the number of households connected from the number of households that should be connected by 2030

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(80,000 households – 50,000 households = 30,000 households), and then dividing the number of households that have been newly connected since the baseline year (10,000 households) by the above difference and expressing the result as a percentage (10,000 households / 30,000 households = 0.333 or 33.3%.

Two year later, in 2026, Happy City is invited to report a second time on the adoption of the district heating technology. In the meantime, another 5,000 households were connected to district heating. The adoption rate is then calculated by adding the 5,000 newly connected households to the number of households connected between the baseline year and the first reporting year 2024, then dividing the total by the target value for 2030 and expressing the result as a percentage (5,000 households +10,000 households = 15,000 households; 15,000 households / 30,000 households = 0.5 or 50.0%).

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4.4.5 Local Entrepreneurship and Local Businesses / Ventures

The number of businesses can inform a city's level of economic activity and economic performance. It provides one indication of the overall business climate in a jurisdiction, and attitudes towards entrepreneurship. Strong entrepreneurial activity is closely associated with a dynamic and growing economy. The number of businesses is also used to inform competitiveness of a city. (ISO/DIS 37120, 2013)

These indicators assess the number of new businesses created (including start-ups and Climate Neutral City Start-ups). An enterprise birth occurs when an enterprise (for example a company) starts from scratch and begins operations, amounting to the creation of a combination of production factors with the restriction that no other enterprises are involved in the event. An enterprise birth occurs when new production factors, in particular new jobs, are created.

Enterprise births do not include:

- dormant enterprises being reactivated within two years;
- new corporate entities being created from mergers, breakups, spin-offs/split-offs or the restructuring of enterprises or a set of enterprises;
- the entry into a sub-population resulting only from a change of activity.

4.4.5.1 Indicator Set

Table 32 Local Entrepreneurship and Local Businesses / Ventures Indicator Set

Indicator Title	Climate-Neutral City Start-ups	New businesses registered	Surviving number of new companies registered after year 3
Unit of Measurement	#/100,000	#/100,000	#/100,000
Required or Recommended	Recommended	Recommended	Recommended
Definition	Number of start-ups working on climate neutral cities solutions per 100,000 inhabitants.	Number of new businesses per 100,000 population.	Surviving number of new companies registered after year 3.
Source	Informed by: Bosch, P., Jongeneel, S., Rovers, V., Neumann, H.-M., Airaksinen, M., & Huovila, A. et al. (2017) *CITYkeys list of city indicators.* Refer to businesses registered indicator.	Informed by Bosch, P., Jongeneel, S., Rovers, V., Neumann, H.-M., Airaksinen, M., & Huovila, A. et al. (2017) *CITYkeys list of city indicators.*	N/A
Calculation Formula	(Number of new Climate Neutral companies registered/Total Population) x 100 000 inhabitants	(Number of new companies registered/Total Population) x 100 000 inhabitants	Surviving number of new companies registered after year 3, /Total Population) x 100 000 inhabitants.

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4.4.5.2 Use Case Examples

Climate-Neutral City Start-ups / New businesses registered

Eurostat (2013) describe that an enterprise birth occurs when an enterprise (for example a company) starts from scratch and begins operations, amounting to the creation of a combination of production factors with the restriction that no other enterprises are involved in the event. An enterprise birth occurs when new production factors, in particular new jobs, are created.

Enterprise births do not include:

- dormant enterprises being reactivated within two years;
- new corporate entities being created from mergers, break-ups, spin-offs/split-offs or the restructuring of enterprises or a set of enterprises;
- the entry into a sub-population resulting only from a change of activity.

These indicators can be calculated as follows:

For instance, if 1000 new Climate-Neutral City Start-ups registered in 2024 within a city of 500,000, the calculation would be as follows:

1000/ 500,000 = 0.002 x 100,000 = 200

Surviving number of new companies registered after year 3

For instance, if 1000 new Climate-Neutral City Start-ups registered in 2024 within a city of 500,000 people, 650 of these survive the third year (2027), the calculation would be as follows:

650/ 500,000 = 0.0013 x 100,000 = 130

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4.5 Finance and Investment

Finance is a significant piece of the puzzle for cities and their transition to Net Zero. As many cities are coming to realise, it is not necessarily possible to finance the entire transition through the municipal budget and cities therefore require commitments from the private sector as well as access to private institutional capital to help implement the transition.

Even when sufficient capital can be deployed from these potential sources, it is important that this funding is directed into the right projects and actions that will effectively facilitate the transition in an optimal way rather than unnecessarily deploying capital into low impact projects. Failure to do so could result in significant funds wasted on glamour projects and will be detrimental to a city's goals of significantly reducing emissions by 2030.

Cities are also required to maintain their fiscal stability and independence and should maintain a healthy balance sheet with manageable debt coverage to ensure this is the case. Failure to do so could result in running an uncontrollable deficit and even bankruptcy for the municipality.

The indicator set provided has been designed in order to measure the increased flows into climate action projects from both the public and private funding avenues, the effectiveness of these flows for combatting GHG emissions, and the stability of the city's finances as they implement their Net Zero transition.

4.5.1 Public Spending

Public spending is the most direct form of financing that cities have access to and will lead the way for financing the Net Zero transition. Over the period of this transition, it is hoped that a city's investment into climate actions should increase in absolute terms as well as in terms of the overall city budget. Similarly – to take into account growth of the city's population over the period – an indicator for public spending per capita is a useful measure to ensure a city continues to adequately invest as it grows. This metric is particularly significant for cities that have a strong annual growth rate.

4.5.1.1 Indicator Set

Table 33 Public Spending Indicator Set

Indicator Title	Capital Invested in Climate Action Projects	Budget Assigned to Climate Action Projects	Capital Invested in Climate Action Projects per Capita
Unit of Measurement	EUR million	% of City Budget	EUR thousand
Required or Recommended	Recommended	Recommended	Recommended
Definition	Capital invested by the municipality in specific climate actions	Allocation of the municipal budget to climate actions and projects as a percentage of the overall municipal budget	Capital invested by the municipality in specific climate actions, divided by the number of residents of the city as per latest estimates
Source	N/A	N/A	N/A
Calculation Formula	Annual Capital Invested in Climate Action Projects	Annual Budget Assigned to Climate Action Projects / Annual Municipal Budget	Annual Capital Invested in Climate Action Projects / Estimated Number of Residents of the City

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4.5.1.2 Use Case Examples

Capital Invested in Climate Action Projects

If the city has invested EUR 139m in projects specifically for climate action within the year 2023, this is the output for the indicator. The idea is to track this over time and for the amount of capital invested into climate actions to increase year over year.

Budget Assigned to Climate Action Projects

If the city has invested – as per the above – EUR 139m in projects specifically for climate action within the year 2023, and the over municipal budget is EUR 942m, then 139 / 942 = 14.7%. The idea is to track this over time and for this to increase as a percentage.

Capital Invested in Climate Action Projects per Capita

If the city has invested EUR 139m in projects specifically for climate action within the year 2023, and the population of the city is 245,342, the calculation is 139,000,000 / 245,342 = EUR 0.57k. The idea is to track this over time and for this to increase or – at the very least – remain in line over the transition period.

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4.5.2 External Financing

Cities cannot finance the transition to Net Zero on their own and may need to bolster their municipal budget with external financing from national investment funds, European funding (such as the European Investment Bank or European Bank for Regional Development), or private financial institutions such pension funds and asset managers. The external financing covered in this section relates to municipal borrowing or investments into projects (such as PPPs), not external funding via grants.

The funding and financing of climate action projects is of growing importance for all of the above organisations and cities should look to involve them in particular for largescale, multi-year projects with a significant upfront capital requirement (e.g. infrastructure). Measuring the growth of private sector funding is an important metric to track this transition over time.

4.5.2.1 Indicator Set

Table 34 External Financing Indicator Set

Indicator Title	Capital Invested in Climate Action Projects	Coverage of Climate Finance Gap
Unit of Measurement	EUR million	% of Capital Deficit Covered
Required or Recommended	Recommended	Recommended
Definition	Capital invested by external financing organisations into specific climate actions	Coverage of the annual climate capital deficit following municipal budget allocations
Source	N/A	N/A
Calculation Formula	Annual Capital Invested in Climate Action Projects from External Finance.	Annual External Finance in Climate Action Projects / Finance Gap between Required Investment and Municipal Spend.

4.5.2.2 Use Case Examples

Capital Invested in Climate Action Projects

If external financial organisations have invested EUR 28m in projects specifically for climate action within the year 2023, this is the output for the indicator. The idea is to track this over time and for the amount of capital invested into climate actions over time to increase year over year.

Coverage of Climate Finance Gap

If a city's target for investment into climate action projects in a year (as identified via their Investment Plan) is EUR 200m, and they have only invested EUR139m, there is a deficit of EUR 61m. If external financial organisations have invested EUR 28m in climate action projects in the year, they are covering 45.9% of the finance gap. 28 / (200 – 139). The idea is for this to be as close as possible to 100% or above. For municipalities that own corporations such as utilities, housing and transport networks, it may make sense to calculate one Coverage of Climate Finance Gap excluding these corporations, and another including the corporations.

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4.5.3 Capital Efficiency

Allocating public and private capital to dedicated climate actions is the first major hurdle for cities once they have developed their investment plans, but it is also important to ensure that the capital deployed is done so efficiently and provides demonstrable reduction in GHG emissions over time. Given cities have developed a GHG Inventory that can be monitored over time, it is possible for cities to see just how effective their investments into each project, sector and sub-sector have been.

This is crucial for ensuring capital is effectively utilised and can be a critical indicator for avoiding mismanagement or misdirection of funds into less effective, glamour projects which would be detrimental to a city's goals of significantly reducing emissions by 2030.

4.5.3.1 Indicator Set

Table 35 Capital Efficiency Indicator Set

Indicator Title	Emission Return on Invested Capital
Unit of Measurement	EUR m
Required or Recommended	Recommended
Definition	Capital invested per Kt CO2 reduced
Source	N/A
Calculation Formula	Total Capital Invested m / Kt CO2 Reduced

4.5.3.2 Use Case Examples

Emission Return on Invested Capital

If a city invests EUR 139m into climate action projects in 2023, and the 2024 calculated reduction of emissions is 181 Kt, the city is spending EUR 0.77m per Kt of realised carbon reductions. 139 / 181 = 0.77. The lower this figure is, the more efficiently capital is being deployed to combat GHG emissions in the city. This can be tracked annually but also over the whole transition period, and can be used as one of the criteria for climate action project selection or prioritisation. As well as tracking the city's EROIC, the calculation can also be used for external capital.

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4.5.4 Fiscal Responsibility

Although investment is required to realise the targeted emissions reductions of the city, it is important to spend within the municipalities means and not build up unsustainable levels of debt. Doing so could risk defaulting on payments or bankruptcy for the city. The below metric is provided as a basic indicator to ensure fiscal responsibility when implementing the climate actions within the city's portfolio.

4.5.4.1 Indicator Set

Table 36 Fiscal Responsibility Indicator Set

Indicator Title	Cost Coverage
Unit of Measurement	% of Costs Covered
Required or Recommended	Recommended
Definition	Coverage of Annual Financing Costs by the Annual Municipal Revenue
Source	N/A
Calculation Formula	(Annual Municipal Revenue from Projects / Annual Financing Costs Projects) * 100

4.5.4.2 Use Case Examples

Cost Coverage

If a city has generated project revenue of EUR 82m in 2023, and has annual financing costs for 2023 of EUR 23m, the Cost Coverage Ratio is If a city has annual financing costs of EUR 23m for 2023, and project revenue is EUR 82m for 2023, the Cost Coverage is 356%. (82 / 23) * 100. The idea is for this to be as high as possible with a view to increasing year on year. As a guideline, anything below 175% should be monitored carefully.

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4.6 Resource Efficiency

4.6.1 Waste Management and Efficiency

According to the waste hierarchy of the EC waste framework directive, the first priority in the waste sector is to minimise the amount of waste. The next steps in waste management are re-use, recycling, recovery and disposal. Landfilling is the least preferable option and should be limited to the necessary minimum.

4.6.1.1 Indicator Set

Table 37 Waste Management and Efficiency Indicator Set

Indicator Title	Recycling rate of municipal waste
Unit of Measurement	%
Required or Recommended	Recommended
Definition	The indicator 'Recycling rate of municipal waste (%)' measures the share of recycled municipal waste of the total municipal waste generation.
Source	European Commission (2022), *Green City Accord, Clean and Healthy Cities for Europe, GCA Mandatory Indicators Guidebook*, Version of 29 April 2022
Calculation Formula	Share of recycled municipal waste of the total municipal waste generation

4.6.1.2 Use Case Examples

For instance, in a hypothetical scenario, if a city produced 20 metric tonnes of municipal waste in 2024 and 2 tonnes of this was recycled that same year, the calculation would be as follows:

2/20 = 0.1 x 100 = 10%

Or 10% of municipal was recycled for the year 2024.

Eurostat describes that this indicator is part of the Circular Economy indicator set. It is used to monitor progress towards a circular economy on the thematic area of 'waste management'. Recycling rate of municipal waste gives an indication of how waste from final consumers is used as a resource in the circular economy. Municipal waste reflects mainly waste generated by the final consumers as it includes waste from households and waste from other sources that is similar in nature and composition to household waste. Although it accounts for around 10% of total waste generated in the EU, because of its heterogeneous composition the sound management of municipal waste is challenging. The recycling rate of municipal waste provides a good indication of the quality of the overall waste management system.

This indicator can be used to monitor compliance with the target included in the article 11.2 of the Waste Framework Directive. "*In order to comply with the objectives of this Directive, and move to a European circular economy with a high level of resource efficiency, Member States shall take the necessary measures designed to achieve the following targets: (a) by 2020, the preparing for re-use and the recycling of waste materials such as at least paper, metal, plastic and glass from households and possibly from other origins as far as these waste streams are similar to waste from households, shall be increased to a minimum of overall 50 % by weight;*"

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4.6.2 Deployment of Material Cycles and Circular Economy

In European cities, a major challenge is to expand circularity beyond traditional resource recovery in waste and material sectors and to provide systemic solutions which can be demonstrated and replicated effectively elsewhere. Cities with the main objective towards carbon neutrality can experience multiple resource efficiency benefits, as well as reduced scope 3 emissions, since the principles of circular economy directly impact upstream and downstream impacts of the material economy. Resource recovery for cities can not only be adopted in the sector of Municipal Solid Waste (MSW) but also in for instance textiles, packaging, and the building sector. Recycling resources will prolong the lifecycles of materials and help a city diverge from linear product use with high CO2 emissions, effecting GHG emissions from both a consumption perspective as well as a waste management perspective. The transition to a circular economy by reusing and recycling materials can reduce pressure on natural resources and create sustainable growth and jobs.

The following indicators will help to provide an indication of the rate of circular material use and resource productivity in a city. Each indicator has been associated to both scope 1 and 3, since CE actions can impact life cycle stages of products and material streams beyond the geographical scope of the city. Monitoring such trends and patterns can be key to understand how the various elements of the circular economy are developing over time in a city.

4.6.2.1 Indicator Set

Table 38 Deployment of Material Cycles and Circular Economy Indicator Set

Indicator Title	Recycling rate for specific material streams	Circular Material Use Rate (CMU)	Resource Productivity
Unit of Measurement	%	%	Euro/Weight
Required or Recommended	Recommended	Recommended	Recommended
Definition	Rate of specific material (Plastic/wood/biowaste/C&D etc) recycled in the economy/city. This indicator reflects the progress in recycling key waste streams.	The circular material use rate (CMU rate) measures, in percentage, the share of material recovered and fed back into the economy - thus saving extraction of primary raw materials - in overall material use.	The indicator is defined as the gross domestic product (GDP) divided by domestic material consumption (DMC). DMC measures the total amount of materials directly used by an economy. It is defined as the annual quantity of raw materials extracted from the domestic territory of the local economy, plus all physical imports minus all physical exports. It is important to note that the term 'consumption', as used in DMC, denotes apparent consumption and not final

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Indicator Title	Recycling rate for specific material streams	Circular Material Use Rate (CMU)	Resource Productivity
			consumption. DMC does not include upstream flows related to imports and exports of raw materials and products originating outside of the local economy.
Source	Eurostat (2018)	Eurostat (2018)	Eurostat (2018b)
Calculation Formula	For each waste stream: waste material recycled/waste material produced in	Ratio of the circular use of materials (U) to the overall material use (M)	Gross Domestic Product (GDP) divided by Domestic Material Consumption (DMC). Calculation methodology described in detail here.
Emission Scope for GHG Indicator (If relevant)	Scope 1, 3	Scope 1, 3	Scope 1, 3

4.6.2.2 Use Case Examples

Recycling rate

To determine the recycling rate, divide the annual recycling quantity by the total amount of solid waste generated.

percent recycled = [kilogram recycled / (kilogram recycled + kilogram garbage)] x 100
40% = [4000 / (4000 + 6000)] x 100

Circular Material Use Rate

For cities to calculate Circular Material Use (CMU) rate, specific boundary conditions should be set for each sector. When data is available across multiple sectors, a singular CMU % can be derived for the full city by adding each sector's material use data. For example, to understand CMU in the construction industry or textiles on a city scale, data is required on amount of material produced as waste, which is used as a proxy for material use (M), and the amount of material recovered (U) for reuse or repurposing by different entities or programs in the city. Note here that recycling is sometimes excluded from the calculation of CMU, but cities have the flexibility to define the boundary conditions to include recycling in this calculation. This gives the ratio for the circular use of materials (U) to the overall material use (M). This indicator can help cities keep track of the share of material recovered and fed back into the economy - thus saving extraction of primary raw materials in overall material use.

CMU (%) = [Material recovered for reuse or repurposing (U)/Overall material use (M)] x 100.

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Resource Productivity

Resource productivity is used as a proxy for measuring resource efficiency (i.e. how efficiently the economy uses material resources to produce the products and services available in the market, known as Gross Domestic Product - GDP). It is expressed in absolute terms (i.e. EUR per kg).

Resource productivity = Gross Domestic Product (EUR)/Domestic material consumption (Weight).

This tracks how much each city has changed in performance over time and measures (using an index) how much the cities have improved, in percentage terms, compared with a base year. If GDP grows faster compared to material consumption, resource productivity improves, and economic activity is decoupled from material consumption (i.e. the economy is able to create more wealth without a proportional increase in resource consumption).

In 2014, the average for resource productivity for EU28 amounted to 2.01 PPS (purchasing power standard) /kg. The best performers are Luxembourg, the Netherlands, the United Kingdom, Spain and Italy (all between 3.75 PPS/kg and 3.03 PPS/kg), followed by France, Belgium and Germany (all between 2.45 PPS/kg and 2.14 PPS/ kg). Resource productivity in PPS is higher in countries with high income and in economies with large service sectors (financial services, tourism industry, arts and recreation, healthcare and public administration).

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4.6.3 Water Management

Urban water managers require measurements of how much water residents consume to understand patterns of water access and water losses, as well as its overall resource efficiency and the pressure water abstraction places on the environment. Water accounting methods for piped water supplies have been established for the fully pressurized and metered systems typical of high-income nations. These methods assume that the utility provides enough water to meet household demand ("demand-driven" supply systems) and that water meters are ubiquitous (Alegre et al., 2000; IWA, 2003; Mutikanga et al., 2013). However, it should be noted that conventional water accounting methods do not apply in unmetered and intermittent systems. The indicator related to household water consumption, is intended to provide a measure of the pressure on the environment in terms of water abstraction from different water sources through household use. The indicator would also help to identify trends in household water use at the City level.

It should further be noted that the Water Framework Directive (Directive 2000/60/EC) (as amended) obliges Member States to promote the sustainable use of available water resources based on long-term protection and to ensure a balance between abstraction and recharge of water with the aim of achieving a "good water status". Council Directive 98/83/EC on the quality of water intended for human consumption sets drinking water quality standards and obliges the Member States take the measures necessary to ensure that water intended for human consumption is healthy and clean.

Nonetheless, it is important to keep in mind that the availability of water for meeting basic human needs is a prerequisite for life, health and economic development. For instance, the World Health Organisation (WHO) (2003) recommends 50–100l of water per capita per day is required to meet domestic needs such as personal hygiene, washing and cleaning.

With respect to Wastewater, the Urban Wastewater Treatment Directive concerns the collection, treatment and discharge of urban Wastewater and the treatment and discharge of Wastewater from certain industrial sectors. The objective of the Directive is to protect the environment from the adverse effects of the above-mentioned Wastewater discharges. The proposed indicator intends to calculate the percentage of wastewater load compliant with the requirements of the Urban Wastewater Treatment Directive (UWWTD) with respect to collection and treatment. It should be noted that there exists a proposal to update the UWWTD, which was published in October 2022.

4.6.3.1 Indicator Set

Table 39 Water Management Indicator Set

Indicator Title	Household water consumption	% of urban wastewater meeting the UWWTD requirements
Unit of Measurement	litres/capita/day	%
Required or Recommended	Recommended	Recommended
Definition	The indicator 'Household water consumption (litres/capita/day)' measures the average consumption of water (in litres) per day per person, for all domestic uses (excluding industry).	The indicator 'Percentage of urban wastewater meeting the requirements of the UWWTD (regarding collection and secondary treatment) measures a city's capacity to comply with the existing requirements of the UWWTD regarding collection (Article 3) and secondary treatment (Article 4).

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Indicator Title	Household water consumption	% of urban wastewater meeting the UWWTD requirements
Source	Water Framework Directive (Directive 2000/60/EC) (as amended)	Council Directive 91/271/EEC concerning urban waste water treatment was adopted on 21 May 1991 (subsequently amended).
Calculation Formula	Vm = metered volume in kL/con/m (from utility records or bill seen during household survey);	This indicator is calculated by taking the percentage of wastewater load compliant with the requirements of the Urban Waste Water Treatment Directive (UWWTD) regarding collection (Article 3 of UWWTD) and secondary treatment (Article 4 of UWWTD).

4.6.3.2 Use Case Examples

Household water consumption

If your water bill does not provide water consumption data, then you can read your water meter to obtain this information. Water meters measure the total amount of water used in your home and are usually located at the property line or on the house. The meter may measure in cubic meters, cubic feet, gallons, or liters. To obtain your water use over the course of a 24-hour day, read your meter at the same time on two consecutive days. You may want to measure water use for several days and then calculate a daily average.

Residential water can be lost due to leaking pipes, toilets, and faucets. Once any leaks have been repaired in a home, the next step is to evaluate the efficiency of the current fixtures and appliances and whether improvements are required such as Low Consumption Toilets, Low-Flow Shower Heads, Eco friendly appliances such as dishwashers and washing machines and so on.

% of urban wastewater meeting the UWWTD requirements

The 10th report on the implementation of the Urban Waste Water Treatment Directive (UWWTD) shows that compliance rates with EU waste water collection and treatment rules are high and have increased compared to the previous reporting period. This helps prevent pollution of the environment. While the trend remains positive, full compliance with the Directive has not yet been achieved. Finance and planning remain the main challenges for the water service sector.

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4.6.4 Suitable and Resilient Food Production

Sustainable Development Goal 12 (SDG 12 or Global Goal 12), titled "responsible consumption and production", is one of the 17 Sustainable Development Goals established by the United Nations in 2015. The official wording of SDG 12 is "Ensure sustainable consumption and production patterns". It is described by the Food and Agriculture Organisation (FAO) of the United Nations that a growing global population with deteriorating natural resources and increased urbanization means more people to feed with less water, farmland and rural labour. Satisfying expected increases in water, energy and food needs means shifting to more sustainable production and consumption approaches. Resilience and self-sufficiency with respect to food production, whereby one is not reliant on food imports is also an important consideration.

4.6.4.1 Indicator Set

Table 40 Sustainable and Resilient Food Production Indicator Set

Indicator Title	Local food production	Food waste volume
Unit of Measurement	%	t/cap
Required or Recommended	Recommended	Recommended
Definition	Share of food consumption produced within a radius of 100 km	This indicator corresponds to the food waste volume per capita and year.
Source	Bosch, P., Jongeneel, S., Rovers, V., Neumann, H.-M., Airaksinen, M., & Huovila, A. et al. (2017) *CITYkeys list of city indicators.*	N/A
Calculation Formula	(Food produced in 100 km radius (tons) / Total food demand within city (tons)) * 100	Food Waste per Capita (t) = Food Waste per Capita (t) / Population (t). Where : t = year.

4.6.4.2 Use Case Examples

For instance, the yearly intake in Europe was 770 kg per person in 2000 (EEA, 2005).

The food demand can then be calculated by multiplying the number of citizens in Europe for the year 2000, 725,558,036 with 770 kg. The answer is 558,679,687,720kg. This calculation could be applied at the City level.

Crop statistics and animal populations can be acquired at NUTS2 level (Eurostat, 2015). Comparable data on the agricultural yield is only available at the NUTS2 – level.

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4.6.5 Land Use Management Practice

Brownfield is a term used in urban planning to describe "land which is or was occupied by a permanent structure, including the curtilage of the developed land and any associated fixed surface infrastructure." (Department for Communities and Local Government, 2012). It should be noted that many brownfields are contaminated as a result of previous industrial or commercial uses.

The European Environment Agency (EEA) has estimated that there are as many as three million brownfield sites across Europe, often located and well connected within urban boundaries and as such offering a competitive alternative to greenfield investments. Brownfield remediation and regeneration represents a valuable opportunity, not only to prevent the loss of pristine countryside and reduce ground sealing, but also to enhance urban spaces and remediate the sometimes contaminated soils (DG Environment 2013).

With increasing urbanisation, the share of the population living in cities is expected to increase to 70% on a global scale by 2050, and up to 85% in Europe (European Investment Bank, 2018). The 'Growth Rate of urbanised Land" indicator intends to capture this trend. However, it should be noted that such a trend may not be positive as Cities already consume 70% of global resources and 70% of all energy generated. Furthermore, they emit 70% of all GHGs and generate about 50% of all waste. Therefore, the indicator proposed may capture an unintended negative consequence/ effect of urbanisation.

4.6.5.1 Indicator Set

Table 41 Land Use Management Practice Indicator Set

Indicator Title	Growth rate of urbanized land	Brownfield use
Unit of Measurement	m^2/capita/year	% of km2
Required or Recommended	Recommended	Recommended
Definition	Newly urbanised land in m2, per capita, and year.	Share of brownfield area that has been redeveloped in the past period as percentage of total brownfield area.
Source	N/A	Bosch, P., Jongeneel, S., Rovers, V., Neumann, H.-M., Airaksinen, M., & Huovila, A. et al. (2017) *CITYkeys list of city indicators.*
Calculation Formula	Area of newly urbanised land in m2 / population of the City.	The indicator "brownfield redevelopment" is calculated as the brownfield area redeveloped in the last year [km^2] (numerator] divided by the total brownfield area in the city [km^2] (denominator). The result shall then be multiplied by 100 and expressed as a percentage.

4.6.5.2 Use Case Examples

Brownfield Use

With respect to brownfield use, if a City has for example 500 hectares/5 square kilometres of brownfield land, and within the last year, take 2022 as a case year for instance, it redevelops 50 hectares/0.5

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square kilometres of brownfield sites within the City's administrative boundary, the Indicator for brownfield redevelopment is calculated as follows:

0.5 km^2 (brownfield area redeveloped in last year) / 5km^2 (total brownfield area within city boundary) = 0.1 * 100 = 10%.

or 10% of 5km^2.

The strength of this indicator is that there is it is highly relevant with respect to policy aims and it is relatively easy to calculate. However, there is a weakness in that there is limited comparability of data across European cities, as the understanding of the term "brownfield" may differ. In addition, it should be noted that not all cities will have brownfield space to redevelop.

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4.7 Biodiversity

4.7.1 Urban Forestry Plantation and Improved Plant Health

The transition towards climate neutrality will require a city-wide greening strategy. According to Doick et al. (2019), evidence shows that the negative impacts upon human health of urbanisation, such as increased exposure to heat stress and elevated levels of air pollution, are in part caused by the removal of vegetation relative to rural environments. Consequently, trees and the wider green infrastructure of a city are advocated as a cost-effective sustainable remedy. Trees also contribute to human well-being by softening the urban aesthetic and offering a focal point for human social interaction.

The indicator 'Percentage of tree canopy cover within the city' is a status indicator that assesses the proportion of grown trees (with the potential to grow to full maturity) in relation to the municipal area and gives an indication of connectivity. Trees are a vital part of urban infrastructure and offer a multitude of benefits. The EU Forest Strategy, combining biodiversity and climate neutrality targets, includes a roadmap for planting at least 3 billion additional trees in the EU by 2030 in full respect of logical principles. Cities have to step up their efforts to help fulfil this target. The indicator tree canopy cover was chosen to reflect progress in urban tree planting actions.

4.7.1.1 Indicator Set

Table 42 Urban Forestry Plantation and Improved Plant Health Indicator Set

Indicator Title	Percentage of tree canopy within the city
Unit of Measurement	% of the municipal area
Required or Recommended	Recommended
Definition	The indicator 'Percentage of tree canopy cover within the city' is a status indicator that assesses the proportion of grown trees (with the potential to grow to full maturity) in relation to the municipal area and gives an indication of connectivity.
Source	European Commission (2022), *Green City Accord, Clean and Healthy Cities for Europe, GCA Mandatory Indicators Guidebook*, Version of 29 April 2022
Calculation Formula	Total area (m^2/ha/km^2) of tree cover within municipal boundary / total area of municipal boundary (m^2/ha/km^2) * 100

4.7.1.2 Use Case Examples

For instance, if the area of tree cover in a City is 20km^2 and the total area of the City is 100km^2 the calculation would be carried out as follows:

20km2 / 100km2 = 0.2 * 100 = 20%

Or in other words 20% of the City's area has a tree canopy cover.

It is highly recommended to use the tree cover density maps at 10 m or 100 m resolution, while applying the relevant baseline year.

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4.7.2 Ecological Awareness

Ecological Awareness amongst citizens strengthens pro-environmental behaviour and encourages connectedness to nature. Citizen's behaviour has a significant impact on the environment and is therefore very relevant. Encouraging their awareness, their pro-enviornmental identity and ther mindfulness, can help to support sustainable change. Pro-environmental behaviour (PEB) encourages interest in sustainability and sustainable behaviour. Additionally pro-environmental citizens allow prediction of their future behaviour (European Union, 2021c).

4.7.2.1 Indicator Set

Table 43 Ecological Awareness Indicator Set

Indicator Title	Citizen's awareness regarding sustainabilty and the environment	Pro-environmental identity	Mindfulness
Unit of Measurement	Likert Scale	Likert Scale	Likert Scale
Required or Recommended	Recommended	Recommended	Recommended
Definition	The extent to which a CCC Action Plan exploits opportunities to increase citizens' ecological awareness, or to more generally educate citizens about sustainability and the environment, can be evaluated using a five-point Likert scale.	Environmental identity is one part of the way in which people form their self-concept; a sense of connection to some parts of the nonhuman natural environment, based on history, emotional attachment, and/or similarity, that affects the way in which we perceive and act towards the world; a belief that the environment is important to us and an important part of who we are. (Clayton, 2003, pp. 45-46). better predictor of behaviour than environmental attitudes (EA) (Clayton, 2003; Olivos & Aragonés, 2011),	Ability of being conscious or aware of something within the environment.
Source	UNaLab in: European Union (2021c) Evaluating the Impact of Nature-based Solutions - Appendix of Methods. Pg. 808. Bosch, P., Jongeneel, S., Rovers, V., Neumann, H.-M., Airaksinen, M., & Huovila, A. (2017). CITYkeys indicators for smart city projects and	CONNECTING Nature (Grant Agreement no. 730222), in: European Union (2021c) Evaluating the Impact of Nature-based Solutions - Appendix of Methods. Pg. 784 Clayton, S. (2003). Environmental identity: A conceptual and an operational definition. In S. Clayton & S. Opotow (Eds.), Identity and	proGIreg (Grant Agreement no. 776528) In: European Union (2021c) Evaluating the Impact of Nature-based Solutions - Appendix of Methods.Pg. 1028

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Indicator Title	Citizen's awareness regarding sustainabilty and the environment	Pro-environmental identity	Mindfulness
	smart cities. CITYkeys D1.4. Retrieved from http://nws.eurocities.eu/MediaShell/media/CITYkeysD14Indicatorsforsmartcityprojectsandsmartcities.pdf	the natural environment (pp. 45-65). Cambridge, MA: MIT Press. Olivos, P., & Aragonés, J. I. (2011). Psychometric Properties of the Environmental Identity Scale. Psychology, 2(1), 65-74. doi: 10.1174/217119711794394653	
Calculation Formula	Likert Scale	EIS (Clayton, 2003) – 24 items	Validated scale "Cognitive and Affective Mindfulness Scale-Revised" (CAMS-R – Feldman et al., 2007) 12 items with a 4-point Likert scale, from "Rarely/Not at all" to "Almost always".

4.7.2.2 Use Case Examples

Similar indicators have been utilized in the EU-funded projects CITYkeys and UNaLab (Stavanger, Prague, Castellón, Cannes, Başakşehir, Hong Kong and Buenos Aires, etc.), defined as "The extent to which a project exploits opportunities to increase citizens' awareness of NBS and ecosystem services, or to more generally educate citizens about sustainability and the environment. It can be evaluated using a five-point Likert scale (Bosch et al., 2017):

Not at all – 1 – 2 – 3 – 4 – 5 – Very much

1. Not at all: opportunities to increase environmental awareness were not taken into account in the project communication.

2. Poor: opportunities to increase environmental awareness were slightly taken into account in the project communication.

3. Somewhat: opportunities to increase environmental awareness were somewhat taken into account in the project communication, at key moments in the project there was attention for this issue.

4. Good: opportunities to increase environmental awareness were sufficiently taken into account in the project communication; the project utilized many possibilities to address this issue in their communications.

5. Excellent: opportunities to increase environmental awareness were taken into account in the project communication; the project utilized every possibility to address this issue in both online and offline communications."

(European Union (2021) Evaluating the Impact of Nature-based Solutions - Appendix of Methods, pg. 809).

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4.7.3 Ecological Habitat Connection

The fragmentation of natural environments is a major threat to biodiversity as scattered and non-connected natural areas are much less efficient in preserving biodiversity than large and connected areas. To estimate fragmentation, natural areas are defined and then an estimation is made about their connections. The definition of connectivity is based on movement of fauna - can animals move freely between areas of natural habitats? The areas are considered connected if they are less than 100 m apart and not divided by barriers such as roads, modified rivers, walls, etc.

A mesh indicator value is calculated. Natural areas are categorized into separate interconnected patches. The area of each patch is summed, squared and these squares are summed and divided by the total area of natural areas.

4.7.3.1 Indicator Set

Table 44 Ecological Habitat Indicator Set

Indicator Title	Structural connectivity of green spaces
Unit of Measurement	ha
Required or Recommended	Recommended
Definition	Degree of physical ("structural") connectivity between natural environments within a defined urban area.
Source	UNaLab; Chan, L., Hillel, O., Elmqvist, T., Werner, P., Holman, N., Mader, A. & Calcaterra, E. (2014). *User's Manual on the Singapore Index on Cities' Biodiversity (also known as the City Biodiversity Index)*. Singapore: National Parks Board, Singapore.
Calculation Formula	$Indicator\,2 = \frac{1}{A_{total}}\left(A_1^2 + A_2^2 + A_3^2 + \ldots + A_n^2\right)$ Where: • A_{total} is the total area of all natural areas. • A_1 to A_n are areas that are distinct from each other (i.e. more than or equal to 100m apart). • n is the total number of connected natural areas.

4.7.3.2 Use Case Examples

<u>Structural Connectivity of Green Spaces</u>

Satellite images can be used in the computation of this indicator. The User's Manual on the Singapore Index on Cities' Biodiversity (also known as the City Biodiversity Index) provides the following example:

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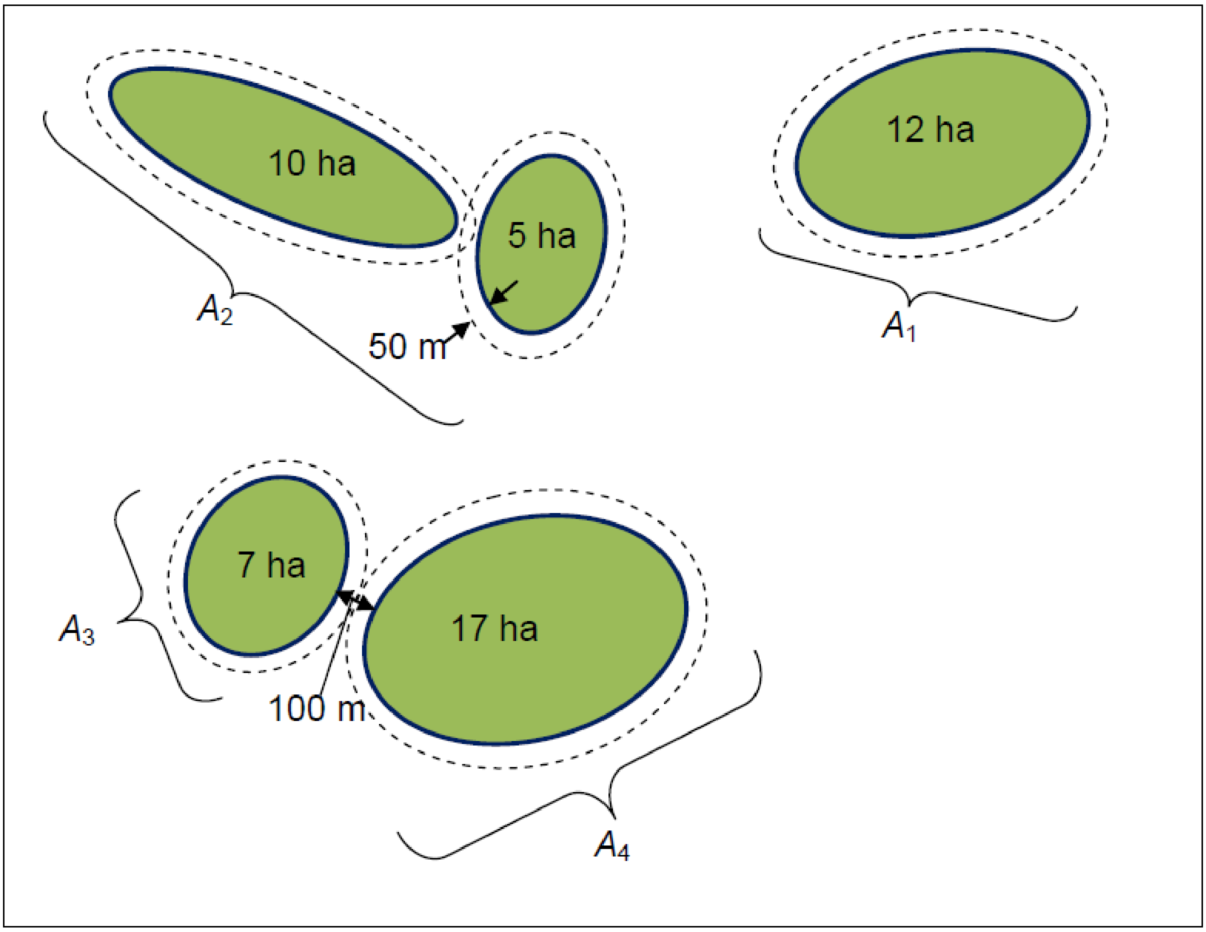

Figure 4: Structural Connectivity of Green Spaces (Source: Chan, L., Hillel et al., 2014)

The Calculation steps are as follows. There are five patches in this landscape. Firstly, a buffer of 50m is added around each patch to find out which patches are within 100m of each other: when the buffers overlap, the distance between the patches is less than 100m. The patch on the right (12 ha in size) is not connected to any other patches, and we name the patch A1 (area = 12 ha).

The two patches on the upper left are connected. Therefore, their areas have to be added, and we give this group of patches the name A2 (area = 10 ha + 5 ha = 15 ha). The two patches at the bottom are exactly100m apart and therefore they are not considered connected and we give them the names A3 (area = 7 ha) and A4 (area = 17 ha).

*A*total is the sum of A1, A2, A3 and A4, i.e. *A*total = 12 ha + 15 ha + 7 ha + 17 ha = 51 ha. It is now possible to calculate the value of the effective mesh size for indicator 2 as:

$$Indicator\,2 = \frac{1}{A_{total}}\left(A_1^2 + A_2^2 + A_3^2 + A_4^2\right) = \frac{1}{51\,\text{ha}}\left(12\times 12\,\text{ha}^2 + 15\times 15\,\text{ha}^2 + 7\times 7\,\text{ha}^2 + 17\times 17\,\text{ha}^2\right) = \frac{707}{51}\text{ha} = 13.86\,\text{ha}$$

This measures effective mesh size of the natural areas in the city. *A1* to *An* may consist of areas that are the sum of two or more smaller patches which are connected. In general, patches are considered as connected if they are less than 100m apart.

This measures effective mesh size of the natural areas in the city. *A1* to *An* may consist of areas that are the sum of two or more smaller patches which are connected. In general, patches are considered as connected if they are less than 100m apart. The following exceptions should also be noted with respect to anthropogenic barriers:

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- Roads (15m or more in width; or are smaller but have a high traffic volume of more than 5000 cars per day)
- Rivers that are highly modified and other artificial barriers such as heavily concretised canals and heavily built-up areas
- Any other artificial structures that the city would consider as a barrier.

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4.7.4 Nature Restoration

The percentage of protected natural areas restored and naturalised areas on public land in a City, naturally assess the share of protected natural areas and restored and naturalised areas in the municipality. A transition to climate neutrality should seek to both restore and protect such areas. Urban ecosystems - which consist of cities and the surrounding socio-ecological systems where most people live - are almost completely artificial but they may include all other ecosystem types (forests, lakes, rivers and agricultural areas can all be part of urban fringe) and they are strongly influenced by human activities. Urban protected areas, such as NATURA 2000 sites, differ with regards to the degree of naturalness, ranging from natural virgin systems with only natural elements, to highly human intervened systems with extensive human activities.

Protected or secured natural areas indicate the city's commitment to biodiversity conversation. Hence, the proportion of protected or secured areas is an important indicator. The definition of protected natural areas should be broadened to include legally protected, formally secured areas, and other administratively protected areas, as different cities have different terminologies and means for protecting their natural areas. This represents a proxy measure for the contribution that an area is making to biodiversity conservation strategies. There are a range of restrictions to agricultural and forestry related activities within these areas which contribute to foster the development and recovery of rare species. Thus, this is a key indicator related to the biodiversity value of spaces.

Natural ecosystems harbour more species than disturbed or man-made landscapes, hence, the higher percentage of natural areas compared to that of the total city area gives an indication of the amount of biodiversity there. A definition agreed at the Third Expert Workshop on the Development of the City Biodiversity Index for "natural areas" is: Natural areas comprise predominantly native species and natural ecosystems, which are not, or no longer, or only slightly influenced by human actions, except where such actions are intended to conserve, enhance or restore native biodiversity.

Natural ecosystems are defined as all areas that are natural and not highly disturbed or completely man-made landscapes. Some examples of natural ecosystems are forests, mangroves, freshwater swamps, natural grasslands, streams, lakes, etc. Parks, golf courses, roadside plantings are not considered as natural. However, natural ecosystems within parks where native species are dominant can be included in the computation. The definition also takes into consideration "restored ecosystems" and "naturalised areas" in order to recognise efforts made by cities to increase the natural areas of their city. Restoration helps increase natural areas in the city and cities are encouraged to restore their impacted ecosystems.

Biodiversity is the measure of biological variety in the environment, and it has an important role in functioning ecosystems services and health of environment and society. Biodiversity is an aspect of natural environment that is most directly affected by anthropogenic influence. City biodiversity is seen as an important aspect of sustainable and resilient urban development. Natural areas are important in preserving biodiversity as natural areas typically harbour much larger biodiversity than urban or constructed green spaces.

With the above definitions in mind the indicators provided below intend to track the percentage of protected natural areas and the percentage of restored and naturalised areas on public land within the city as a consequence of efforts towards achieving a climate neutral city.

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4.7.4.1 Indicator Set

Table 45 Nature Restoration Indicator Set

Indicator Title	Percentage of protected natural areas	percentage of restored and naturalised areas on public land within the city
Unit of Measurement	%	%
Required or Recommended	Recommended	Recommended
Definition	It assesses the proportion of natural areas within the City.	It assesses the share of protected natural areas and restored and naturalised areas in the City.
Source	European Commission (2022), *Green City Accord, Clean and Healthy Cities for Europe, GCA Mandatory Indicators Guidebook*, Version of 29 April 2022 Also informed by : Chan, L., Hillel, O., Elmqvist, T., Werner, P., Holman, N., Mader, A. & Calcaterra, E. (2014). *User's Manual on the Singapore Index on Cities' Biodiversity (also known as the City Biodiversity Index)*. Singapore: National Parks Board, Singapore.	Chan, L., Hillel, O., Elmqvist, T., Werner, P., Holman, N., Mader, A. & Calcaterra, E. (2014). *User's Manual on the Singapore Index on Cities' Biodiversity (also known as the City Biodiversity Index)*. Singapore: National Parks Board, Singapore.
Calculation Formula	(Area of protected or secured natural areas) / (Total area of the city) x 100 Possible sources of data include government agencies in charge of biodiversity, city municipalities, urban planning agencies, biodiversity centres, nature groups, universities, publications, etc.	(Total area of natural, restored and naturalised areas) / (Total area of the city) x 100 Possible sources of data on natural areas include government agencies in charge of biodiversity, city municipalities, urban planning agencies, biodiversity centres, nature groups, universities, publications, etc. Google maps and satellite images can also provide relevant information to calculate this indicator.

4.7.4.2 Use Case Examples

Percentage of Protected Natural Areas

For instance, for the calculation of the percentage of protected areas indicator, if the area of protected natural, restored and naturalised areas in a certain city is 20 km^2 and the total area of such city is 100 km^2 the calculation would be carried out as follows:

(20 km^2 / 100 km^2) x 100 = 0.2 x 100 = 20%

Or in other words, 20% of the city's area is made up of protected areas.

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Percentage of Restored and Naturalised Areas in a City

With respect to the calculation of the percentage of restored and naturalised areas in a city indicator, it needs to be known the area for natural, restored and naturalised area, as well as the total area of the city. Following with the example of previous city (100 km^2), if the area of natural areas in the urban zone is 35 km^2, the calculation would be almost the same of the previous example:

$(35\ km^2 / 100\ km^2) \times 100 = 0.35 \times 100 = 35\%$

Or in other words, 35% of the city's area is occupied by natural areas (natural, restored and renaturalised areas).

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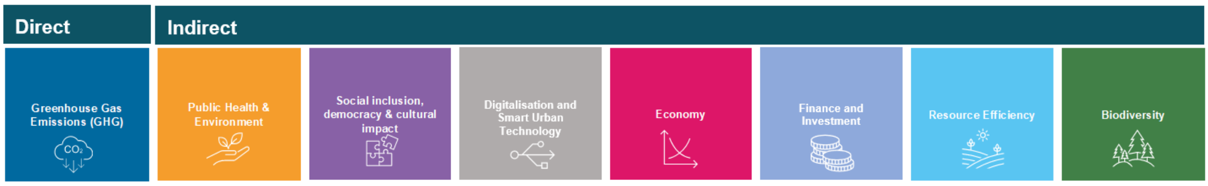
Appendix A: Visualisation of Direct Benefits and Co-Benefits Monitoring Framework



Required/ Recommended indicators (see indicator name)

Required

Recommended

DOMAIN	SUBDOMAIN	INDICATOR NAME	UNIT OF MEASUREMENT
Greenhouse Gas Emissions (GHG)	Stationary Energy	GHG emission from stationary energy	t CO2 equivalent
		Energy use by fuel/energy type within city boundary	MWh/year
	Transport and Mobility	GHG emission from transport	t CO2 equivalent
		Fuel consumption for in-boundary transportation per fuel type	MJ/kg/kWh
	Waste and Water	GHG emission from waste	t CO2 equivalent
		Mass of waste processed per end-of-life treatement type within city boundary	t CO2 equivalent
		Mass of waste processed per end-of-life treatement type outside city boundary	t CO2 equivalent
	Industrial Processes and Product Use (IPPU)	GHG emission from IPPU	t CO2 equivalent
		Emission generation potential per unit of input/output for industrial processes within the city boundary	CO2 equivalent per kg of production
		Emissions from non-energy product use	T CO2 equivalent
	Agriculture, Foresty and other Land Use (AFOLU)	GHG emission from AFOLU	t CO2 equivalent
		Net annual rate of change in carbon stocks per hectare of land	t CO2/ha
	Energy Generation	Local RES energy production	MWh
		Energy Autonomy	%
	Grid-supplied energy (electricity, heat, steam or cooling)	GHG emission from grid supplied energy	t CO2 equivalent
		Grid specific emission factor	tCO2 eq/MWh
		Transmission and distribution loss factor for grid supplied energy	%
	Carbon Removal and Residual Emissions	Amount of permanent sequestration of GHG within city boundary	t CO2 equivalent
		Negative emissions through natural sinks	t CO2 equivalent

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DOMAIN	SUBDOMAIN	INDICATOR NAME	UNIT OF MEASUREMENT
Public Health & Environment	Air quality	PM2.5 concentration levels	µg/ m3
		PM10 concentration levels	# of days
		NO2 concentration levels	µg/ m3
	Noise pollution	% of population exposed to night-time noise (Lnight) >= 50 dB	%
		% of population exposed to avg. LDEN ≥ 55dB	%
	Road safety road safety	Road Deaths	# of deaths / 100,000 inhabitants
		Traffic safety active modes	# of deaths / 1000,000,000 trips
	Urban Heat Island (UHI) effect Temperature Increase and Heatwave Incidence	Urban Heat Island (UHI) Effect	°C UHImax
		Mean value of daily maximum temperature (TXX)	°C TXX
		Mean value of daily minimum temperature (TNN)	°C TNN
		Heatwave (HW) incidence	# of HW in summer
	Physical and mental well being	Wellbeing of citizens (questionnaire)	Likert scale
	Liveability, attractiveness & aesthetics of the built environment	Green Spaces	hectares / 100,000
		Quality of public spaces	# (rating from 0 to 10 of overall satisfaction with green and non-green public spaces)
	Equitable & affordable access to housing	Affordabilty of Housing	% of households
		Fuel poverty	% of households

DOMAIN	SUBDOMAIN	INDICATOR NAME	UNIT OF MEASUREMENT
Social Inclusion, Innovation, Democracy and Cultural Impact Co Benefits	Citizen & communities' participation	Openness of public participation processes	% of processes
	City capacities for participation / engagement	Policy support for promoting climate neutrality	# Number
		Citizen involvement in co-creation/co-design of climate neutrality actions	# Number
	Improved social justice	GINI coefficient	#
	Social cohesion, gender, equality & equity	Inclusion of different social groups	Likert (number)
	Functioning of democratic institutions	Voter participation	% of people
	Social Innovation	Skills and Capacity Building – Social Innovation Experts	# Number
		Skills and Capacity Building - Social Innovation skills development activities	# Number
		Empowerment and Inclusion – Inclusion and Collaboration	# Number
		Funding for Social Innovation initiatives for climatFunding for Social Innovation initiatives for climate neutrality	# Number (euros)
	Behavior change towards low carbon lifestyle and practice	Modal share of green transport modes and public transport)	%
		Modal share of green transport modes and public transport)	%

DOMAIN	SUBDOMAIN	INDICATOR NAME	UNIT OF MEASUREMENT
Digitalisation and Smart Urban Technology	Green ICT and Smart Metering	% of households and buildings with reduced energy consumption as a consequence of installing smart energy metres	% of households
		% of households and buildings with reduced water consumption as a consequence of installing smart water meters	% of households
		% of municipal buildings equipped with building energy management systems	% of public buildings
	EGovernment	% of city services available online	% of total services
		Improvement in online government services	Likert Scale
	Access to information	Business-to-government (B2G) data sharing	# of Private Datasets Shared with the City / Local Authority
	Urban Data Platforms	Usage of Urban Data Platforms	# Users /Day
		User Satisfaction with Urban Data Platforms	User Satisfaction Score (Likert Scale)

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DOMAIN	SUBDOMAIN	INDICATOR NAME	UNIT OF MEASUREMENT
Economy	Investment in R&I	Research intensity	%
	Number of skilled jobs & rate of employment	Green jobs	% of jobs
		Youth unemployment rate	% of people
	Economic thriving (GDP)	Gross Domestic Product	€/cap
	Technological readiness & rate of adoption	Adoption rate of key climate neutral technologies	%
	Local entrepreurship & local businesses / ventures	Climate-Neutral City Start-ups	#/100.000
		New businesses registered	#/100.000
		Surviving number of new companies registered after year 3	#/100.000

DOMAIN	SUBDOMAIN	INDICATOR NAME	UNIT OF MEASUREMENT
Finance and Investment	Public Spending	Capital Invested in Climate Action Projects	EUR million
		Budget Assigned to Climate Action Projects	% of City Budget
		Capital Invested in Climate Action Projects per Capita	EUR thousand
	External Spending	Capital Invested in Climate Action Projects	EUR million
		Coverage of Climate Finance Gap	% of Capital Deficit Covered
	Capital Efficiency	Emission Return on Invested Capital	EUR million
	Fiscal Responsibility	Cost Coverage	% of Costs Covered

DOMAIN	SUBDOMAIN	INDICATOR NAME	UNIT OF MEASUREMENT
Resource Efficiency	Waste management and efficiency	Recycling rate of municipal waste	%
	Deployment of material cycles & circular economy	Recycling rate for specific material streams	%
		Circular Material Use Rate (CMU)	%
		Resource Productivity	Euro/Weight
	Water management	Household water consumption	litres/capita/day
		% of urban wastewater meeting the UWWTD requirements	%
	Sustainable and resilient food production	Local food production	%
		Food waste volume	t/cap
	Land use management practice	Growth rate of urbanized land	m²/capita/year
		Brownfield use	% of km2

DOMAIN	SUBDOMAIN	INDICATOR NAME	UNIT OF MEASUREMENT
Biodiversity	Urban Forestry, Plantation & Improved Plant Health	Percentage of tree canopy within the city	% of the municipal area
	Ecological awareness	Citizen's awareness regarding sustainabilty and the environment	Likert scale
		Pro-environmental identity	Likert scale
		Mindfulness	Likert scale
	Ecological habitat connection	Structural connectivity of green spaces	ha
	Nature restoration	Percentage of protected natural areas	%
		Percentage of restored and naturalised areas on public land within the city	%

Figure 5: Visualisation of Impact Framework

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Appendix B: Complete Catalogue of Social Innovation Indicators

Social innovation can foster innovative social practices for reducing GHG emissions at the urban level, such as by sharing, co-creating people-centred solutions (i.e., in urban planning, circular economy), or by fostering public-private/cross-sector partnerships through collaborative platforms to engage and empower multiple stakeholders to collaborate toward climate neutrality. In addition to technological solutions and nature-based solutions, social innovations provide "people-based solutions" by developing urban ecosystems for systemic change toward sustainable practices and related behavioural change.

Social innovation indicators are related to specific social innovation actions as outlined in the social innovation actionable pathways in Deliverable 9.3 and related publications (Bresciani et al., 2023). The following table provides the complete list of process and outcome indicators. Cities are suggested to select the indicators which are relevant for their readiness level and specific actions/projects.

Category	Indicators	Indicator description	Type of data
1. Public administration capacity building in social innovation	SI1.1.1 Public administrators' social innovation skills development activities	Total number of people involved into capacity building or training activities on social innovation for climate neutrality (i.e., workshops/awareness campaigns for increasing awareness of social innovation for climate neutrality to the public administration, citizens, urban stakeholders, etc.)	numeric
	SI1.1.2 PA Social Innovation skills development	According to the city civil servants, what is social innovation and which are the main benefits of supporting social innovation for climate sustainability? Do they believe that their knowledge of social innovation has improved as a consequence of training? Are there any social innovation initiatives boosted/supported by the civil servants who underwent the course?	textual
	SI1.2 Social Innovation experts	Total Number of experts in social innovation to which the municipality has access, including public administration employees and other professionals with skills related to social innovation or co-creation for climate neutrality (i.e., public officials who participated to social innovation for climate neutrality training, professionals from university centers focusing on social innovation, professionals from social innovations consultancies, etc.)	numeric
2. Social Innovation in the transition team and in the city's strategy making	SI2.1 Social innovation experts participating to the city transition team/climate task force	Number of social innovation experts (public administrators or external experts) participating to the city' transition team/task force, with expertise on social innovation for climate sustainability	numeric
	SI2.2 Social innovations in the city strategy/climate action plan	Number of social innovations supporting initiatives embedded into the city's strategy/climate action plans for climate neutrality (i.e., urban planning, circular economy, etc.) or co-created with citizens, to achieve systemic change for sustainability	numeric

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	SI2.3.1 Media strategy on SI for climate sustainability	Has the city developed a communication and (social) media strategy to boost the press coverage of the cities' initiatives on social innovation for climate sustainability? How are the information for the media collected and distributed? Which are the main lessons learned?	textual
	SI2.3.1 Press and media coverage on city's initiatives for climate neutrality	Number of articles in the press, appearance in broadcast media and social media covering the city's initiatives for climate neutrality	numeric
3. Funding for Social Innovation initiatives for climate neutrality	SI3.1 Funds for Social Innovation	Total Amount of funding dedicated to the city's Social Innovation initiatives (for training, for social innovation business seeding, creating and managing platforms, etc.) per category: philanthropy, crowdfunding, social bonds, cross-sector partnerships, change in ownership, platform for attracting investors, in-kind donations, hours of volunteering, others.	numeric
4. Citizens' capacity building in social innovation for climate neutrality	SI4.1.1 Citizens' Social Innovation for climate neutrality skills development SI4.1.2 Social innovation initiatives created	Number of beneficiaries who attended Social Innovation for climate neutrality training provided by the city or partners, per category: citizens, companies' personnel, NGOs personnel, schools, other (please specify)	numeric
		Proportion of participants to SI training initiatives that created social innovation for climate neutrality	
5. City Social Innovation mapping/ observatory	SI5.1.1 Activities and partners mapped in the city's Social Innovation observatory	Number of social innovations and potential partners actively mapped in a SI innovation observatory or social innovation urban mapping/tracking platform	numeric
	SI5.1.2 Number of social innovations for climate neutrality in the city	In the city, how many social innovations, NGOs and social enterprises focus on social innovation for climate sustainability?	textual
6. Social innovation policies	SI6.1.1 Policies that support social innovation for climate neutrality	Which policies has the municipality developed to support social innovation for climate neutrality? Which are the benefits, challenges and lessons learned?	textual

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	SI6.1.2 Co-created policies that support social innovation for climate neutrality	Which social innovation initiatives have been developed from policy initiatives co-created with citizens? Which are the benefits, challenges and lessons learned compared to developing policies not co-created with citizens?	textual
	SI6.2 Percentage of procurement from sustainable providers	Percentage of procurement of public services of the city from sustainable providers or social innovations out of the number of total public services procured	Numeric (percentage)
7. Co-creation platforms and environments	SI7.1.1 Social Innovation Infrastructure	Number of co-creation platforms (i.e., SI lab, living lab, SI platform, SI incubator, SI accelerator, networking events, SI dedicated places, dialogue platforms, other)	numeric
	SI7.1.2 Social Innovation Infrastructure	Which co-creation platforms has the PA established (i.e., SI lab, living lab, SI platform, SI incubator, SI accelerator, networking events, SI dedicated places, other)? What are the main benefits, challenges, and learnings for each platform?	textual
	SI7.1.3 Number of newly established enterprises, initiatives or social Innovations for climate neutrality	How many new social enterprises or social innovations (networks/partnerships) have been established in the city to tackle climate neutrality thanks to the co-creation platforms established by the public administration?	numeric
	SI7.2 Open data for climate action initiatives	Is the city providing open data and platforms to share public administration data (such as citizen science)? How is the open data used by citizens to develop initiatives for climate neutrality or social innovations?	textual
8. Incubating and accelerating social innovations for climate neutrality	SI8.1.1 Public administration support for bottom-up social innovation projects for climate neutrality	How does the public administration support bottom-up social innovation projects and activities for climate neutrality?	textual
	SI8.1.2 Social innovations for climate neutrality supported by the public administration	Number of social innovations the public administration supported with consulting, mentoring and funding to start and scale up	numeric
	SI8.1.3 Social innovations funded with PA business seeding	Number of initiatives funded with business seeding to start a social innovation for climate neutrality	numeric

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	SI8.1.4 Sustaining social innovations	How do social innovations for climate neutrality of the city sustain their operations and impact over time? How can the city support innovators sustain their operations to scale their impact toward climate neutrality?	textual
	SI8.1.5 Participation to social innovations for climate neutrality	How many people have joined or co-created initiatives for climate neutrality through the city's initiatives?	numeric
	SI8.1.6 Assessing the impact of social innovations for climate neutrality	How does the city measure the impact of the social innovations it supports or it has co-created? Which are the main learnings from measuring the impacts?	textual
	SI8.1.7 Inclusion of minorities	To what extent does the city promote participation among women, people with disabilities and minorities to social innovation for climate neutrality initiatives promoted by the public administration?	textual
	SI8.1.8 Targeting minorities	How are social innovations targeted at vulnerable groups (i.e., disabled, unemployed, linguistic minorities, etc.) specifically supported (with dedicated training and funds) by the public administration?	textual
	SI3.1.1 Funds for incubating and accelerating social innovations for climate neutrality	Amount of funds the city invests yearly for incubating and accelerating social innovations for climate neutrality	Numeric (Euros)
	SI8.2.1 Beneficiaries of mentoring or scaling program of social innovation for climate neutrality	Number of beneficiaries who attended a scaling or mentoring program of social innovation for climate neutrality	numeric
	SI8.2.2 SI initiatives for climate sustainability funded for scaling	Number of high-potential social innovation initiatives for climate sustainability funded for scaling (an already established social innovation)	numeric
	SI8.2.3 Most successful social innovation initiatives for climate neutrality	Which are the most successful social innovation initiatives for climate neutrality in the city? What can be learned in terms of challenges, benefits and strategies for scaling? Please provide data and experiences referring to specific impact categories (stationary energy, energy generation, mobility & transport, green industry, circular economy, nature based solutions)	textual

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	SI8.2.4 Social innovations replication	Proportion of Social innovation initiatives for climate sustainability r replicated in other contexts, out of the number of SI initiatives joining the mentoring programme	Numeric (%)
9. Co-creation and cross-sector partnerships	SI9.1.1 Cross-sector partnerships for climate neutrality	Number of public-private or cross-sector partnerships developed for the aim of reducing GHG emissions/energy consumption through platforms set up by the public administration	numeric
	SI9.1.2 Cross-sector partnerships' contribution to climate neutrality	Which cross-sector partnerships and public-private partnerships have been developed in the city to boost climate neutrality through social innovation? Which are the main positive and negative aspects of the partnership and the lessons learned? Please describe for each partnership how it has contributed to climate neutrality	textual
	SI9.2 Social innovation initiatives co-created by the PA to address climate neutrality	Which social innovation initiatives has the PA co-created with citizens (including companies, NGOs, etc.) or other entities (including other cities, other public authorities) to address climate neutrality? Please describe how each initiative supports climate neutrality (stationary energy, energy generation, mobility & transport, green industry, circular economy, nature-based solutions) and social inclusion: what can be learned and how can they be improved?	textual
10. Systemic innovation approaches which include social innovation	SI10.1 Systemic change	How is the city embedding social innovation as a lever to support systemic change toward climate neutrality in the city (for example in urban planning, circular economy, energy communities, etc.)?	textual
	SI10.2 Social Innovation impact on climate neutrality	How do the social innovation initiatives fostered by the public administration contribute to climate neutrality? Please provide data and/or experiences according to specific impact category (stationary energy, energy generation, mobility & transport, green industry, circular economy, nature based solutions).	textual
	SI10.3 Wellbeing derived from SI initiatives	How has the wellbeing of citizens and urban stakeholders changed as a consequence of social innovation policies and initiatives developed by the Public administration? What still need to be addressed?	textual

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Appendix C: Additional Finance and Investment Co-Benefit Indicators

Presented below are additional Finance and Investment Co-Benefit Indicators that could be applied when monitoring CCC Investment Plans.

External Financing

Indicator Title	Public to Private Capital Ratio
Unit of Measurement	Ratio of Public vs Private Spending
Required or Recommended	Recommended
Definition	The amount of public spending versus external financing into the climate actions listed in the CNC Action Plan and the Investment Plan
Source	N/A
Calculation Formula	Annual External Finance (loans) on Climate Action / Annual Public Spend on Climate Action

<u>Public to Private Capital Ratio</u>

If a city invests EUR139m into climate action projects in a year and external financial organisations invest EUR 28m, the Public to Private Capital Ratio is 4.96x. 139 / 28. There is no real goal for this ratio but it is a useful indicator to track through the implementation process.

Capital Efficiency

Indicator Title	Emission Return on Invested Capital (by Sector)
Unit of Measurement	EUR m
Required or Recommended	Recommended
Definition	Sectoral capital invested per sectoral Kt CO2 reduced
Source	N/A
Calculation Formula	Total Capital Invested in Sector m / Kt CO2 Reduction in Sector

<u>(Sectoral) Emission Return on Invested Capital</u>

If a city invests EUR 23m into green energy projects in 2023, and the 2024 calculated reduction of emissions is 42Kt, the city is spending EUR 0.55m per Kt of realised carbon reductions within the green energy sector. 23 / 42 = 0.55. The lower this figure is, the more efficiently capital is being deployed to combat GHG emissions in the city. This can be tracked annually but also over the whole transition period, and can be used as one of the criteria for climate action project selection or prioritisation. The sectoral calculation can also be used to see which sectors require a smaller amount of capital invested to achieve significant emissions reduction.

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Fiscal Responsibility

Indicator Title	Debt to Budget Ratio
Unit of Measurement	Multiple of Budget
Required or Recommended	Recommended
Definition	Total outstanding debt for the Municipality as a percent of total Municipal Budget
Source	N/A
Calculation Formula	Total Outstanding Debt / Annual Municipal Budget

Debt to Budget Ratio

If a city has total outstanding debt valued at EUR 456m, and receives an annual municipal budget of EUR 1,142m in 2023, the Debt to Budget ratio of the city is 0.40x. This multiple is useful to track over time to ensure budget is in line with previous years and municipal debt levels are sustainable. This can also be applied at a sectoral level to assess any risks within the municipality.

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